Chapter 6
Measuring Financial Stress and Vector Error Correction from a Global Flow of Funds Perspective

Abstract This chapter constructs a statistical monitoring system and vector error correction model to measure risks to the global flow of funds (GFF). Taking China as a referent, we inspect how GFF and macroeconomic growth affected stability of financial systems and build statistical monitoring systems for GFF while referring to indicators of financial soundness. Then we link the real and financial economies and create a Chinese financial cycle index and financial stress index with regard to GFF. Third, VEC models observe how short-term fluctuations affect long-term equilibrium after external shocks. Fourth, we expand the empirical analysis based on these statistical methods and raise future issues for discussion.

Keywords Global flow of funds · Financial soundness indicators · Financial cycle index · Finance stress index · Vector error correction model

6.1 Introduction

Chapter 4 discussed the global flow of funds (GFF) between the US and China. Although the causes of imbalances between the Chinese and US economies differ, they share one imperative: governments should strengthen supervision of international fund flows to prevent future financial crises.

Scholars have sought to establish robust indicators of financial crisis since the 1990s. Kaminsky et al. (1999) designed a model to signal currency crises. They determined the signal range and selected significant early warning indicators. If the early warning index crosses a specified threshold, a financial crisis is considered possible within the next 24 months. The International Monetary Fund (IMF) also has researched an early warning system for financial crises (Abiad 2003).

Illing and Liu (2003) established a financial stress index for Canada. Drawing from previous studies, they selected the banking sector, equities markets, and an FX market index as variables and assembled weighted combinations of those variables into a single financial stress index (FSI). FSIs seek to test the uncertainty, expected losses, and overall risk to entire financial systems. An index of a country’s major financial markets can be consulted as a continuous variable, with extreme values
indicating financial crises. FSI examines financial stress in a broader framework that can timely reflect the stress on a country’s financial system, help policy-makers and investors assess risks, and aid in preventing financial crisis.

Financial stress refers to imbalances in the long-term circulation of capital that portend shocks to economic equilibrium. Heightened pressure may signal interruptions in the flow of funds as a continuous process of change.

The St. Louis Fed unveiled a financial market stress index (STLFSI) in 2010 (Fig. 6.1, Kliesen and Smith 2010) to help the public monitor financial market conditions weekly. It contains 18 weekly averages of daily data: seven interest rates, six yield differentials, and five other indicators that capture financial stress. Data may move together as financial stress in the economy changes. Figure 6.1 displays the 2007–2008 US financial crisis and the abrupt rise and fall in FSI, which reflects changes in financial stress. Declines in FSI indicate greater stability and less stress in financial markets.

Like other financial market indices, STLFSI measures types of financial market stress. Falling asset prices are an example, as they may indicate eroding corporate profits as economic growth slows. Other pressures include the market’s changing perception of various risks. Risk is usually measured by spreads. For example, default risk is measured as differences in yield between “risky” assets (e.g., corporate bonds) and “risk-free” assets (Treasuries). But financial market stress can be elsewhere. The current STLFSI2 is a revision of the original STLFSI.

Xiaoxing and Lei (2012) used aggregate credit weights to weight each indicator in reference to the previous study and modeled a financial stress index that includes banks, stocks, foreign exchange (FX), and insurance markets. They show that the characteristics of pressure on China’s financial markets are obvious, and high stress often accompanies an international financial crisis.

Kamada and Nasu (2013) developed a financial cycle index (FCI) of early warning indicators to discern the emergence of financial crisis. The index is derived from

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1 The average value of the index, which begins in late 1993, is designed to be zero. Thus, zero is viewed as representing normal financial market conditions. Values below zero suggest below-average financial market stress, while values above zero suggest above-average financial market stress.
the theory of economic cycles. Its indicators track medium-term volatility (usually 10 years) in leading, coincident, and lagging indexes of economic activity. The FCI displayed unusual volatility the year before the 2008 US financial crisis.

These studies indicate that FSIs seek to assess uncertainty and change in entire financial systems. They index the real and financial economies to reveal a country’s capital circulation. They test the system’s ability to resist external shocks and assess potential impacts.

By comparison, FCIs are early warning indicators that test the likelihood of a financial crisis by observing capital cycles. They track indicators of a financial crisis, subtract the ratio of a declining index from that of a rising index, and judge the precursors of a crisis by the direction of change. Selecting appropriate indicators to signal crises is essential for the preparation of FCI.

A comparison between FCIs and FSIs shows that the former observe the impact on financial markets of current and future structural economic imbalances in the context of business cycle fluctuations. The latter reflect the risk of selected external shocks being transmitted through the financial system. Although the indexes have different focuses, they complement each other by observing financial stability and strengthening supervision of internal and external pressures on national economies.

Most studies of financial early warning systems address currency or banking crises. Few seek to measure the severity of crises or to reflect entire financial systems. A common shortcoming is that these studies ignore how international capital flows affect financial stability. Therefore, studies of financial soundness indicators (FSIs) by the IMF have emerged. FSIs employ three computational frameworks—systems of national accounts, international accounting standards, and the Basel Committee on Banking Supervision—to build 12 core indices and 27 encouraged indices that reflect financial stability (Table 6.1). However differing analytical goals, create two shortcomings in an FSI’s ability to capture structural problems and assess financial risks. First, FSIs sum sectors and provide no statistical basis for the argument that structural economic changes affect financial stability. Second, FSIs focus on financial stability but lack feedback about financial risks from the real economy and factors overseas.

The 1997 Asian financial crisis and the 2008 US subprime mortgage crisis showed that long-term structural imbalances cause crises. As imbalances accumulated, affecting one or several macro or micro variables, sharp short-term leakages in the fund flows collapsed the financial cycle. To investigate long-term equilibrium in GFF and how short-term fluctuations affect financial stability, it is necessary to compile an FCI based on GFF. A GFF-based FCI can indicate the current financial situation, trends, and future scenarios and give early warning of financial crises. On this basis, an FSI can be constructed to expose the comprehensive impact of international capital cycles on the financial system and to test for financial stress.

