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Measuring the Instability of China's Financial System: Indices Construction and an Early Warning System

Lixin Sun and Yuqin Huang

Abstract
In this paper, employing several econometric techniques, the authors construct a financial stress index (CNFSI) and a financial conditions index (CNFCI) to measure the instability of China's financial system. The indices are based on the monthly data collected from China's inter-bank markets, stock markets, foreign exchange markets and debt markets. Using these two indices, they identify the episodes of systemic financial stress, and then evaluate the indices. The empirical results suggest that the CNFSI performs better than the CNFCI. Furthermore, the authors propose four leading indicators for monitoring China's financial instability, and provide a primary early warning system for China's macroprudential regulations.

JEL G18 C43 E44
Keywords Financial stress index; financial conditions index; China's financial system; leading indicators; early warning system

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Measuring the Instability of China's Financial System: Indices Construction and an Early Warning System

1. Introduction

The global financial crisis of 2008 has renewed the post-crisis research interests in the instability of the financial sector. Although full-blown financial crises did not occur in China during past decades, China did experience several periods of financial instability since 1978. Specifically, the high non-performing loans ratio in China's banking sector harms the soundness of the financial system, thereby depressing China's sustainable rapid economic development during the mid-1990s. Empirical studies have suggested that the stability of financial system is not only the precondition but also the foundation for sustainable economic developments. Therefore, exploring the methods to measure and monitor the instability of China's financial system, and thereby providing early warning signals and preventing possible financial distress has important implications for ensuring the stability and sustainability of China's economic growth.

In this paper, first, we construct a financial stress index (FSI) and a financial conditions index (FCI) to measures the systemic risks in China's financial system. Several techniques, including GARCH modelling, VAR approach and econometric benchmarking are employed in developing two indices. China's FSI (CNFSI) comprises several sub-indices, which gauge the instabilities of different financial markets including interbank markets, stock markets, foreign exchange markets and debt markets. China's FCI (CNFCI) is built up by extracting the financial information from the numerous variables and covering the same above markets.

Second, by using these two indices, we identify the episodes of financial stress for China, and then conduct predictive tests and total errors analysis to evaluate them. The predictive tests show that both CNFSI and CNFCI perform better, but the empirical results from total errors analysis suggest that the CNFSI is more suitable for measuring and assessing China's financial instability than the CNFCI.

Third, we seek to find some variables that help predict the systemic financial stress identified by the indices. Based on the empirical results, we propose four types of leading indicators for monitoring China's financial instability: the growth rates of deposits and loans (Credit Indicator), real estate prosperity index or housing price index (Investment or Property Indicator), CPI inflation (Price Indicator) and the growth rates of M2 (Monetary Indicator). Combining the leading indicators and the CNFSI constructed, finally, we provide a primary early warning system for China's macroprudential regulations.

The rest of the paper is structured as follows. Section 2 provides a literature review. Section 3 describes the data. Section 4 constructs the indices, identifies the episodes of financial stress, and compares the two indices. Section 5 examines the leading indicators for China's financial instability and proposes an early warning system for China's macro-prudential regulations. Section 6 concludes.

2. Literature Review

Financial instability has many sources. Our study, likely in the recent research heart of macro-finance linkages, focuses on the instability of a financial system as a whole, viz the financial instability caused by systemic risks. Systemic risk, according to the definition by Bandt and Hartmann (2000), is "a systemic event that affects a considerable number of financial institutions or markets in a strong sense, thereby impairing the general well-functioning of the financial system". ECB (2010) defines the systemic risk as a risk of financial instability "so widespread that [it] impairs the functioning of a financial system to the point where economic growth and welfare suffer materially." Oet et al. (2011) provides a definition for system risk from the supervisors' view: "systemic risk may be referred to as the risk of correlated default of financial institutions affecting largely the system's risk capital and liquidity with subsequent negative feedback effects on real markets." Although currently there is no commonly accepted definition for a systemic risk, most economists recognized the significance of the identification and measure of systemic risks, which are key factors for post-crisis financial stability and macro-prudential regulations.

Many measures of systemic risk have been developed, one direction of which is attempting to construct a continuous financial index, which contains an entire set of information that describes conditions of the entire financial system, either loose or stress by predetermined standards. These financial indices, including FSIs and FCIs, which can "provide a timely snapshot of the contemporaneous severity in a financial system", and can be "updated in a more timely fashion with forwarding-looking features" according to Illing and Liu (2003), are very useful in measuring and assessing the soundness or instability of a financial system. The indices eliminate some drawbacks derived from binary measures and logit models for systemic risk. Moreover, a well-constructed index "should not be meaningful as a monitoring tool but also useful within a large EWS (Early Warning System)"[3].

An FCI, is used to reflect and assess the "stress exerted on economic agents by uncertainty and changing expectations of loss in financial markets and institutions" (Illing and Liu (2003)). It "is a continuous variable with a spectrum of values, where extreme values are called financial crises." FSIs can be employed for identifying the financial distress severity and dating the systemic conditions, and thereby warning and predicting the possible breakthrough of a crisis in the financial system. One of the advantages in using FSIs is that an FSI is continuous of high frequency (daily, weekly, monthly etc.), covering numerous systemically important financial markets. There are two key elements in constructing an FSI: variables choice and weighting method. The variables adopted should cover the main components (markets) of the regarded financial system. The literature gives alternative weighting schemes: (1) equal weights; (2) equal variance weights; (3) credit weights; and (4) principal components. Cardarelli et al. (2009) designed an FSI by an equal-variance weighting, including seven variables grouped into three categories in banking, securities, and foreign exchange markets for 17 advanced economies over the past 30 years. The notable Cleveland Financial Stress Index (CFSI) by Oet et al. (2011) comprises eleven variables from inter-bank markets, foreign exchange markets, credit markets and equity markets. The CFSI is summed by a variable weighting approach in terms of

[3] Illing and Liu (2003).

variable transforming function. Craig and Keeton (2009) introduced the Kansas City Financial Stress Index (KCFSI), which also covers eleven variables with various spreads, aggregated with the weights by factor analysis. Following Cardarelli et al. (2009), Balakrishnan et al. (2009) constructed financial stress indices for emerging markets (EM-FSI). Table B in the Appendix provides a summary description of the empirical studies of various FSIs.

The monetary condition index (MCI, Freedman 1994) introduced by the Bank of Canada is a prototype of FCI. MCI, calculated by weighted average of the refinancing rate and the exchange rate, evolved into a financial conditions index by broadening its scope of variables. Hatzius et al. (2010) defines financial conditions as " the current state of financial variables that influence economic behaviour and (thereby) the future state of the economy. Theoretically, such financial variables may include anything that characterizes the supply or demand of financial instruments relevant for economic activity." Hence, an FCI should cover all the contents about the future state of the economy contained in these current financial variables. Using similar methodology as in constructing an FSI, Angelopoulou et al. (2013) summarizes several ways from which the weights of FCIs are generally derived: (1) structural models as in Goodhart et al. (2002); (2) reduced form models likely in Mayesand and Viren (2001); (3) Principal Components Analysis in Stadahl et al. (2011); (4) impulse responses of a VAR or Kalman filter. FCIs have been developed for a number of countries (US, Canada, Finland, Sweden, Germany, UK, Euro area etc.). Table C in the Appendix presents a detailed description of FCIs. Hatzius et al. (2010) argued that "an FCI should measure financial shocks-exogenous shifts in financial conditions, eliminating variability in the financial variables that can be explained by current and past real activity" so that it reflects exogenous information associated with the financial sector rather than feedback from macroeconomic conditions, which are incorporated into most "old" FCIs. Against this background, our CNFCI follows most old ones.

Some researchers, for example, Hatzius et al. (2010), take FSIs as a special form of FCIs, hence, FCIs should reflect the information contained in FSIs and beyond. However, Oet et al. (2011) argued that a financial stress index approach is more fitting

than a financial conditions approach.