This study introduces the GFF, establishes FCI and FSI, and constructs an econometric model for empirical analysis. To investigate long-term equilibrium of GFF and how short-term fluctuations influence financial stability, it is necessary to compile a financial stress index based on GFF analysis. FSIs test overall risk to an entire financial system via an index of a country’s major financial markets. As a continuous
Table 6.1 Financial soundness indicators: the core and encouraged sets

| Core Set                              | Encouraged Set                                                                 |
|---------------------------------------|-------------------------------------------------------------------------------|
| **Deposit takers**                    | **Deposit takers**                                                            |
| Capital adequacy                      | Capital to assets                                                             |
| Regulatory capital to risk-weighted   | Large exposures to capital                                                    |
| assets Regulatory Tier 1              | Geographical distribution of loans to total loans Gross asset position in      |
| capital to risk-weighted assets       | financial derivatives to capital Gross liability position in financial        |
| Nonperforming loans net of provisions| derivatives to capital Trading income to total income Personnel expenses to   |
| to capital                            | noninterest expenses Spread between reference lending and deposit rates Spread |
| Asset quality                         | between highest and lowest interbank rate Customer deposits to total (non-     |
| Nonperforming loans to total gross    | interbank) loans Foreign-currency-denominated loans to total loans Foreign-    |
| loans to total loans                  | currency-denominated liabilities to total liabilities Net open position in     |
|                                      | equity to capital                                                             |
| Earnings and profitability            | Liquidity                                                                     |
| Return on assets                      | Liquid assets to total assets (liquid asset ratio) Liquid assets to short-      |
| Return on equity                      | term liabilities                                                             |
| Interest margin to gross income       |                                                                              |
| Noninterest expenses to gross income  |                                                                              |
| Liquidity                             |                                                                              |
| Liquid assets to total assets (liquid |                                                                              |
| asset ratio)                          |                                                                              |
| Liquid assets to short-term liabilities |                                                              |
| Sensitivity to market risk            | Net open position in foreign exchange to capital                              |
| **Other financial corporations**      |                                                                              |
| Assets to total financial system      |                                                                              |
| assets Assets to gross domestic       |                                                                              |
| product (GDP)                         |                                                                              |
| **Nonfinancial corporations sector**  |                                                                              |
| Total debt to equity                  |                                                                              |
| Return on equity                      |                                                                              |
| Earnings to interest and principal    |                                                                              |
| expenses                              |                                                                              |
| Net foreign exchange exposure to     |                                                                              |
| equity                                |                                                                              |
| Number of applications for protection |                                                                              |
| from creditors                        |                                                                              |
| **Households**                        |                                                                              |
| Household debt to GDP                 |                                                                              |
| Household debt service and principal  |                                                                              |
| payments to income                    |                                                                              |
| **Market liquidity**                  |                                                                              |
| Average bid-ask spread in the        |                                                                              |
| securities market                     |                                                                              |
| Average daily turnover ratio in the   |                                                                              |
| securities market                     |                                                                              |
| **Real estate markets**               |                                                                              |
| Real estate prices                    |                                                                              |
| Residential real estate loans to      |                                                                              |
| total loans                           |                                                                              |
| Commercial real estate loans to total |                                                                              |
| loans                                 |                                                                              |

*Source* IMF (2006), Table 1.1 Guide to compiling financial soundness indicators
variable, its extreme values manifest crises. By constructing factors that influence real and financial economies and major domestic and foreign financial markets, FSIs observe fund flows and stress on financial systems and assesses their impact on stability (Lai and Xing 2010).

This chapter constructs a GFF-based monitoring system from concepts and theoretical frameworks discussed in Chap. 5. It proceeds as follows. Section 6.2 references FSIs to build a GFF-based statistical monitoring system. Section 6.3 links the real and financial economies and matches domestic fund flows with international capital flows to construct a Chinese financial cycle index (CFCI). Section 6.4 discusses risks in external fund flows and the current status of China’s external flow of funds. Section 6.5 discusses explanatory variables in the financial stress model and tests the stationary of their data. It explains our use the Johansen test method, inspects financial stress and first-order single co-integration among all modeled variables, and constructs a vector error correction model (VEC model). Section 6.6 discusses the VEC model featuring parameters related to financial stress and employs it in an empirical analysis. The Conclusion summarizes and raises future issues.

### 6.2 Building a GFF-Based Statistical Monitoring System

#### 6.2.1 GFF-Based System Analysis

Chapter 5, Sect. 5.2 presented a theoretical framework for GFF. We now apply that framework in a GFF-based system of analysis. We extend flow of funds analysis to global flows, combine physical with financial transactions, link domestic fund flows with international capital flows, and create an analytical system that captures domestic savings-investment, foreign trade, and international capital flows. GFF extends domestic fund flows internationally and reveals changes in domestic and international capital flows. GFF-based analysis can derive relations among the domestic flow of funds, current account balances, and financial account balances. It can track external fund flow between a home country and elsewhere and reveal structures of economic dependence and financial stability. The GFF framework includes the savings-investment balance, surplus or deficit in domestic funds (net external financial investment), foreign trade balances, international flows of capital, and increases or decreases in FX reserves. Figure 6.2 depicts the relation among GFF, financial stress, and crises.

As Fig. 6.2 indicates, GFF contains domestic and foreign elements. Financial markets link physical transactions domestically and abroad with financial transactions. To facilitate a smooth flow of funds (trading), regulators have designated trading systems and policies to maintain long-run stability and balanced development. However, markets change constantly in the short run, forming imbalances in the real economy [e.g., savings below investment ($S < I$) and current balance deficits ($IM < EX$)]. Shocks to financial markets include capital shortages, capital outflows
(FO > FI), FX shortages, and others. Cyclical stagnation and blockage occur in fund flows, generating financial pressures, systemic risks, and crises.

To test the financial stress caused by GFF imbalances and to give early warning of a crisis, it is necessary to monitor GFF mechanisms. A statistical monitoring system should operate on the macro and micro levels. The macro level includes the real economy, domestic flow of funds, balance of payments, market volatility, and price changes. Macro monitoring reveals savings-investment imbalances caused by foreign trade and capital flows and structural problems in the real economy. It reveals the risks of foreign financial investment and monitors the scale, mode, and direction of international capital flows. Micro monitoring detects accumulating risks among financial institutions, financial market turmoil, and financial transaction risk. Micro-level risks arise among depository institutions, non-financial firms, households, the real estate market, and securities markets. They include capital adequacy, asset quality, earnings, liquidity, and sensitivity to markets that could trigger a currency or banking crisis.

### 6.2.2 Definition of Financial Crisis from the GFF Perspective

Recognizing the possibility of a financial crisis presupposes a GFF-based statistical definition of “financial crisis.” Drawing upon definitional equations in external flow of funds accounts and national accounts, GFF is summed up in four equilibria.