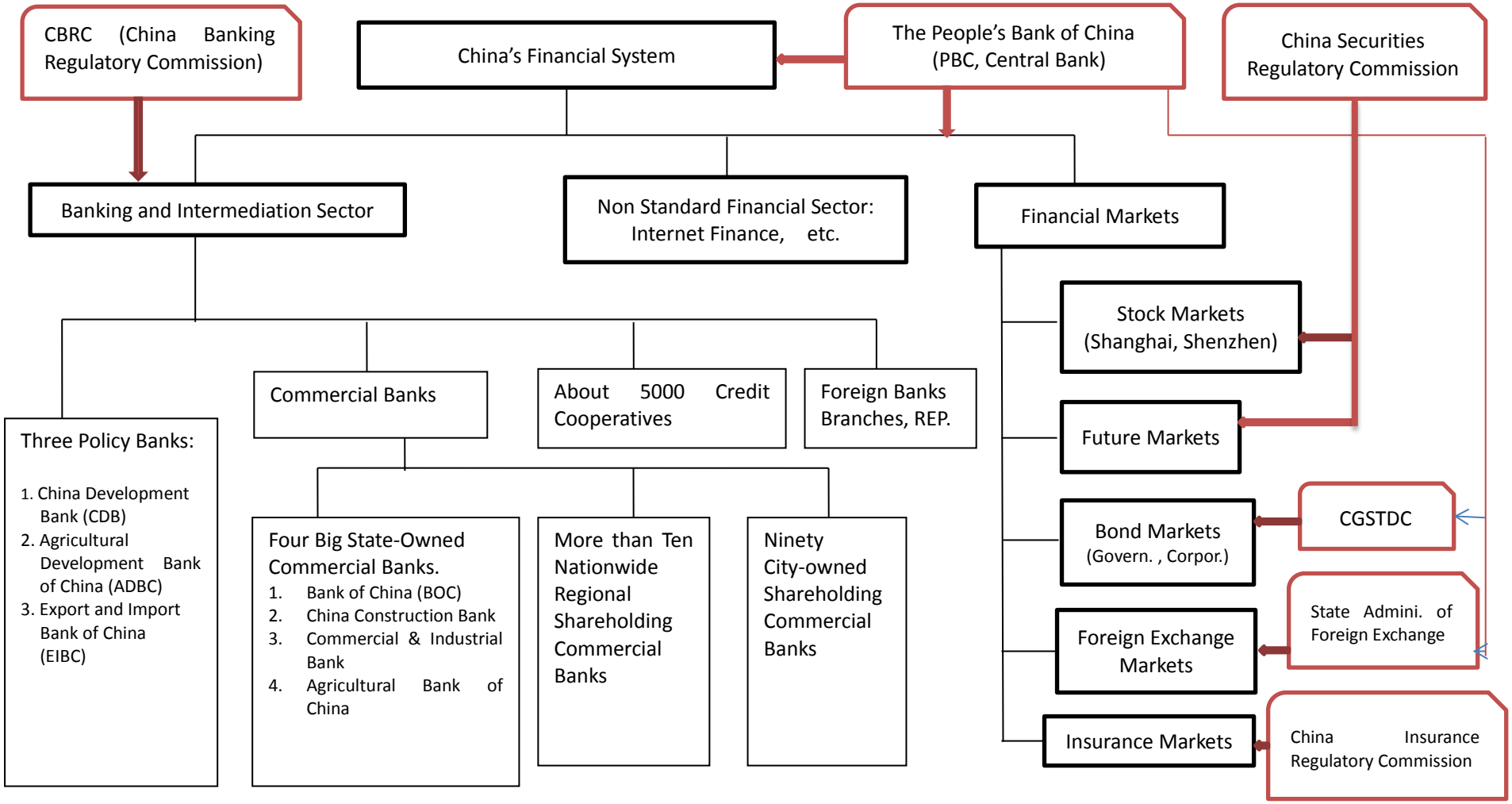
Using leading indicators and an early warning system to monitor financial instability has a long history. The relevant literature dates back to the 1970s. KLR (1998) provided a review of the literature for indicators of crises in the Appendix of their paper. Methodologically, EWS is divided into two groups: parametric (regression based) and non-parametric (signal extraction). Using parametric methods, Frankel and Saravelos (2012) investigated the crisis incidence of the global financial crisis in 2008-09. They find that foreign exchange reserves, real exchange rate, credit growth, real GDP growth and the current account balance as a percentage of GDP are the most reliable indicators to explain crisis incidence. A typical non-parametric EWS, the so called "Signal" approach developed by KLR (1998), involves monitoring the evolution of a number of leading economic indicators, issuing a signal that a crisis of financial instability could occur within the next 24 months when one of these indicators deviates from a given threshold. To predict the risks of banking crises and explore the nexus between the monetary stability and financial stability, Borio and Lowe (2002a, b) use the asset price and credit indicators. Comelli (2013) conducts a broad comparison about the in-sample and out-of-sample performances of three parametric and non-parametric early warning systems (EWS) for currency crises in emerging market economies. The framework of the leading indicators and EWS in this study follows KLR (1998).

3. China's Financial System and Data

3.1 China's Financial and Financial Regulation System

China's financial system (Figure 1), comprising the banking sector, financial markets, and nonstandard financial sector, is dominated by the banking sector. The banking sector is still controlled by the big-four state-owned commercial banks even with the entrance and growth of many domestic and foreign banks and financial institutions in recent years. The total assets and liabilities of the banking sectors, according to the CBRC, China's regulator of the banking system, were 13.36 trillion yuan (RMB)

Figure 1 China's Financial and Financial Regulation System

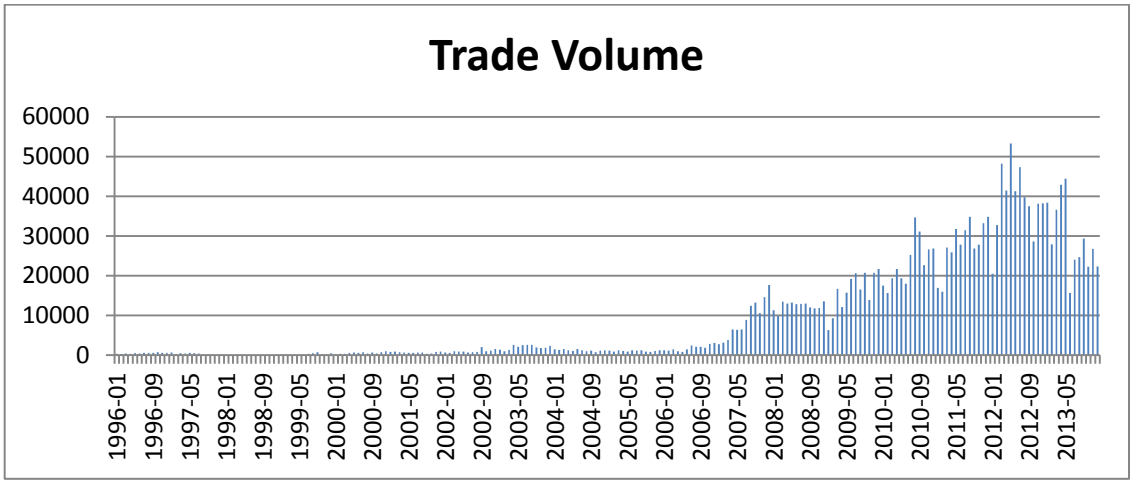


and 12.50 trillion yuan, respectively, at the end of 2012, of which the big-four accounts were approximately 44.93% and 44.89%. The CBRC, as the state authorized supervisory body for banks, was separated from the People's Bank of China (hereafter the PBC) in 2004. The PBC, China's central bank, did not operate as a central bank until September 1983. On 18 March 1995, the Third Plenum of the Eighth National People's Congress ratified The Law of the People's Republic of China concerning the People's Bank of China, and the PBC began to implement monetary policy legally as the Central Bank of China. The PBC is authorized to be responsible for the monetary stability and the financial stability of the entire financial system in China.

China's money market consists of three submarkets; the inter-bank borrowing market, the inter-bank bonds repurchase market and the commercial paper market.
The inter-bank borrowing market of China has operated since 3 January 1996, when the number of members was 63. In 2002 there were more than 500 participants and at the end of 2005 there were 695 members. These comprised policy banks, commercial banks, financial companies, insurance institutions, security brokers, investment funds and foreign banks. At the end of 2012, the monthly trade volumes of the inter-bank market reached 3.8236 trillion (RMB). Trade categories include overnight, 7 days, 14 days, 20 days, 30 days, 60 days, 90 days and the longest maturity of 4 months (120 days). Figure 2 summarises the trade volume of the inter-bank market since 1996.

Figure 2 Statistics of National InterBank Market based on Maturity since 1996.

(Unit: 100 Million Yuan. Source: CEInet statistics database)

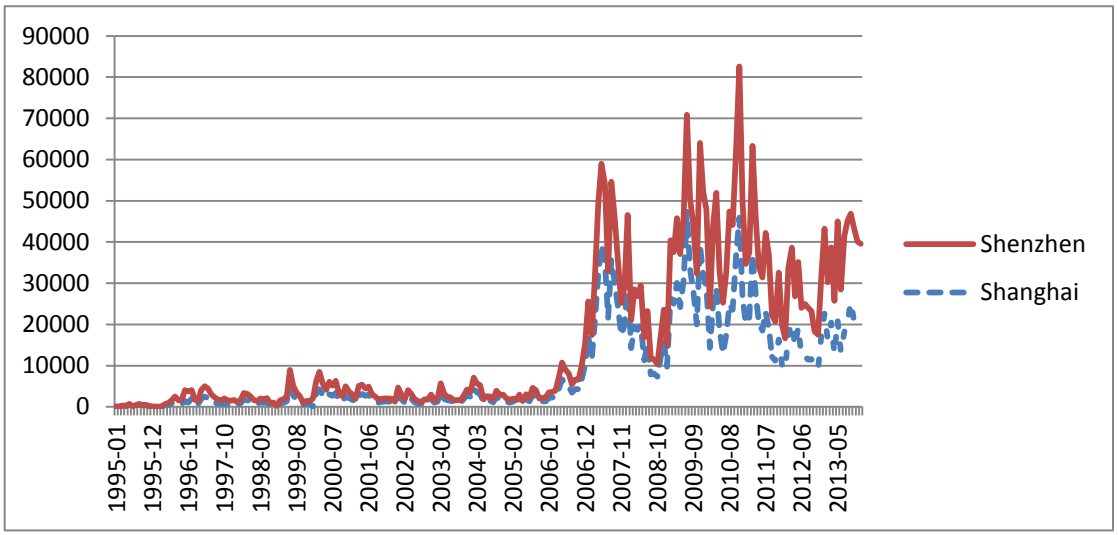


Source: CEI

Two stock markets, the Shanghai Stock Exchange and Shenzhen Stock Exchange, were established in 1990. After two decades of development, they are still underdeveloped and inefficient in allocating the financial resources due to large

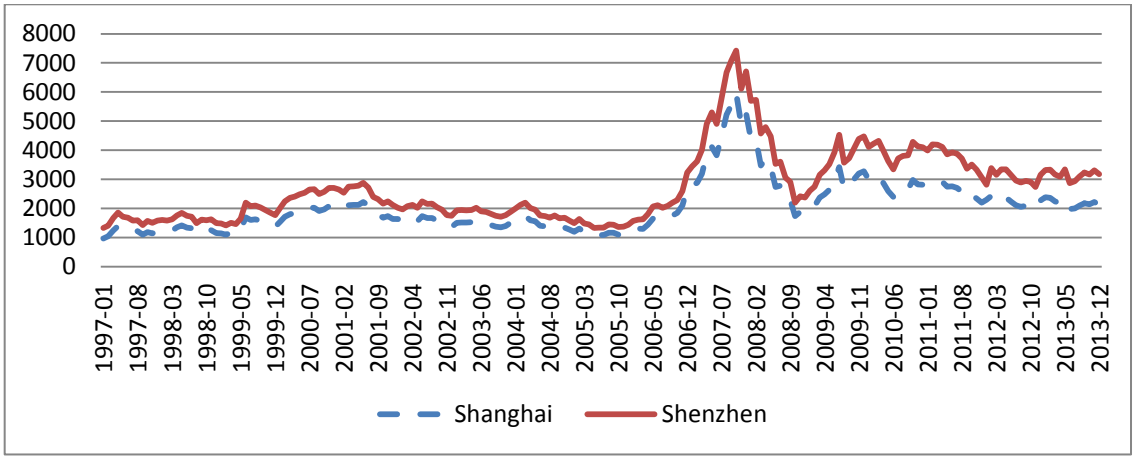
speculations and inside trading, but they are becoming increasingly important in China's economic development. The market value of two stock markets was approximately 2.304 trillion yuan and the trade volume was approximately 0.317 trillion yuan (RMB) in December 2012. China's Securities Regulatory Commission, established in October 1992, is responsible for regulating the stock markets and the futures markets, which are very small and in a primary development stage. Figures 3 and 4 present the evolution of the stock indexes and trade volume for China's stock markets, respectively.

Figure 3 Trade Volumes of Chinese Stock Markets (Units: 100 M Yuan)



Source: CEI

Figure 4 Stock Indexes of China's Stock Markets (Source: CEI)



Source: CEI

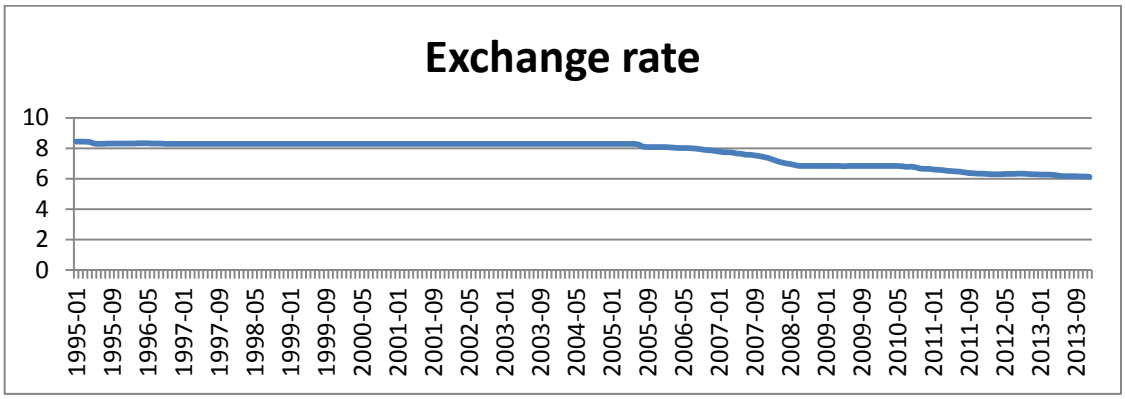
There exist three bond markets in China: the inter-bank bonds market, the stock exchange market and the commercial bank over the counter market. The wholesale

transactions of booked bonds and policy banks bonds are conducted in the inter-bank bonds market by the institutional investors while the bonds are traded on the Stock Exchange between institutions and individuals. In the commercial banks over the counter market treasury bonds are issued to individuals and corporations where they are traded by investors. Among these three markets the stock exchange trade dominates according to turnover. The entire bond market is organized by 2-level custody arrangements. As China's central Securities depository (CSD) for the bond Market, the China Government Securities Depository Trust & Clearing Co. Ltd, (CGSDTC) takes the responsibility of the General Custodian, which is under supervision by the PBC.

China kept a fixed exchange rate system for a long time; the foreign exchange transactions have been strictly controlled by the government up to now although some deregulation is under way. With the capital flows being controlled, China can have an independent monetary policy under a fixed exchange rate regime. The participants of foreign exchange markets are primarily composed of institutional investors in China. On 21 July 2005, the Chinese government reformed the exchange rate regime by moving to a managed floating exchange rate system with reference to a basket of currencies. On 18 May 2005, foreign currency trading was formerly launched in the inter-bank foreign exchange market where spot transactions of eight currency pairs were conducted. This included the euro vs. US dollar, the Australian dollar vs. the US dollar, the British pound vs. the US dollar, the US dollar vs. the Swiss franc, the US dollar vs. the HK dollar, the US dollar vs. the Canadian dollar, the US dollar vs. the Japanese yen, and the euro vs. the Japanese yen. On 2 August 2005, the PBC released a Notice on Expanding Designated Banks Forward Purchases and Sales Business and Launching RMB and Foreign Currencies Swaps which permits qualified commercial banks to undertake RMB and foreign currency swaps. Further, on 4 January 2006, the PBC issued the Public Announcement on Further Improving the Inter-Bank Spot Foreign Exchange Market (Public Announcement of the PBC No. 1[2006]), introducing the market-maker system and over the counter transactions (OTC transactions) into the inter-bank spot foreign exchange market. By the end of 2013, China's currency had appreciated approximately 30%. Figures 5 and 6 show the evolution of the exchange rates and foreign exchange stock in China since 1995, respectively. The foreign exchange markets are regulated by the State Administration of Foreign Exchange, which is directed by the PBC (the head of the State

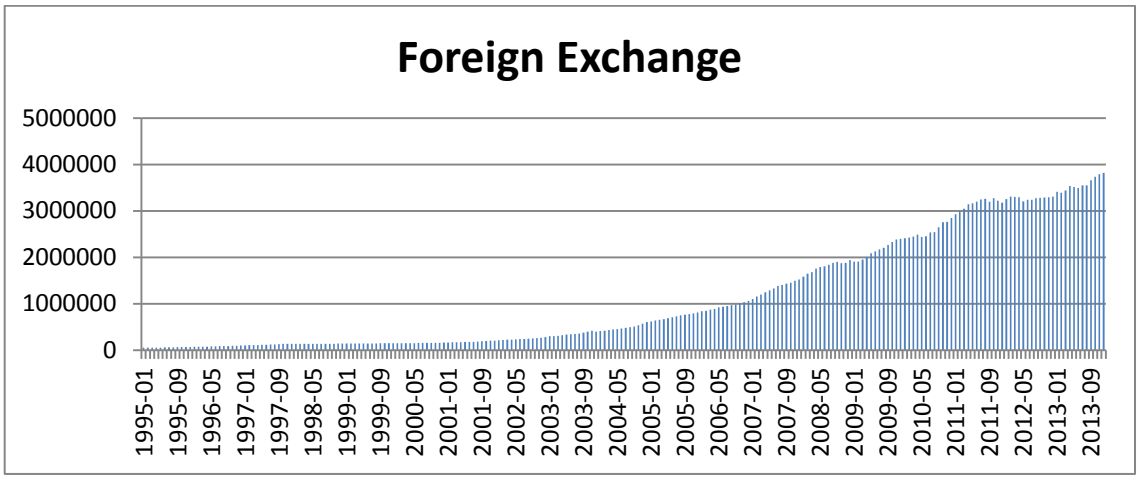
Administration of Foreign Exchange is generally one of the deputy presidents of the PBC).

Figure 5 Changes in Exchange Rates since 1995



Source：CEI

Figure 6 Foreign Exchange Accumulation since 1995



Source: CEI

China’s insurance markets are also dominated by large state-owned insurance corporations, which are regulated by China Insurance Regulatory Commission (CIRC).

The PBC, CRBC, CSRC, and CIRC are parallel regulators under the State Council, China’s central government, while the PBC is authorized to oversee the monetary and financial stability.

3.2 Data

Following the extensive literature on financial indices and indicators, we choose various observable variables in designing our indices to reflect the panorama of financial conditions in China. Most chosen variables cover the period from Jan. 1994 to Dec. 2012 with monthly frequency sourced from the databases of China Economic

Information Network (CEIN), Wind Information Co. Ltd (Wind), the People's Bank of China (PBC), China Banking Regulatory Commission (CBRC) and National Bureau of Statistics (NBS). While our data are of high quality, we still face some severe constraints: the non-performing loans ratios are annual, the housing price index is not available after 2012, and most bond yield data dated from Jan. 2012. For a detailed description of variables and data sources, see Table A in the Appendix.

China's financial system mainly comprise the banking sector (interbank markets), equity (stock) markets, debt markets, foreign exchange markets, and derivative security markets. Given that the derivative markets are tiny, underdeveloped and very shallow at the moment, we focus on the former four markets in this paper. The variables employed in constructing an FSI and an FCI for China's economy include various spreads, non-performing-loans ratio, deposits-to-loans ratio, exchange rates and foreign reserves, stock index, see Table A in Appendix and Section 4.

In addition, some macroeconomic variables are also included in the sample set because they are closely related to the macro-financial linkages in China. The first one is the change in prices level, denoted by CPI inflation, reflecting the completely loose or tight financial conditions with its rising and declining. The second is the growth rates of M2, containing the information about the monetary policies and conditions in monetary markets. The third group of variables consist of the house price index and the real estate prosperity index, representing the asset prices and investments, respectively. Finally, the growth rates of loans and deposits are chosen because most research suggests that credit variables are key factors in predicting the financial stress.