Savings–Investment and Current Account Balance:
\[ S - I = \Delta FA - \Delta FL = EX - IM. \] (6.1)

Overseas income and expenditures balance

\[ EX - IM = (FO - FI) + CRA. \] (6.2)

\[ r_{t-1} FI_{t-1} \] is interest payments of external debt. Changes in FX reserves as \( CRA = FRA_t - FRA_{t-1} \), change Eqs. (6.2) to (6.3).

\[ (EX_t - IM_t) - (FI_t - FO_t - r_{t-1} FI_{t-1}) - (FRA_t - FRA_{t-1}) = 0 \] (6.3)

The left side of Eq. (6.3) captures the current account balance, the financial account balance, non-trade income, and changes in FX reserves. Under fixed exchange rates, FX reserves sufficient to cover a trade deficit and repayment of foreign debt due are set as \( FRA' \).

Equations (6.1), (6.2), and (6.3) can reveal whether GFF is out of balance. Conditions leading to a financial crisis are expressed by Eq. (6.4).

\[ (EX_t - IM_t) - (FI_t - FO_t - r_{t-1} FI_{t-1}) + FRA_{t-1} < FRA', \] (6.4)

where, \( S = \) Total savings, \( I = \) Total investments, \( \Delta FA = \) Changes in financial assets,
\[ \Delta FL = \text{Changes in Financial liabilities: } FO = \text{Fund inflows, } FI = \text{Fund outflows,} \]
\[ CRA = \text{Changes in reserve assets, and } FRA = \text{Stock of foreign reserve assets.} \]

Equation (6.4) intimates several ways in which GFF imbalances can foster financial crises. A crisis can emerge, first, if FX reserves cannot cover a current account deficit (\( IM > EM \)). Second, a crisis can occur when sharp increases in foreign equity yields, interest rates, and FX rates generate domestic capital outflows that exceed international inflows of capital (\( FI \)), also, a currency crisis can arise when FX reserves are insufficient to meet domestic funding needs. Third, a crisis can arise through deficits in foreign trade and financial balances. Fourth, sharp appreciation or depreciation of the domestic currency can cause a balance of payments crisis or external debt payment crisis.

The above description of the GFF mechanism indicates that financial crises can arise in one or several countries and spread. They become evident through financial indicators, deteriorations in short- and long-term cycles, imbalances in trade or currencies, and many other indicators. For example, the 2008 US financial crisis triggered a global economic crisis characterized by sharp and swift changes in capital flows.
6.2.3 About the Financial Stability Statistics Guide

Lack of statistical information for monitoring financial risks became apparent during the 1997 Asian financial crisis. Hoping to construct a system for reporting global financial stability, the IMF organized a conference in 1999 from which FSIs were born. In 2000, the IMF statistically surveyed financial stability among participating countries. Based on those surveys, the IMF introduced its FSI in 2001. In 2002–2004, IMF drafted the Guide, a guidebook for establishing and promoting FSIs. After soliciting views on its draft, IMF published the Guide on its website in July 2004 and as an official document in March 2006.

The intent in establishing an FSI was to assess the strength and vulnerability of financial systems and to bolster their supervision. FSIs in their current form adopt the computational frameworks of the system of national accounts, international accounting standards, and the Basel Committee on Banking Supervision. However, they differ in three ways. First, their treatment of sector information differs from that of accountants and bank supervisors. Second, the statistical focus differs. Like national accounts, they are a symmetrical record of flows and positions within and across sectors. FSIs record flows and positions within a sector to avoid data distortions but not necessarily among sectors, because the data required differ by sector. Third, observational targets differ. National accounts target all economic activity, whereas FSIs summarize and merge to avoid double counting of capital and activity. In that respect they resemble the tallies of bank supervisors, commercial accountants and although those focus on individual entities.

Table 6.1 contains 12 core and 27 encouraged sets for constructing an FSI. Core sets apply to all countries, and encouraged sets can be adopted for each country’s needs. Core sets cover capital adequacy, asset quality, earnings and profitability, liquidity, and sensitivity to market risk. Encouraged sets cover depositaries, other financial entities, nonfinancial corporations, and four household sectors plus market liquidity and real estate markets. With developments in information technology and financial products, international capital flows exhibit intense changes in magnitude and speed. As a result, monitoring system pressures and volatility of international capital circulation becomes more important for constructing an FSI and for regulators.

FSIs cover several aspects of financial stability. Capital strength is important for every organization, especially as a buffer for unexpected losses. However, monitoring financial stability requires attention to asset structure, quality, exposure to financial risks, and income and expenditures. The focal point for non-financial corporations is their ability to pay liabilities and to finance debt. In short, a financial stability index needs to monitor changes in savings (exposure to risks) and flows because they reflect shifting vulnerability in financial sectors and help to assess their ability to handle stress and risks. These economic indicators are reference values for compiling a financial pressure index. Next we discuss how to build a GFF-based statistical monitoring system using them.

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2IMF, Financial Soundness Indicators, 2006, p 54.
6.2.4 Selecting Indexes to Monitor GFF

GFF analysis reveals the characteristics and structure of domestic and international fund flows. It includes all domestic investment-savings flows, links flows of funds with current account balances, and connects international capital flows. Items relevant to financial markets include inflows of domestic funds, overseas funds by domestic savings, and loans by banks as fund sources (fund inflows). Financial markets split the supply of funds into the domestic economy and overseas sectors as fund uses (fund outflows). Financial market indicators track debts and credits and the spectrum of financial liquidity.

To test financial stress and warn of systemic crises, we need a new statistical framework that corresponds to the operational structure of GFF as the foundation of a monitoring system. This framework must reflect dynamic changes among economic entities and financial statistics and link domestic fund flows with international capital movements. Four aspects of external fund flows should be monitored. First, they must indicate any influence on current accounts from structural economic changes that disrupt savings-investment. Second, they must indicate risks to international capital flows caused by surplus or deficit of domestic funds. Third, they must indicate shocks to international capital flows caused by imbalances in current accounts and by large-scale international capital inflows or outflows. Fourth, they must indicate changes in FX reserves and pressure on financial stability from abrupt changes in FX reserves.

In building computational rules for monitoring of international flows of funds, the four previously mentioned frameworks are useful: statements of national accounts, the Basel Committee on Banking Supervision, FSIs generated by the IMF, and Treasury International Capital provided by the US Department of the Treasury. According to the structure of international fund flows (Eqs. 6.1 through 6.4), we designed the GFF-based monitoring system indicated in Table 6.2.

Of the four elements of international fund flows, we picked factors that affect savings-investment balances (S-I): disposable income, final consumption, net savings ratio, CPI, market interest rates, GDP, and government expenditures.