4. Indices Construction and Evaluation

4.1 A National Financial Stress Index for China's Financial System (CNFSI)

Our FSI designed to gauge the severity of financial instability in China comprises eight variables covering four markets: banks risk spread, banks non-performing loan ratio, and banks loan-to-deposit ratio for banking industry; Shanghai stock market index for stock markets; exchange rate and foreign reserves for foreign exchange markets; and risk spread and sovereign spread for debt markets. As mentioned in section 3, the variables are summarized in Table A of the Appendix.

4.1.1 Banking Sector

Three measures with four variables are adopted to reflect the stress in the banking sector: risk spread, non-performing loans ratio, and overall loans-to-deposits ratio. We

calculate the FSI for the banking sector (BankFSI) by variance-equal weighting.

Risk spread

Risk spread in banking sector is the spread between risky and risk-free rates to reflect the interbank liquidity constraints and the expectations of default risk. The calculation is

$$Interbank\ Risk\ Spread_t = 3\ mons\ L_t - 3\ mons\ TBR_t \quad (1)$$

where *3 mons* L_t denotes the three-month borrowing rates in China's interbank market; *3 mons* TBR_t is the three-month government bond rates.

Non-Performing loan ratio

The overall non-performing loan ratio for the state-owned commercial banks is chosen to assess the stress of banking sector in China. This is because the capital owned by the state commercial banks dominated the capital structure of China's banking industry[4]. The data source is from the website of China Banking Regulatory Commission, the official regulator of China's banking system, and Shi and Peng (2003).

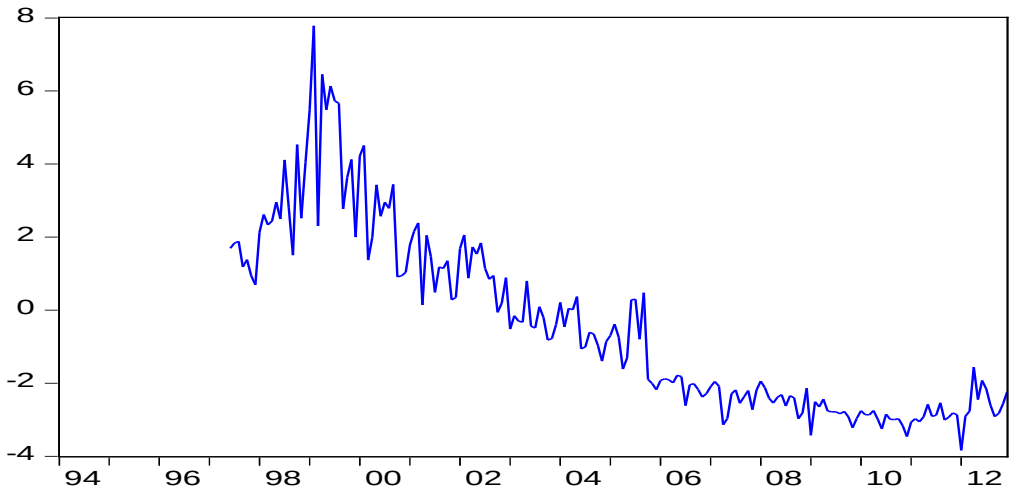
Loans-to-Deposits ratio

This variable measures the constraint and default risks faced by China's banking sector. The calculation is straightforward.

FSI for the banking sector (BankFSI)

Using equal-variance weighting method, we build a sub-FSI for China's banking industry since 1997, shown in Figure 7.

Figure 7 A Financial Stress Index for China's Banking Sector (BankFSI)



[4] The share of the capitals owned by the state banks has been above 70%, according to the CBRC.

Figure 7 reveals that the stress in China's banking sector reached a peak in 1999, which coincides with the identified bank crisis in later 1998 by Laeven and Valencia (2008); then, the BankFSI decreased gradually (The soundness of China's banking sector was improved after 2000).

If we exclude the bank risk spread because the data are not available until 1997, an alternative BankFSI for China's banking sector covering the period from January 1994 to December 2012 is obtained (Figure 8).

Figure 8 Financial Stress Index without Risk Spread for China's Banking Sector

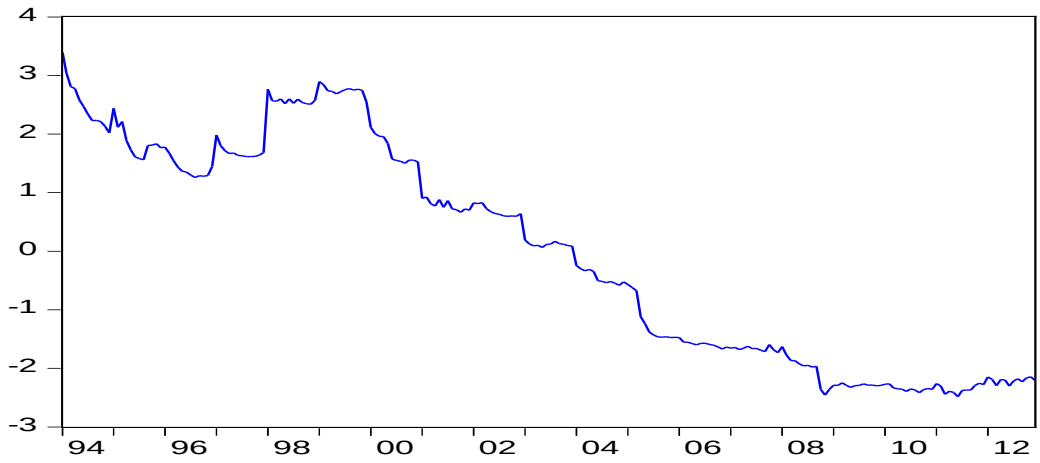


Figure 8 shows two episodes of banking stress: 1994-1995 and 1998-1999. Comparing Figure 8 with Figure 7, we see that the second BankFSI is more smoothing than the first one, and two BankFSIs demonstrate similar trends after 1997.

4.1.2 Stock Markets

The systemic stress and risks in stock markets are measured by the volatility of the stock index. We estimated the volatility using a GARCH (1, 1) model.

Following Bollerslev (1986), a simple GARCH (1, 1) model is defined as

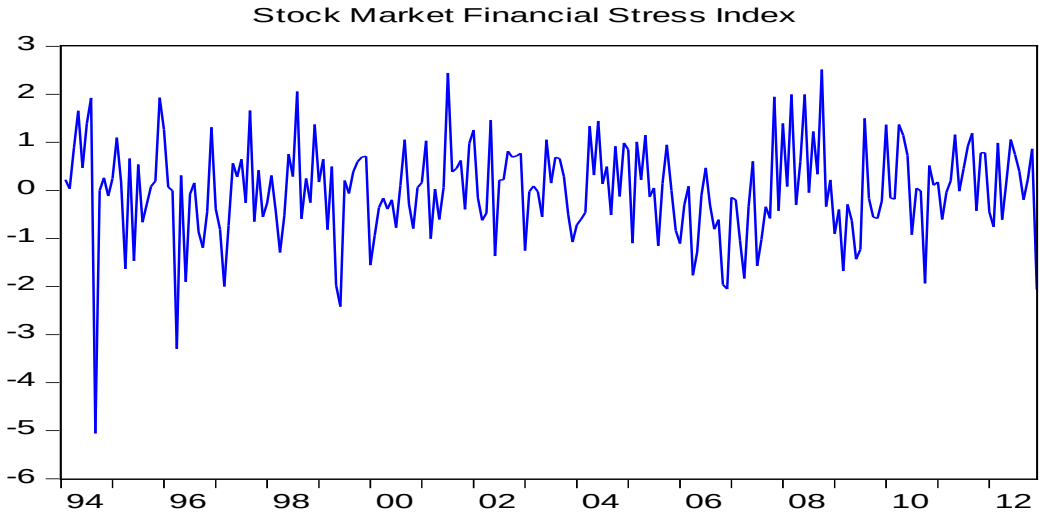
$$V_t = C_0 + \theta X' + \varepsilon_t, \varepsilon_t \sim IID(0,1) \quad (2)$$

$$\sigma_t^2 = c + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2. \quad (3)$$

where V_t denotes the month-to-month change in the Shanghai stock market index in our study, and the standard deviation σ_t predicts the risk in the stock market.

The FSI for China's stock markets (SMFSI) constructed by GARCH (1, 1) is presented in Figure 9. Figure 9 indicates that China's stock markets are very volatile over the examined period.

Figure 9 China's Stock Market FSI (SMFSI)



4.1.3 Foreign Exchange Market

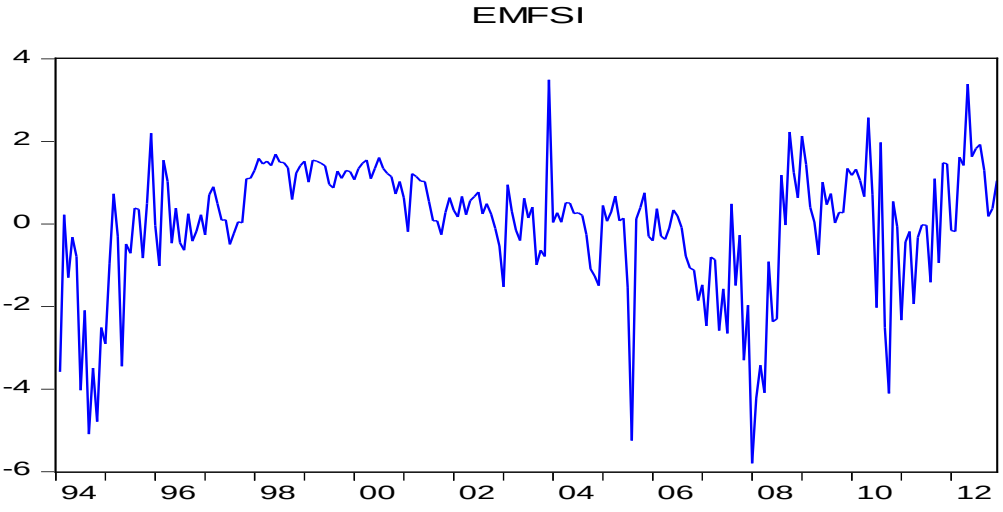
The stress in China's foreign markets is also measured by the volatility. Following Balakrishan et al. (2009), the FSI for foreign exchange markets (EMFSI) is defined as

$$EMFSI = \frac{\Delta e_t - \mu_{\Delta e_t}}{\sigma_{\Delta e_t}} - \frac{\Delta RES_t - \mu_{\Delta RES_t}}{\sigma_{\Delta RES_t}} \quad (4)$$

where Δe_t denotes the month-to-month change in real exchange rate, and ΔRES_t is the month-to-month change in foreign reserves; μ_x, σ_x represent the average values and standard variances of the respective variables, respectively.

Figure 10 depicts the EMFSI for China's foreign exchange markets.

Figure 10 FSI for China's Foreign Exchange Market (EMFSI)



EMFSI captures several episodes of exchange rate volatilities in China's foreign exchange market including an abrupt appreciation in later 1994 and then deep depreciation in 1995 by China's government to enhance the exports, the announcement on a floating exchange system by China's government in 2005, the global financial crisis of 2008, and the Euro area sovereign debt crisis, all these produced dramatic fluctuations in EMFSI, shown by Figure 10.

4.1.4 Debt Market

Two indicators are employed to measure the stress in China's debt markets. The first one is the bond yield spread, which is a useful predictor of recession[5]; the second is the sovereign debt spread, showing international liquidity.

Bond yield spread

The spread between the long-term bond yield and the short-term bond yield is used as a possible predictor for the economic recession and as a proxy for the uncertainty in the government bond markets.

$$Bond\ yield\ spread_t = C\ 10\ TB_t - C\ 1TB_t \quad (5)$$

where C10TB represents the 10-year government bond yields, and C1TB denotes 1-year government bond yield. That we do not use 3-month Treasury bill yields is because, on the one hand, the 3-month bond in China's short-term bond market is less issued and its volume of issuance is tiny, and on the other hand, the 1-year government bond is most popular and has a very long issuance history in China.

Sovereign debt spread

This term is defined by China's 10-year government bond yields minus the US 10-year government bond yields:

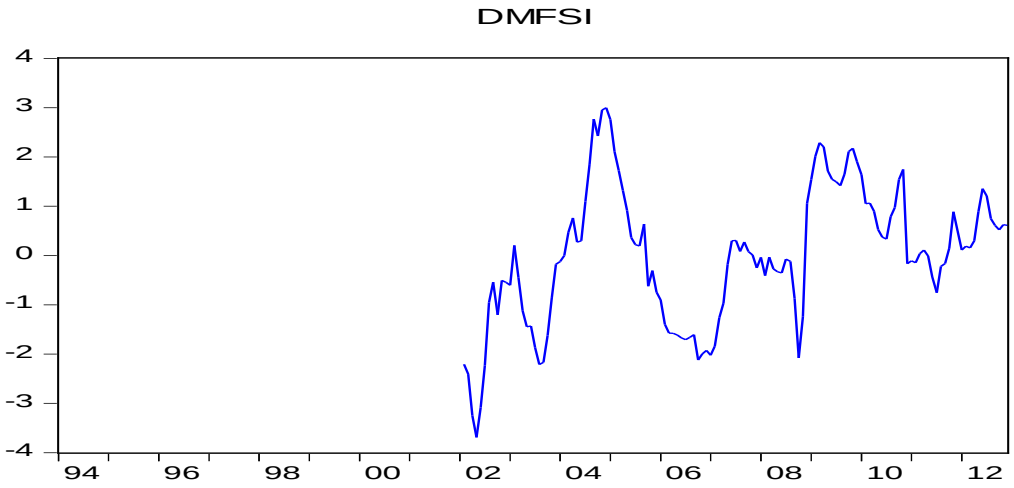
$$Sovereign\ debt\ spread_t = C\ 10\ TB_t - US\ 10\ TB_t \quad (6)$$

Combining the bond yield spread and the sovereign debt spread, we obtain an FSI for China's debt markets by equal-variance weighting in Figure 11.

In Figure 11, we find that the financial stress increased in China's debt market after 2009 due to the contagion effects of the international financial crisis.

[5] See, for example, Oet et al. (2011), Estrella and Mishikin (1996), Harbrich and Biano (2011).

Figure 11 FSI for China's Debt Markets

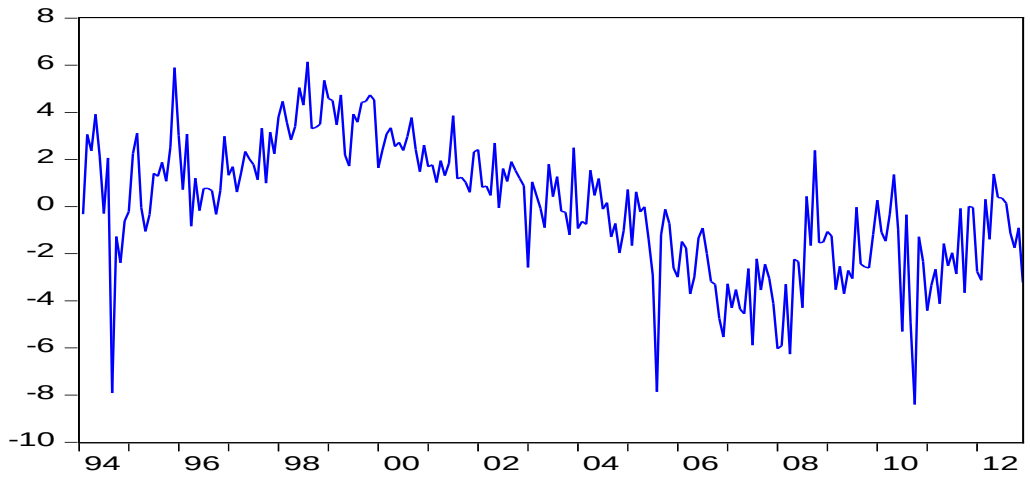


4.1.5 Overall FSI for China's Financial System (CNFSI)

We employ both equal-variance weighting to construct an overall FSI (CNFSI) for China's financial system, and then take the better one as the CNFSI.

Given that the sample period for the debt market is too short (from 2002 onwards), and the trade volume in debt market is very tiny in China, we construct the CNFSI excluding DMFSI by equal-variance weighting from 1994 to 2012; Figure 12 plots the CNFSI.

Figure 12 CNFSI (excluding debt markets) by Equal-Variance Weighting



4.1.6 Identification of Episodes of Financial Stress by CNFSI

Considering the reality that no financial crisis has happened since 1994 in China, following Lai and Lu (2010) and other studies in the literature, we identify the

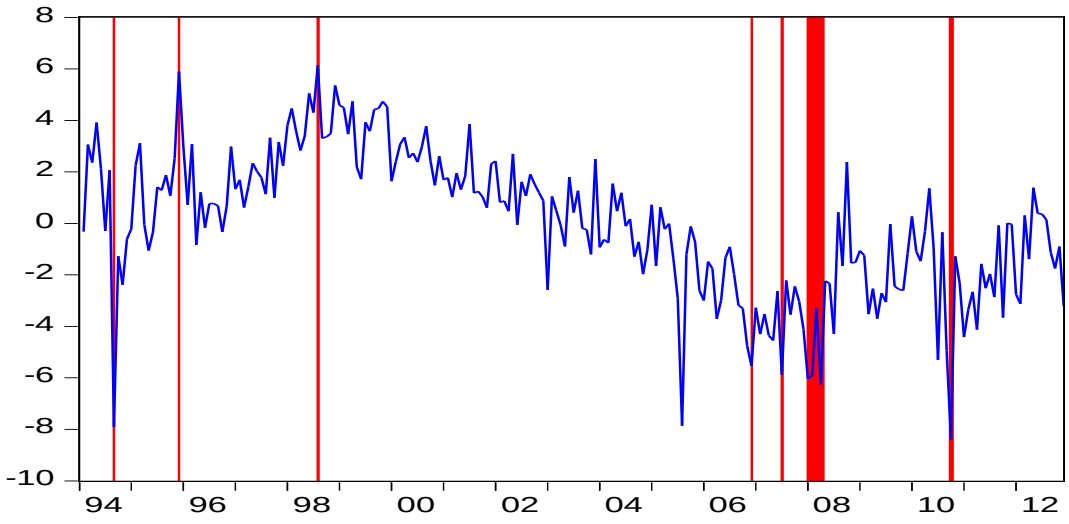
episodes of systemic financial stress by measuring the deviations of the CNFSI from its long-run trend. When the CNFSI is two times of standard deviation more than the long-term average level, it suggests a financial systemic stress.

Hence, the identification standard of a system financial stress is defined as

$$CNFSIE = \left| \frac{CNFSI_t - \mu_{CNFSI_t}}{2\sigma_{CNFSI_t}} \right| \tag{7}$$

where $CNFSIE$ denotes the identification standard, μ_{CNFSI_t} and σ_{CNFSI_t} denote the average value and standard deviation of CNFSI time series. When CNFSIE is greater than 1, the systemic financial stress should be signalled. The identified episodes of systemic financial stress are presented in Figure 13.

Figure 13 Identified Episodes of Financial Stress by CNFSI



To provide useful and convenient tools for the supervisors and the public, we develop a non-parametric alarming grade system in terms of the degree of deviations of each systemic stress,

Blue systemic financial stress alarming signal: $1 \le CNFSIE < 1.5$

Orange systemic financial stress alarming signal: $1.5 \le CNFSIE < 2.5$

Red systemic financial stress alarming signal: $2.5 \le CNFSIE$

Table 1 presents the episodes of systemic financial stress identified by this standard from January 1994 to December 2012. Table 1 shows that China's financial systemic stress sources from both domestic and global shocks during past decades.