As factors that affect surplus or shortage of domestic funds (ΔFA-ΔFL), we picked the ratio of sectoral financial surplus or deficit to GDP, the ratio of net outflow of funds to GDP, the spread between highest and lowest interbank rates, regulatory capital to risk-weighted assets, liquidity to total assets, liquid assets to short-term liabilities, non-performing loans to total loans, residential real estate loans to total loans, and real estate prices.

As factors that affect external trade flows (EX-IM), we chose real effective exchange rates, consumption expenditures of US, regional GDP, an import price index, Chinese GDP, and the ratio of China’s trade balance to GDP.

As factors that affect external flow of funds (FO-FI), we picked economic growth rate, spread between overseas and domestic interest rates, interest rates of central bank, foreign-currency-denominated loans to total loans, government bond yields in the US, holdings of US government bonds to total foreign reserve assets, return on
equity, change in reserve assets, profit from investment, net FX exposure to equity, FDI, large exposure to capital, and net open position in FX to capital.

We use GFF statistics to measure long-term structural problems. The GFF model contains 11 endogenous and 17 exogenous variables (Chap. 5). It observes changes in expectations and risk and lags in relevant economic variables. It explains the state of fund flows during continuous adjustment from balance to imbalance over the medium-to-long term. As a dynamic model, its system of simultaneous equations replicates financial market equilibrium. However, this model can neither capture short-term waves or stability in external fund flows, nor can it observe shocks from abrupt changes in foreign financial markets. Moreover, the model does not emit an early alarm for crises when we seek to understand how profit and risk affect international capital flows or how changes in fund flows affect domestic economic growth. Therefore, continuous research is needed to create an index that shows the short-term trend of GFF and financial stress.

### 6.3 Creating a Financial Cycle Index

External flows of funds are affected by country-specific interest rates, stock prices, FX, and other factors. Therefore, the GFF model does not necessarily capture short-term equilibrium in a country’s flow of funds, but it can predict future progress and simulate effects of financial policies by capturing changes in mid- or long-term trends. In designing the model, we must attend to domestic factors, changes in international markets, and benefits and risks of foreign capital flows. Given these concerns, we observe causal relationships of each economic variable and structural problems in the external flow of funds in building the GFF model shown in Chap. 5.

However, this model cannot reflect recent capital flows and financial stability, speculate about potential financial crises, nor describe stresses from dramatic changes in financial markets. That said, we constructed an FCI and an FSI for GFF analysis. We selected 195 months from January 2004 (before the US financial crisis) to March 2020 (during the COVID-19 pandemic) as a financial cycle to observe transformations in financial stress in China.

#### 6.3.1 Purpose and Basis of Selection

For a GFF-based statistical monitoring system (Table 6.2), we selected \( n \) time series indicators, excluding seasonal variations, irregularities, and changes in trend. We call the adjusted time series index a diffusion index (DI). It is defined by \( n + /n \), when moving in an extended direction compared with the previous period and setting the number of series to \( n + \). DI uses monthly data expressed as percentages. It focuses on timeliness, sustainability, and correspondence to changes in GFF. Correspondence is the degree to which an index reveals the amount and direction of fund flows
Table 6.2  Global flow of funds statistics

\[ S - I = \Delta FA - \Delta FL = EX - IM \]

| GFFS                                      | Source            | Source            |
|-------------------------------------------|-------------------|-------------------|
| Net savings ratio                         | SNA               | GDP               |
| Disposable income                         | FOF               | Government Expenditure |
| CPI                                       | CBQSB             | Final consumption |
| Spread between lending and deposit rates  | FSIs              | Purchasing Managers’ Index |
| Net outflow of funds to GDP               | IFS               | Spread between highest and lowest interbank rate |
| Sectoral financial surplus or deficit to GDP | FOF             | Liquid asset to total assets |
| Regulatory capital to risk-weighted assets| FSIs              | Liquid asset to short-term liabilities |
| Nonperforming loans to total gross loans  | FSIs              | Residential real estate loans to total loans |
| Trade balance to GDP                      | BOP               | Real estate prices |
| Real effective exchange rate              | IFS               | Consumption Expenditure of the US |
| Yuan Change rate                          | BOP               | Total GDP of main areas |
| CA = (FO-FI) + CRA                        |                   |                   |
| Economic growth rate                      | SNA               | Return on equity |
| Spread between overseas and domestic interests | FSIs           | Changes in reserve assets |
| Interest rates of central bank            | CBQSB             | Profit from investment |
| Foreign-currency-denominated loans to total loans | FSIs         | Net foreign exchange exposure to equity |
| Government bonds yields of the US         | FRB               | FDI               |
| Holding US government bonds to total FRA  | FSIs              | Large exposures to capital |
| Federal funds rate of the US              | TIC               | Net open position in foreign exchange to capital |

Notes: CBQSB = China Quarterly Statistical Bulletin, NBS = National Bureau of Statistics, BEA = US Bureau of Economic Analysis, GAC = General Administration of Customs, China, TIC = US Treasury International Capital (TIC) System

and reflects the dynamics of domestic and the international financial markets. We can classify GFF indexes as leading, coincident, or lagging (Table 6.3) based on temporal movements by different indexes.

Changes in real estate prices can lead to increased land use, construction, and household consumption. These in turn expand capital demand, so it is set as a leading index. A rise in producer prices can raise prices for other production inputs and consumer prices and thereby greater capital demand. Widening inter-bank lending
Table 6.3 Composition of financial cycle index indicators

| Leading Index                      |
|-----------------------------------|
| Index of house price              |
| Producer price indices            |
| Interest rate on loans            |
| Purchasing Managers’ Index        |
| Coincident Index                  |
| Growth rate of total loans        |
| Growth rate of net export         |
| Lagging Index                     |
| Growth rate of exchange rate      |
| Effective federal funds rate      |

spreads increase availability of credit and its cost. The Purchasing Managers’ Index (PMI)\(^3\) is an index of trends in manufacturing and services. It features a diffusion index that summarizes whether purchasing managers view market conditions as expanding, unchanged, or contracting. Therefore, it is set as a leading indicator. The new credit index shows changes in new loan originations, which relates directly to changes in capital flows and the business climate.

An increase in net exports generates can generate a foreign trade surplus. Increases in foreign financial assets relate directly to the magnitude of fund flows. Therefore, these are used as coincident indexes of financial market trends. Because China has not fully opened capital markets, the RMB exchange rate and the effective federal funds rate affect the external flow of funds. Therefore the RMB exchange rate index and the effective federal funds rate are used as lagging indicators.

### 6.3.2 Steps and Methods for Building FCI

Within the definition of the DI, we can observe changes in the indices above. When any coincident index increases 50%, we consider it as phase of expanding fund flows or economic development. Increases below 50% indicate shrinking fund flows and possibly economic contraction.

Set the value of any index at time \( t \) as \( y_i(t) (i = 1, 2, \ldots, n) \) and its rate of change becomes

\[
    r_i(t) = \frac{y_i(t) - y_i(t-d)}{y_i(t)}.
\]

\(^3\)The US, Great Britain, Singapore, and 22 other countries have formulated PMI indexes, and institutions have instated a global index and a Euro zone index. PMI has become a barometer of changes in the world economy. China has released monthly PMI data since 2005.
During period $= d$, we may set $d = 1$ (comparing with the previous month) or $d = 3$ (comparing three previous months). To simplify explanation, set $d = 1$. DI at any point can be written as

$$DI(t) = \frac{1}{2n} \sum_{i=1}^{n} \{\text{sgn}(r_i(t)) + 1\}, \quad (6.6)$$

where $\text{sgn}$ is a sign function, defined as

$$\text{sgn}(x) = \begin{cases} 
-1 & (x < 0) \\
0 & (x = 0) \\
1 & (x > 0) 
\end{cases}$$

From Eq. (6.6), DI is the average value of each index $\text{sgn}(r)$. $\text{sgn}$ is an increasing function, and DI changes directionally with $r$. Hence DI can reflect changes in fund flows and changes in disparate economies.

However, DI captures only increases or decreases in variable series, not their magnitude. To defeat this shortcoming we can use the composite index, which is built in four stages below.

i. For an individual series $y_i(t)$, a symmetrical change rate $r_i(t)$ is

$$r_i(t) = \frac{y_i(t) - y_i(t - 1)}{\{y_i(t) + y_i(t - 1)\}/2}. \quad (6.7)$$

When $y_i(t)$ is 0 or negative, we can put $r_i(t)$ as $r_i(t) = y_i(t) - y_i(t - 1)$.

ii. Calculate the average, standard deviation of $r_i(t)$ as

$$\bar{r}_i(t) = \frac{1}{T} \sum_{\tau=t'}^{T} r_i(\tau) \quad \text{and} \quad S_i(t) = \left[\frac{1}{T} \sum_{\tau=t'}^{T} \{r_i(\tau) - \bar{r}_i(t)\}^2\right]^{1/2}$$

where $T = 195$ (195 months). $t' = t - T + 1$ is the period 16 years previous. We standardize our 195 months of data over the 16-year period.

$$z_i(t) = (r_i(t) - \bar{r}_i(t))/S_i(t). \quad (6.8)$$

iii. For each leading, coincident, and lagging index, compound an individual index as follows and calculate an average (composition) rate of change ($v(t)$).
\[ v(t) = \bar{r}(t) + \bar{s}(t) \cdot \bar{z}(t). \] (6.9)

When considering the number of indices that constitute \( n \)

\[ \bar{r}(t) = \frac{1}{n} \sum_{i=1}^{n} r_i(t), \quad \bar{s}(t) = \frac{1}{n} \sum_{i=1}^{n} s_i(t), \quad \bar{z}(t) = \frac{1}{n} \sum_{i=1}^{n} z_i(t), \]

iv. So we can derive an FCI in which FCI \((t)\) is set by standard time to 100 and calculate an average rate of change sequentially:

\[ FCI(t) = FCI(t - 1) \frac{2 + v(t)}{2 - v(t)}. \] (6.10)

Equation (6.10) indicates the central rate of change (FCI \((t)\)) is consistent with \( v(t) \) and can be written

\[ v(t) = \frac{FCI(t) - FCI(t - 1)}{\{FCI(t) + FCI(t - 1)\}/2}. \] (6.11)

The change in \( v(t) \) is the average change in FCI\((t)\)—i.e., the rate of change in financial market trends. Therefore, the rate of change in FCI\((t)\) is essentially the same as the change in \( v(t) \). When FCI\((t)\) increases (decreases), financial instability increases (decreases), and the economy is rising (falling). FCI is composed of seven indicators that capture the comprehensive impact on the financial cycle of factors that lead, coincide with, and lag market changes. A change in FCI indicates changes in the business cycle. Applying the method described above to 195 monthly data points for the seven indicators in Table 6.3, the FCI\((t)\) is shown in Fig. 6.3.

![Fig. 6.3 China’s financial cycle index (FCI with 195 monthly data points)](image-url)
Figure 6.3 displays China’s financial trends during the period studied. FCI exhibits three major ups and downs from January 2004 to March 2020. The first fluctuation in 2007–2009 is attributable to the US financial crisis. FCI dropped from 0.4 in April 2007 to −1.5 in July 2008. Following RMB 4 trillion in support from the Chinese government, the FCI rose back to 1.5 in March 2010. The second fluctuation is the decline in FCI in 2014–15. There are two reasons for these movements. China’s foreign trade declined significantly in 2014, and new loans fell sharply to 8.2% in September 2014. The third notable fluctuation (2019–2020) is attributable to COVID-19. All Chinese economic indicators fell, prompting FCI to decline to −1 in March 2020.

These three swings in FCI tell a cyclical tale of China’s fund flows that illustrates two problems: they coincide with structural imbalances in the real economy and the structural imbalance in savings and investment from 2004–2009 and 2014–2015. That is consistent with our theoretical hypothesis. Another revelation is that FCI trends in China relate to the financial crisis in the United States in 2007–2008 and the impact of COVID-19. Therefore, we must investigate the impact on China’s financial system from changes in domestic and foreign economic variables.

6.4 Create a Financial Stress Index

After investigating changes in GFF and financial stability using FCI, we further explore financial stress using FSI constructed via GFF monitoring to assess pressure on financial stability. Stress testing and FCI play different but complementary roles in surveillance. Stress testing is a predictive tool to assess the impact of unexpected shocks (e.g., the 2008 crisis) on the soundness of GFF. FCI uses indices that reflect current conditions.

6.4.1 Establishing China’s FSI

FSI addresses the weakness inherent in models that use EWIs by improving the reference variable. In particular, FSI is continuous, of high frequency (daily), and covers equity markets, bond markets, FX markets, and banking. Therefore, it is suitable for analyzing financial stability in developed economies with numerous systemically important financial markets and institutions. Financial stress is a continuous variable with a spectrum of values wherein extremes designate a crisis. Stress increases with expectations of financial losses (a widening in distribution of probable losses).