Table 1 Identification of Episodes of Financial Stress by CNFSI

Episodes	CNFSI	Grades of alarming Signal	Possible Sources of Financial Vulnerabilities
Sept. 1994	-7.915592	Blue	Higher non-performing loans ratios and lower deposits-to-loans ratios of the banking industry in China, Overheated economy (CPI inflation reached approximately 27%, and remained above 20% during the entire year).
Dec. 1995	5.893915	Blue	Higher non-performing loans ratios and lower deposits-to-loans ratios of the banking industry in China. In 1995, an overheated economy led to a very strict contractionary monetary policy in tackling the higher inflation.
Aug. 1998	6.139003	Blue	Banking crisis identified by Laeven and Valencia (2008). Spill over of Asia Financial Crisis (July 1997).
Dec. 2006	-5.540553	Blue	?
July 2007	-5.880105	Blue	Spill over of Global Financial Crisis from the US
Jan 2008 Feb 2008, April 2008	-6.034455 -5.908281 -6.260356	Blue	Spill over of Global Financial Crisis from the US
Oct. 2010	-8.398406	Orange	Spill over of Global Financial Crisis and the European Sovereign Debt Crisis

4.2 A National Financial Conditions Index for China (CNFCI)

4.2.1 Constructing the CNFCI

In constructing the CNFCI, we use most variables that were used in constructing the CFSI, and add some new variables reflecting the monetary and credit supplies, asset prices etc. Note that in constructing the FCI, we replace the loans-to-deposits ratio by deposits-to-loans ratio, which provide positive contributions to financial conditions. The set of chosen variables includes the following: the deposits-to-loans ratio of the banking industry, non-performing-loans ratios of the banking industry, risk spread of banks, 3-month interbank borrowing rates, the growth rates of M2 for the money supply, CPI inflation for the change in the price level, the national housing price index for asset price and the real estate prosperity index for the demand for investment, the stock market index for equity market, the exchange rate and the change in foreign

reserves for foreign exchange markets.

Following Swiston (2008), Osorio et al. (2011), we estimate the CNFCI using the weighted average approach, in which the weights are extracted from a VAR model:

$$By_t = C(L)y_t + D(L)x_t + \varepsilon_t \quad (8)$$

where y_t is a (m x 1) vector of endogenous variables, x_t is an n vector of exogenous variables, B, C and D are matrices of the estimated coefficients, L is a lag operator, and i is the number of lag or the order of the VAR. The error term ε_t is a vector of innovations, which are *I.I.D.*

Endogenous variables in the VAR model comprises growth of industrial production (proxy for growth of real GDP), CPI inflation, deposits-to-loans ratio, risk spread of banks, 3-month interbank borrowing rates, growth rates of M2, national housing price index, real estate prosperity index, stock market index, exchange rate and the change in foreign reserves. The CNFCI is thus estimated by

$$FCI_t = \sum_{i=1}^{n} w_i \left(\frac{z_{i,t} - \overline{z}_i}{\mu_{Z_{i,t}}}\right) \quad (9)$$

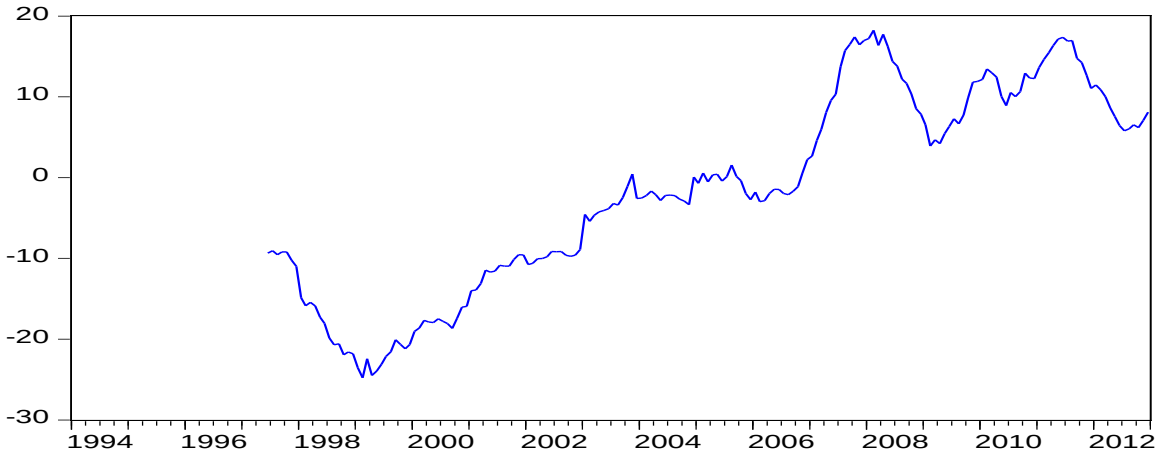
where the weight w_i is calculated by the cumulative responses of the growth of industrial production to one-unit shock from the financial indicator z_i, whereas $\overline{z}_i$ and $\mu_{Z_{i,t}}$ denote the average value and standard deviation of z_i over the whole sample period, respectively.

We use the cumulative responses of growth of industrial production to a one-unit shock in financial variables within 12 periods (months) to calculate the weights for each financial indicator. The VAR models satisfy the requirements of mathematical stability, no heterogeneity, no AR and normal distributions in residuals.

Figure 14 presents the CNFCI without the debt market since 1997 constructed by a weights-sum approach.

In Figure 14, we find that the financial conditions had a deep deterioration in 1998, which could have been caused by spill-overs of the Asian Financial Crisis and then improved gradually, but declined dramatically after 2008, which could be explained by the Global Financial Crisis, eventually recovering after 2009, but with fluctuations.

Figure 14 CNFCI without the debt market constructed by weight-sum approach.



4.2.2 Episodes of Financial Vulnerability by CNFCI

We identify the episodes of systemic financial distress by establishing a cut-off in terms of percentiles of the CNFCI. For example, if the CNFCI declines 50% within 12 months, we should be cautious of an episode of financial distress. This standard suggests the following deterioration periods of financial conditions in China since 1997: Oct. 1997- Feb 1999 (Asia Financial Crisis), August 2005-Dec. 2005, April 2008-Feb 2009 (Global Financial Crisis), and May 2011-July 2012 (Global Financial Crisis and the European Sovereign Debt Crisis). In total, four episodes of financial instability have been marked by the CNFCI since 1997, two of them being coincidental with the episodes of financial stress identified in table 1 by using the CNFSI.

4.3 Evaluation on Two Indices

4.3.1 Evaluation by Predictive Analysis

We examine and compare the two indices by testing their ability to predict the output gap. As our data are monthly, we use the growth rates of industrial production to proxy the growth rates of GDP.

In-Sample Predictions:

First, we conduct formal predictive tests by using an in-sample estimation equation:

$$IPgrowthgap_{t+h} = C + \sum_{i=1}^{T} \beta_i IPgrowthgap_{t-i} + \sum_{j=1}^{N} \gamma_i index_{t-j} + \varepsilon_t \qquad (10)$$

where *IPgrowthgap* denotes the gap of the growth rates of industrial production, proxy for the gap of output growth. Index denotes the CNFSI or the

CNFCI, respectively. C is the constant, and ε_t is the error term. *IPgrowthgap* is calculated by H-P filter. To simplify, we use the OLS to investigate the indices' ability to predict the output growth gap. The results are reported in Table 2.

Pseudo-Out-Of-Sample Predictions:

Following Hatzious et al. (2010) and Osiorio et al. (2011), we conduct a "pseudo-out-of-sample" prediction tests by estimating the same equation (10) recursively and calculating the root mean squared error (RMSE). The results are also shown in Table 2.

The in-sample and post-sample prediction tests in Table 2 show that both the CNFSI and the CNFCI are effective in predicting the fluctuations of GDP, and the CNFCI performs a little better than the CNFSI.

Table 2 Predictive Tests of Indices on Output Gap-In Sample

(Dependent Variable: industrial production growth gap)

Variables	CNFSI (S.D)	CNFCI (S.D)
Constant	0.030232 (0.182854)	-0.086813 (0.189762)
IPgrowthgap(-1)	**0.209906 *(0.067161)**	**0.140289**(0.074434)**
IPgrowthgap(-2)	**0.168424*(0.068575)**	**0.180691*(0.068375)**
IPgrowthgap(-3)	0.083180 (0.063669)	**0.127333**(0.068817)**
Index(-1)	**-0.258720*(0.106432)**	**0.880044*(0.164421)**
Index(-2)	-0.043165 (0.110709)	**-0.845124 *(0.265282)**
Index(-3)	**0.238863* (0.105852)**	-0.028931(0.177783)
Adjusted R^2	0.1285	0.229417
F-statistic	6.480693	10.08043
RMSE	2.8693	2.5938

***** and ** denotes 5% and 10% significance, respectively.

4.3.2 Evaluation by Total Errors and Noise/Signal Analysis

In this section, we employ the ratios of noises to true signals, Type I errors, Type II errors and total errors to evaluate the two indices. The noise/signal ratio is defined as a ratio of incorrect alarm to correct warning signals. Type I errors measure the ratio of failing to signal a "true" high-stress event, calculated by the amount of no-signal-issuing for "true" stress divided by the total number of "true" stress. Type II errors are ratios that incorrectly signal, calculated by the number of wrong signals divided by the number of total signals. The "true" high-stress events are judged and

justified by the reality of China's financial situations from 1994 to 2012 and the literature[6]. Following Comelli (2013), we assume that the policymakers are more cautious, they dislike more missing a stress episode than issuing a false signal. This implies that the policymakers think that missing the alarm of a stress episode can potentially be much costlier than issuing a false signal in terms of foregone output. Therefore, we calculate the total errors according to the following equation:

$$\text{Total Errors} = (2/3)*\text{Type I Errors} + (1/3)*\text{Type II Errors}. \quad (11)$$

The performance of the index can be assessed by comparing the total errors and noise/signal ratio. The better index should be the one that can minimize the total errors and the noise/signal ratio. Table 3 summarizes the predicting accuracies of financial stress by the CNFSI and CNFCI, respectively. The results suggest that CNFSI is a more suitable index for identifying and predicting the systemic stress of China's financial system than is the CNFCI.