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4China put forward a series of fiscal, monetary and other policies to cope with the 2008 international economic crisis and stabilize the economy, with a total scale of about 4 trillion yuan (about us $586 billion). IMF sees China stimulus helping global economy. https://www.reuters.com/article/us-financial-g20-imf/imf-sees-china-stimulus-helping-global-economy-idUSTRE4A94P220081110.
or uncertainty (lower confidence about distribution of probable losses). Stress is the product of a vulnerable structure and an exogenous shock. Financial fragility describes weaknesses in financial conditions and/or in the structure of the financial system (Illing and Liu 2003).

Based on the characteristics of China’s fund flows and the timeliness and sustainability of GFFS data, we selected the variables below for the FSI.

I. Spread between overseas and domestic interests
II. Average return on Shanghai Stock Exchange Composite Index
III. Holding of US government bonds to total FRA
IV. Exchange market pressure index
V. Purchasing Managers’ Index.

\[
EMPI_t = \frac{er_{ij} - \mu_{er_{ij}}}{\sigma_{er_{ij}}} - \frac{CRAR_{ij} - \mu_{CRAR_{ij}}}{\sigma_{CRAR_{ij}}}
\]

(6.12)

\(er\): monthly change in exchange rates
\(CRAR\): monthly change in reserve assets.

Because we could not obtain monthly data for the ratio of net open FX positions to capital,\(^5\) that was entered in Table 6.1. Five variables in Table 6.4 constitute China’s FSI. Variable A denotes factors stressing global fund flows from the spread between overseas and domestic interest rates. Variable B denotes equity market returns from the Shanghai Composite Index to mirror stress on capital markets. Variable C is Chinese holdings of US government bonds to total foreign reserve assets and tests the risk in holding US sovereign debt. Variable D, the FX market pressure index, shows the stress on Chinese finance from appreciation in the RMB and increases in FX reserves.

In Eq. (6.12), \(\mu\) and \(\sigma\) indicate the average and standard deviation, respectively, in sequences of \(er\) and \(CRAR\). Variable E, the PMI, shows the effect of changes

\(^5\)“Net open position” means the net sum of all foreign currency assets and liabilities of a bank or financial institution, including all spot and forward transactions and off-balance sheet items.
in the real economy on financial stress. These five variables are monthly spanning January 2004–March 2020. We calculated averages and standard deviations for each. Variables A, B, C, D, and E are from Table 6.4. We standardized variables $Z_{Ai}$, $Z_{Bi}$, $Z_{Ci}$, $Z_{Di}$, $Z_{Ei}$ in consistent units and summed them to obtain a GFF-based $FSI$ in Eq. (6.13).

$$FSI_t = Z_{Ai} + Z_{Bi} + Z_{Ci} + Z_{Di} + Z_{Ei}$$ (6.13)

The weighted summary of these five standardized variables obtains the financial stress-weighted GFF-based $FSI$ in Eq. (6.14).

$$WFSI_t = \sum_{i=A}^{E} w_{it} Z_{it} = 0.2Z_{Ai} + 0.23Z_{Bi} + 0.27Z_{Ci} + 0.21Z_{Di} + 0.1Z_{Ei}$$ (6.14)

where, $w_{ij} = \gamma_{FSI:zi}/\sum_{i=A}^{E} \gamma_{FSI:zi}$. That is, the weight of each variable is calculated as the proportion of the correlation coefficient between each variable and $FSI$ in the total correlation coefficient of each variable. Weights of the five variables in Table 6.4 are 0.20, 0.23, 0.27, 0.21, and 0.10, respectively.

Figure 6.4 indicates changes in $FSI$ and $WFSI$ in China from January 2004 to March 2020. There are 113 months in which $FSI > 0$ and 82 in which $FSI < 0$. When $FSI$ exceeds 0, financial pressure increases. Financial pressures increased during more than half of the period from 2014 to 2020. $FSI$ remained relatively stable from January 2004 to June 2007. It was volatile until August 2010, especially since August 2007 when it slid from $-0.33$ to $-7.3$ in August 2008 due to Variables B (return on equity), C (holdings of US government bonds to total FRA), and D (FX pressure index). $FSI$ rose to 0.3 in May 2009 and reached its maximum (3.6) in August 2010. These changes reflect stress from the US subprime mortgage crisis from late 2007.
until May 2008. Figure 6.4 also displays FSI rising since 2015, reaching 2.15 in May 2018. China’s financial stress has been high since 2015.

### 6.4.2 Recognizing Periods of Financial Stress

Previous studies reveal three ways to identify periods of stress: when FSI hits 1.5X to 2X its historical averages, when FSI exceeds the index average by a critical value (e.g., 90%), and when one country’s FSI exceeds that of other countries. We use the first method. In a normal distribution $P(|x - \mu| \leq 2\sigma) = 0.9545$, meaning it is statistically significant when FSI reaches a value twice its historical value. Because imported variables are standardized, FSI appears as Eq. (6.15).

$$P(|FSI - \mu_{FSI}| > 2\sigma_{FSI}) = 0.05. \tag{6.15}$$

Hence we have $(FSI - \mu_{FSI}) > 2\sigma_{FSI}$, and we can obtain Eq. (6.16), the financial stress identification index (FSII):

$$FSII_t = \frac{(FSI_t - \mu_{FSI})}{2\sigma_{FSI}} - 1 \tag{6.16}$$

$FSII_t$ is our index for recognizing periods of financial stress. When $FSII_t > 0$ in Eq. (6.16), we designate a period as stressful and in need of appropriate policies. When $-1 < FSII_t < 0$, financial stress is normal. When $FSII_t < -1$ it is relatively low.

Employing Eq. (6.16), we compiled $FSII$ from January 2004 to March 2020 and graphed it in Fig. 6.5. There, trends reveal systematic stresses on China’s financial stability that originate in the global flow of funds, domestic capital markets, holdings of US bonds, FX appreciation, and higher FX rates.

![Fig. 6.5 Changes in China’s Financial Stress Identification Index 2004–2020](image-url)
From January 2004 to August 2008, stress was relatively low. Since August 2008, \textit{FSII} has risen and exceeded 0. In 2009 and after, \textit{FSII} continues rising and peaks in May–August 2010. \textit{FSII} exceeds 0 during 2017–2018, a period of rising financial stress. In short, financial stress has been intensifying, and China’s government should pay attention.

Figures 6.4 and 6.5 display characteristics and changes in China’s \textit{FSII} from January 2004 to March 2020. Under the GFF perspective, both figures reveal stress on international capital flows caused by international interest rate differentials, stress on domestic capital markets caused by changes in equities markets, stress on the real economy caused by changes in production and sale of commodities, stress on international financial market risk caused by holding US debt, and stress on FX markets caused by exchange rate appreciation and changes in FX reserves. These pressures based on global flow of funds constitute systemic pressures on China’s financial soundness. For February 2007 to November 2010, China’s systemic pressures show a clear uptrend, indicating that factors from external capital circulation intensified on China’s financial system. Heightened uncertainties of assorted origins aggravated financial risk in China.

Another period of concern is July 2015 to yearend 2018, when the \textit{FSI} peaks at 3.82 in July 2018. During this period China’s stock market collapsed, the RMB devalued against the dollar, and FX reserves declined. China’s external economic environment provides two reasons for the increase in \textit{FSI}. First, the exchange rate of RMB against the US dollar depreciated since 2015 (3.8% in July 2018). Second, the growth rate of FX reserves fell from 3.08% in September 2013 to $-1.48\%$ in March 2020. These events elevated the market pressure index from $-1.39$ in April 2014 to 5.83 in July 2018 (Fig. 6.6).

Intensified financial stress since 2008 compels attention. Changes in \textit{FSI} reveal conditions of financial stability in the medium term and trends in financial stress over the long term. They allow observers to analyze how domestic and international fund flows affect systemic financial pressure. \textit{FSI} provides a reference for policy

![Fig. 6.6 Changes in exchange market pressure index](image-url)
authorities to monitor risks, adopt measures to mitigate pressures, and maintain financial stability. $FSI$ depicts the waxing and waning of financial stress but not its underlying reasons, nor does it indicate how to regulate financial stress. We must give reasons for changes in $FSI$ that align with economic theory and market practice to observe long-term structural relations with other economic variables and short-term fluctuations and to mitigate risk. That necessitates a GFF-based model to predict $FSI$, reveal causality among primary exogenous variables and the $FSI$, and anticipate trends.

6.5 Co-Integration Analysis and the VEC Model

The complexity of relations between variables in a single sequence cannot reflect changes in financial stress. Therefore we introduced co-integration analysis and established a VEC model to observe interactions among multiple variables and to measure the structural impact on formation of financial stress. To observe changes in $FSI$ with the VEC model, appropriate variables must be selected and the stationarity of all variables tested to confirm their co-integration. Then the VEC model can be constructed with information about those relationships to enable analysis.

6.5.1 Selection of Variables

To monitor changes in the $FSI$ according to the three dimensions of GFF in Eq. (6.1–6.3), we selected the following explanatory variables from the considerations of real economic growth, stock market changes, real estate price volatility risk, bank credit market risk, FX market risk, the US financial market impact, the risk of huge FX reserves held by China, and possibilities for data collection. The Purchasing Manager’s Index ($PMI$), Shanghai Stock Exchange Composite Index ($SSEC$), House Price Index ($HPI$), interest rate on loans ($R$), the exchange rate between RMB and the US dollar ($REXC$), the US federal funds effective rate ($USFFER$), and the growth rate of foreign reserve assets ($GRFRA$) are taken as explanatory variables for the $FSI$.

We selected monthly data for these eight explanatory variables from January 2004 to March 2020 ($FSI_t$, $PMI_t$, $SSEC_t$, $HPI_t$, $R_t$, $REXC_t$, $USFFER_t$, $GRFRA_t$). Figure 6.7 displays trends in their variation. Fluctuations in these variables during the sampled period differ, but all exhibit obvious changes before and after 2008.

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6 $PMI$ is derived from the US purchasing managers’ index. It is a health check on the manufacturing industry. It measures production of new orders, commodity prices, inventories, employees, orders for delivery, new export orders, and imports. It is an important subsidiary index among leading economic indicators.

7 The housing price index is the abbreviation of the national real estate development boom index, which is composed of six sub-indexes: land under development, housing under construction, and the average selling price of commercial housing.
Fig. 6.7 FSI and Variations in Explanatory Variables. Sources China quarterly statistical bulletin, National bureau of statistics, SAFE, https://www.safe.gov.cn/, Gexun.com, https://www.hexun.com/, FRB

PMI indicates the real economy was trending downward during the period studied, hitting a low of 35.7% in February 2020. SSEC shows changes in equities markets, which fell to a nadir (−25%) in October 2008 and fluctuate plus or minus 20% thereafter. HPI tracks real estate prices. After dramatic fluctuations around 2008, it drops to 0.95 in April 2015 and rises from December 2015 to March 2020. R indicates that the inter-bank lending rate increased significantly from December 2010 to January 2015 but remained stable during other periods, peaking at 6.6% in May 2013. EREXC shows little change during the period. There are appreciable fluctuations in August 2005 and January 2008 and drastic fluctuations from September 2015 to February 2020. Changes in USFFER are most obvious, increasing from 1% in January 2004 to 5.3% in August 2006. However, it plummets after August 2007 and drops to 0.2% in December 2008. Thereafter it hovers at its lowest value until October 2015 and recovers after April 2016 to 2.4% in March 2019. RFRA indicates the rate of increase in FX reserves declined slowly throughout the period. Although the absolute value of FX reserves increases, its growth rate declines to −3.1% in December 2015.

The eight explanatory variables exhibit large fluctuations from January 2004 to March 2020. Unit root tests of each are needed to verify whether a stationary time series.
6.5.2 Unit Root Test

To determine whether FSI and the relevant variables are co-integrated, we performed an Augmented Dickey–Fuller (ADF) test. Results for unit root tests appear in Table 6.5. Except for the absence of a unit root for SSEC, all remaining time series variables are non-stationary, but they become integrated of order 1. That is, I (1) after first-order differences.

Table 6.5 displays results for unit root tests on FSI with all explanatory variables for nonstationary sequences. ADF is the Augmented Dickey–Fuller (1979) test, DF-GLS is GLS de-trending based the Dickey–Fuller test proposed by Elliott et al. (1996). Both tests contain constant terms. The lag for each variable is selected per the Schwarz Bayesian criterion, and the selected lag (k) is in parentheses. The lower half of Table 6.5 reveals critical values attain 10%, 5%, and 1% significance for ADF and DF-GLS.

Two cases warrant discussion, first see A. default-test results. A class test is to do no differential processing of the original sequence of variables, maintain the default level. Figure 6.7 reveals that the time series of FSI, REXC, etc. exhibit no obvious changes in trend, so only the test of the constant appears in the test equation. The time series for PMI, HPI, R, SUFFER, and RFRA trends obviously upward or downward, so we include the constant and drift terms in the test equation. Tests of default variable A show that t-statistics for FSI and all explanatory variables exceed critical values at 1% significance, so the null hypothesis cannot be rejected. Sequences of variables have unit roots and are non-stationary.