Table 3 Episodes of Financial Systemic Stress Identified by the CNFSI and CNFCI

Index	No. of Episodes identified since 1997	No. of Financial Stress in Reality	Noise/True Signal Ratio (%)	Type I Error (%.)	Type II Error (%.)	Total Errors (%)
CNFSI	5	4	25	**0**	**20**	**6.7**
CNFCI	4	4	25	25	25	25

5. Leading Indicators and an EWS for China's Macroprudential Regulations

With the identified episodes of financial systemic stress (distress) in section 4.1 by the CNFSI, we investigate whether some variables can be selected to be the leading indicators for China's financial instability. We choose eight variables including the growth rates of total loans and total deposits and most variables in the dataset for constructing the two indices. These indicators are commonly employed in the macroprudential literature to predict financial instability (Borio and Lowe, 2002 and 2004). They capture the building up of financial vulnerability and imbalance in macroeconomic conditions. Table 4 summarizes the indicators.

Methodologically, following the "signals approach" by Kaminsky and Reinhart

[6] See, for example, the database from Laeven and Valencia (2008).

(1996) and KLR (1998)[7], we set the early warning window within 12 months prior to the start of episodes of financial distress identified in section 4.1. Following Borio and Lowe (2002 a, b) and Borio and Drehmann (2009), first, we detrend the variables with an H-P filter, and then we compare the deviations of the values of the variables from their long-term trend (or average level) with the "optimal thresholds" (percentage deviation from the trend within 12 months) to find the possible leading indicators for monitoring China's financial instability. The optimal thresholds are determined using an iterative search procedure following Reinhart et al. (2000) to minimize the total errors. The performances of the indicators are examined according to the Type I, Type II, total Errors and noise/signal ratio, which are defined in section 4.3.

Table 4 Assessments of the Leading Indicators

Indicators	Thresholds of Warning Issuing	Number of Financial stress	Number of warning Issuing	Number of Predicted	Noise/True Signal Ratios (%)	Type I Errors (%)	Type II Errors (%)	Total Errors (%)
3 months interbank borrowing rates	1.5%	3 (after 1997)	7	2	250	33.3	71	45.87
Deposits-to-loans ratios	4%	5 (1994-2012)	8	5	60	0	37.5	**12.5**
Growth rates of total deposits	6%	5	6	4	**50**	20	33.3	**24.43**
Growth rates of total loans	6%	5	6	4	**50**	20	33.3	**24.43**
CPI inflation	4%	5	4	4	**0**	20	0	**13.33**
Housing price index	5%	5	8	4	**50**	20	50	**30**
Real estate prosperity index	4%	5	4	3	**33.3**	40	25	**35**
Growth rates of M2	4%	3 (after 1997)	3	2	**50**	33.3	33.3	**33.3**

Figure 15 depicts the volatilities of these indicators, their thresholds for issuing alarming signals (precautious lines) and the identified episodes of financial stress with the early warning window (12 months prior to the start of the systemic financial stress). Table 4 reports the performance of these early warning indicators. On the basis of total errors and noise/signal ratio, it is shown that the volatilities of banking deposits-to-loans ratios, growth rates of M2, 3-month inter-bank borrowing rates, CPI inflation, housing price index, real estate prosperity index, growth rates of total deposits and total loans are fitting to be the leading indicators (early warning

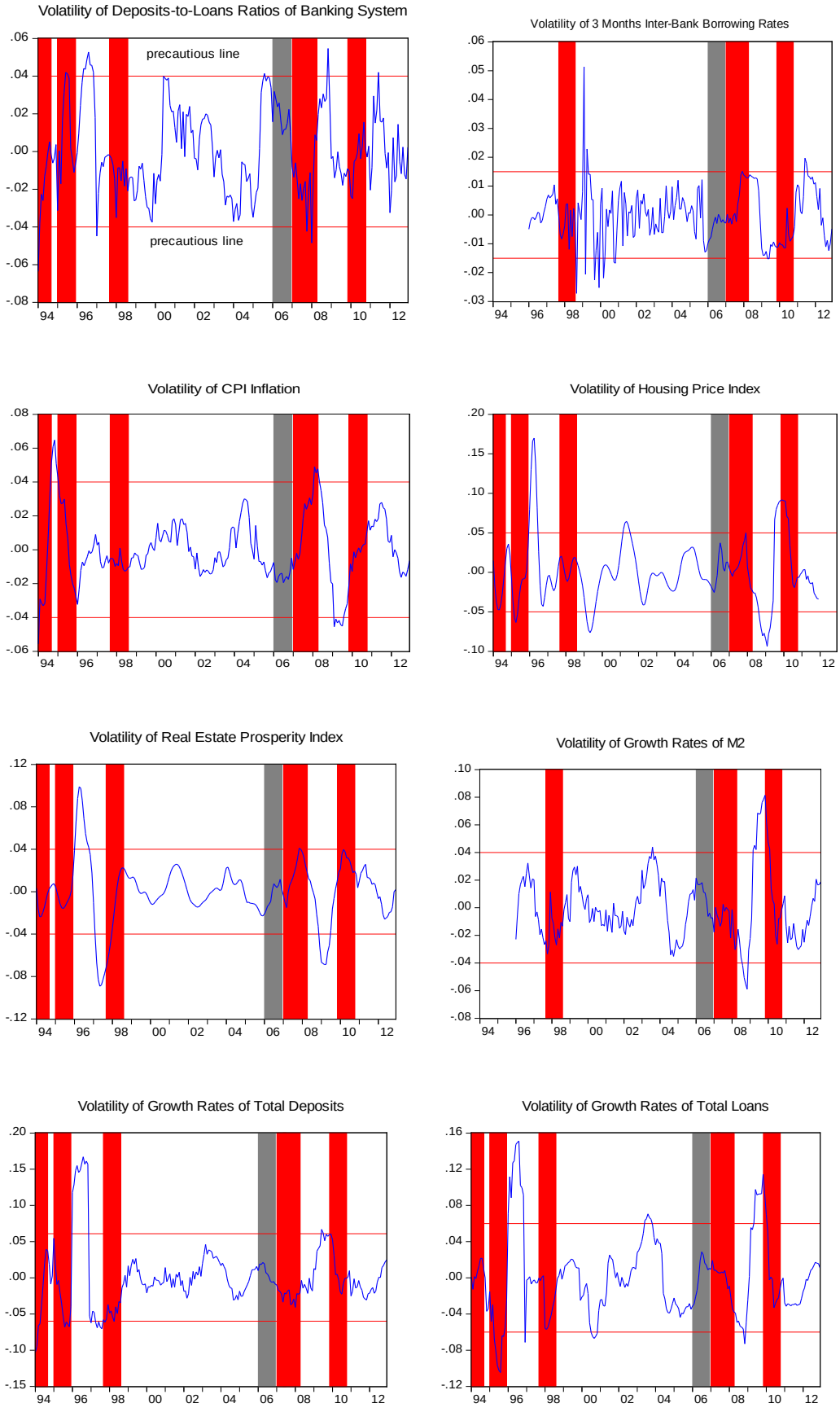
[7] This is also named non-parametric leading indicators.

indicators) of China's financial vulnerabilities.

The results suggest that the deposits-to-loans ratio, the growth rates of deposits and loans (Credit Indicator), housing price index or real estate prosperity index (Property Price or Investment Indicator), CPI inflation (Price Indicator) and the growth rates of M2 (Monetary Indicator) are relatively reliable leading indicators in issuing early warnings for China's financial instability. Most importantly, the price indicator (CPI inflation) and the credit indicators (deposits-to-loans ratio, growth rates of total deposits and loans) perform best in helping predict the identified episodes of financial stress among all the indicators chosen in this study.

Thus, we propose a macro-prudential early warning system, comprising the CNFSI and four leading indicators (Price, Credit, Asset or Investment, and Money) with their thresholds, to monitor the instability of China's financial system. In this early warning system, following Borio and Lowe (2002), when the deviations of any two of the four indicators from their long run trends exceed their respective thresholds (4% for deposits-to-loans ratio, 6% for growth rates of aggregate loans, 4% for CPI inflation, 5% for housing price index or 4% for real estate property index, and 4% for growth rates of M2), the policymakers and regulators should pay attention to a possible financial stress within 12 months, and if the CNFCI also meet the identification standard of a systemic risk, the relevant alarm signal should be issued and the macro-prudential policy would be implemented to avoid possible financial distress.

Figure 15 the Leading Indicators



6. Concluding Remarks

In this paper, we construct a financial stress index (CNFSI) and a financial conditions index (CNFCI) to measure and assess the instability of China's financial system. The CNFSI is aggregated by several subindices for interbank markets, stock markets, foreign exchange markets and debt markets with equal weighting. The evolution of the CNFSI specifies the change in financial stress, and identifies the episodes of financial vulnerability in China from 1994 to 2012. The CNFCI contains the financial information extracted from eleven variables covering the main components of the financial system and important macroeconomic activities, reflecting China's current financial state including the situation of stress.

The evaluation of these two indices is conducted by predictive tests and total errors analysis. The empirical results from both comparisons suggest that the CNFSI and the CNFCI constructed in our paper are both useful for measuring the stability of China's financial system. The total error analysis supports that the CNFSI is more fit for monitoring the financial instability in China than the CNFCI.

Using the identified episodes of financial stress, we find four leading indicators for China's financial instability: deposits-to-loans ratio, or growth rates of total loans and deposits (credit indicator), CPI inflation (Price indicator), housing price index or real estate prosperity index (asset or investment indicator), growth rates of M2 (monetary indicator). Combining these leading indicators with the CNFSI, and their thresholds, we form an early warning system for China's macroprudential regulations.

Further research is necessary for seeking more effective methods to examine the thresholds of financial disruptions, and exploring the nexus of monetary instability and financial instability.

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Appendix

Table A: Selected Variables for China's FSI and FCI, and Data Sources

Markets	Variables	Descriptive Statistics Mean (Standard Dev.)	Data Sources	Frequency and Periods
Banking Sector	Risk Spread	0.6815 (1.1089)	Wind*	Monthly (June1997-Dec 2012)
	Non-Performing Loan Ratio	0.17035 (0.11767)	CBRC, Wind, Shi (2004),	Annually (1994-2012)
	Total Loans to Total Deposits Ratio	0.7835 (0.1152)	Wind	Monthly (Jan 1994-Dec 2012)
Stock Market	Stock mark index	1827.11(979.02)	CEIN**	Monthly (Jan 1994-Dec 2012)
Foreign Exchange Market	Exchange rate	7.8217(0.7304)	CEIN	Monthly (Jan 1994-Dec 2012)
	Foreign exchange reserves	947223.9 (1077239)	CEIN	Monthly (Jan 1994-Dec 2012)
Debt Market	Bond yield spreads	1.269 (0.5089)	Wind	Monthly (Feb 2002-Dec 2012)
	Sovereign debt spreads	-0.142595 (1.1198)	Wind	Monthly (Feb 2002-Dec 2012)
Macroeconomic Variables	CPI inflation	4.223 (6.472)	CEIN	Monthly (Jan 1994-Dec 2012)
	Growth rates of M2	17.622 (4.33)	CEIN	Monthly (Jan 1996-Dec 2012)
	Growth rates of total deposits	0.2107 (0.088)	CEIN	Monthly (Jan 1994-Dec 2012)
	Growth rates of total loans	0.1812 (0.078)	CEIN	Monthly (Jan 1994-Dec 2012)
	Housing price index	105.098 (5.93)	CEIN	Monthly (Jan 1994-Dec 2011)
	Real estate prosperity index	101.49 (4.141)	CEIN	Monthly (Jan 1994-Dec 2012)

*Wind Information Co. Ltd.

**China Economic Information Network

Table B: Summary Description of FSIs

Authors	Banking System	Equity (Stock) Market	Foreign Exchange Market	Credit (or Debt) Markets	Weights	FSI
Lai and Lu (2010) (Chinese)	1. Term spread 2. The risky spread of banking system	Volatility of stock market CMAX: $CMAX = x_i / \max[x \in x_{T-j}, j = 0,1,...T]$ Or GARCH Model	EMPI $EMPI = \frac{\Delta e_t - \mu_{\Delta e_t}}{\sigma_{\Delta e_t}} - \frac{\Delta RES_t - \mu_{\Delta RES_t}}{\sigma_{\Delta RES_t}}$	Excluding	Equal variance weights: Standardizing sub-index by $I_{i,t} = \frac{I'_{i,t} - \mu_{I'_{i,t}}}{\sigma_{I'_{i,t}}}$	FSI=-I1+I2-I3+I4 Identification of episode of financial stress: $FSII = \frac{FSI_t - \mu_{FSI_t}}{2\sigma_{FSI_t}} - 1$
IILING and Liu (2003)	Banking beta-measuring relative volatility of equity return: $\beta = COV(r,m)/VAR(m)$ r and m are the annual total returns, to the banking sector index and the overall market index	CMAX: $CMAX = x_i / \max[x \in x_{T-j}, j = 0,1,...T]$	CMAX: $CMAX = x_i / \max[x \in x_{T-j}, j = 0,1,...T]$	Debt Market: Risk spreads between risky and risk-free bond yields	Credit weights: relative size of markets	$FSI_t = \sum_{i=0}^{I} w_{it} SubIndex_{it}$
Oet et al. (2011)	1. Financial Beta $\beta = COV(r,m)/VAR(m)$ 2. Bank bond spread 3. Interbank liquidity spread 4. Interbank cost of borrowing	Stock market crash: $x_t / \max[x \in x_{t-j}, j = 0,...,364]$ x is the overall stock index	Weighted dollar crash= $x_t / \max[x \in x_{t-j}, j = 0,...,364]$ x is the trade weighted $US exchange index	Credit Market 1 Governed interest spread 2Corporate bond spread 3 Liquidity spread 4 90 day commercial paper treasury bill spread 5 Treasury yield curve spread	CDFs: $\int_{-\infty}^{x_j} f(x_{jt})dx_{jt}$ CDF(Z_t)= $\frac{Rank(Z_t)}{No.of.daily.obersv.}$	Cleveland $FSI_t = \sum_j [w_{jt} \int_{-\infty}^{x_j} f(x_{jt})dx_{jt}] \times$
Cardarelli et al. (2009)	1 Banking sector Beta: 2 TED spread 3 Inverted term spread	1 Corporate spread 2 Stock declines 3 Time-varying stock volatility GARCH(1,1), volatility of overall market index monthly return	Time varying real effective exchange rate volatility GARCH(1,1)		Weight: the real costs of capital:	Episodes of financial stress are identified when the index is one standard deviation above its trend (by HP filter).

Balakrishnan et al. (2009)	Banking system Beta: $\beta_{it} = COV(r_{it}^{b}, r_{it}^{m}) / \sigma_{i,m}^{2}$	1 Stock market returns= year-on-year change in the stock index multiplied by negative one. 2 Stock market volatility: GARCH(1,1), 12 lags; monthly	EMPI: $EMPI = \frac{\Delta e_t - \mu_{\Delta e_t}}{\sigma_{\Delta e_t}} - \frac{\Delta RES_t - \mu_{\Delta RES_t}}{\sigma_{\Delta RES_t}}$	Sovereign debt spread=the bond yield minus the 10-year US treasury yield	Variance-equal weighting	$EM - FSI_{it}$
Craig et al. (2009)	1 TED spread 2 Idiosyncratic volatility of bank stock prices 3 Cross-section dispersion(CSD) of bank stock returns	Implied volatility of overall stock prices	N/A	2-year swap spread; 10-year treasury spread; Aaa/10-year Treasury spread; Baa/Aaa spread; High-yield bond/Baa spread; Consumer ABS/5-year Treasury spread;	Factor analysis	Kansas City FSI (KCFSI)
Hollo et al. (2012)-CISS	Banking sector 1. Realised volatility of the idiosyncratic equity return of the Data stream bank sector stock market index over the total market index; 2. Yield spread between A-rated financial and non-financial corporations 3. CMAX as defined above interacted with the inverse price-book Money Market: 1. Realised volatility of the 3-month Euribor rate, 2. Interest rate spread between 3-month Euribor and 3-month French T-bills. 3. Monetary Financial Institution's (MFI) emergency lending at Eurosystem central banks	1. Realised volatility of the DataStream non-financial sector stock market index: 2. CMAX for the DataStream non-financial sector stock market index. 3. Stock-bond correlation	Realised volatility of the euro exchange rate vis-à-vis the US dollar, the Japanese Yen and the British Pound, respectively	1. Realised volatility of the German 10-year benchmark government bond index 2. Yield spread between A-rated non-financial corporations and government bonds 3. 10-year interest rate swap spread	Equal weights for subindex; standard portfolio theory (from VAR) for aggregating subindex into FSI	$CISS_t = (w \circ s_t) C_t (w \circ s_t)'$

Table C: Summary Description of FCIs

Full Name (Short Name)	Authors	Frequency & sample period	Methodology	Financial system or variables	Data Sources
Bloomberg U.S. Financial Conditions Index (BFCI)	Rosenberg (2009)	Daily, 1994-2009	Weighted average	Money market, bond market, equity market	Bloomberg
Morgan Stanley Financial Conditions Index U.S. (MS FCI)		Daily 1995-	Weighted average		Bloomberg
National Financial Conditions Index (NFCI)	Brave and Butters (2010)	Weekly 1973-2006	First principal component	More than 30 variables including various spreads and yields etc.	Chicago FED
Citi Financial Conditions Index (Citi FCI)	D'Antonio (2008)	Monthly 1983-2000	Weighted average	corporate spreads, money supply, equity values, mortgage rates, the trade-weighted dollar, and energy prices	Citi Research
I.M.F. U.S. Financial Conditions Index (IMF FCI)	Matheson (2011)	Monthly 1994-2009	Dynamic Factor Analysis	Approximately 30 variables	Author
Deutsch Bank Financial Conditions Index	Hooper et al. (2007, 2010)	Quarterly 1983-2009	First principal component Weighted average	the exchange rate, and bond, stock, and housing market indicators	
Golden Sachs Financial Conditions Index (GS FCI)	Dudley and Hatzius (2000); Dudley, Hatzius and McKelvey (2010)	Quarterly 1980-2009	Weighted average	CDX, Moody's A-rated corporate bond index	Golden Sachs, FED
OECD Financial Conditions Index	Guichard, Haugh and Turner (2009)	Quarterly 1999-2008	Weighted average	credit conditions, corporate bond spreads, Real short rates, real long rates, real exchange rate, households wealth	US Federal Reserve, Eurostat, Bank of Japan, UK Office of National Statistics, OECD.
NBER Financial Conditions Index	Hatzious et al. (2010)	Quarterly 1970-2010	Principal components analysis	45 variables	FED, Bloomberg etc.