However, a first-order difference treatment for all variables demonstrates from test values of the difference variables B that the t values of all variables obviously changed and no critical value is statistically significant. That finding indicates all non-stationary sequences are first-order single integer stationary after treatment for first-order differences. That is, I (1) holds. Figure 6.8 reveals that characteristic roots of all first-order variables are within the unit circle, indicating the sequence is stationary and satisfies requirements of a values-attitudes-behaviors model.

| Variable | A. Level variable | B. Difference variable |
|----------|------------------|------------------------|
| FSI      | −2.046           | −13.237                |
| PMI      | −3.477           | −10.659                |
| HPI      | −1.853           | −6.755                 |
| SSEC     | −5.970           | −11.721                |
| R        | −2.860           | −12.655                |
| REXC     | −6.604           | −11.430                |
| USFFER   | −1.162           | −4.872                 |
| RFRA     | −2.260           | −15.301                |
| ADF      | 10%(*), 5%(**)−2.5777, −2.8820 | 1%(***)−3.4771 |
Fig. 6.8 Results of stability tests for the values-attitudes-behavior model

FSI is co-integrated with all explanatory variables treated with first-order differences, which satisfies preconditions for the co-integration test. In other words, time series of FSI and other explanatory variables are non-stationary, but their linear combinations are stationary, reflecting a stable long-term structural relation among variables.

6.5.3 Analysis of Co-integration

Before testing a set of time series for co-integration or long-term equilibrium, one should inspect them for order of integration. If variables number more than two, that is, more than one variable, the single-order number of the explained variable cannot exceed the single-order number for any variable. When the integral order of the explanatory variable exceeds the integral order of the explained variable, the integral order of at least two explanatory variables must be higher than the integral order of the explained variable. If there are only two explanatory variables, their integral order should be identical. Since we seek to verify co-integration between FSI and other eight explanatory variables, the Johansen test is necessary. Johansen analysis simultaneously observes and captures multiple co-integration relations. The first and most critical step in applying Johansen is to test the number of co-integration relationships. The test covers five condition.

i. The component variables of FSI and the co-integration vector contain no constant terms and trend variables.

ii. The component variables of FSI include no constant terms and trend variables, but the co-integration vector contains constant terms (restricted constant).
iii. The component variable of FSI contains a constant term—a variable in the form of time t—but the co-integration vector contains a constant term and no trend variable.

iv. Both FSI and the co-integration equations contain a linear deterministic trend (restricted).

v. FSI contains a quadratic trend term, and the equation for the co-integration relationship contains a linear trend term.

Results for the Johansen test appear in Table 6.6. It displays the test of trace statistics versus maximum intrinsic value (max-eigen value) using the five conditions above. Although results for the two tests are inconsistent, the conclusion of the trace test should be selected when its conclusion differs from the max-eigen value (Johansen and Juselius 1990). Table 6.6 displays that, including results from testing the constant and trend terms. There are at least two simultaneous co-integrations. That is, the co-integration vector has at least an order of two.

A more detailed test of trace statistics is needed to assure the co-integration vector has an order of two. Of the five cases for Johansen co-integration above, case (i) cannot occur in practice. That is, the co-integration equation (CE) and FSI have no constant terms and trend variables. The specification in case (v) also rarely occurs. For the sake of prudence, therefore, we test cases (i), (iii), and (iv) of the co-integration modes for trace statistics. Results appear in Table 6.7.

Comparison between trace statistics and critical values in Table 6.78 reveals two co-integrations in Model 2, three in Model 3, and three in Model 4, especially when the order of Model 2 is two. The co-integration vector includes only constant terms and no trend variables. Based on testing for trace statistics, there are at least two co-integration relations between FSI and each explanatory variable. This finding precisely meets our research purpose to obtain theoretically the basis for co-integration between FSI and the selected explanatory variable, indicating long-term equilibrium between FSI and the selected explanatory variable.

Figure 6.7 reveals no obvious trend change in the original time series. The order of the co-integration vector is two in Table 6.6, and the test in Table 6.7 assures at least two co-integrations between FSI and the composite variables (τ = 2). So we choose Model 2 because it features FSI combination variables with no deterministic trend and a co-integration vector with a deterministic trend (intercept (no trend) in CE and no-intercept in VAR). The lag is set to 1 because our main variables—stock prices, interest rates, and exchange rates—change daily. Per conditions enumerated above, we speculate on the CE, as displayed in Table 6.8.

The top portion of Table 6.8 displays parameter estimates of the standardized CE, showing standardized results for the number of each possible co-integration. In row CE1 the FSI coefficient (b_{11}) is normalized to 1, and PMI is deducted from the co-integration vector (b_{12} = 0) of CE, expressed as FSI variables normalized to 1 with the structural quantitative relationship of other explanatory variables. In row CE2 the PMI coefficient (b_{22}) is normalized to 1, and column FSI deducts (b_{21} = 0)

---

8 An * in Table 6.7 indicates the trace statistic exceeds the critical value and there is co-integration among variables.
### Table 6.6 Length of lag and number of co-integrations

Sample: 2004M01 2020M03  
Included observations: 190  
Series: FSI PMI HPI SSEC R REXC USFFER GRFRA  
Lags interval: 1 to 4

| Data Trend | No Intercept No Trend | Intercept No Trend | Intercept No Trend | Intercept Trend | Intercept Trend 4 |
|------------|-----------------------|--------------------|--------------------|-----------------|------------------|
| Test type  | Trace                 | Max-Eig            | Trace              | Max-Eig         |                  |
|            | 2                     | 1                  | 2                  | 0               |                  |
|            | 2                     | 0                  | 3                  | 0               |                  |
|            | 3                     | 0                  | 3                  | 0               |                  |
|            | 4                     | 0                  |                    | 0               |                  |
**Table 6.7** Test of co-integration vector orders

| Model 2 | Model 3 | Model 4 |
|---------|---------|---------|
| **Hypothesized** | **Trace** | **0.05** | **Hypothesized** | **Trace** | **0.05** | **Hypothesized** | **Trace** | **0.05** |
| No. of CE(s) | Statistic Critical | Value | Prob.** | No. of CE(s) | Statistic Critical | Value | Prob.** | No. of CE(s) | Statistic Critical | Value | Prob.** |
| None * | 246.0538 | 208.4374 | 0.0002 | None * | 245.2238 | 197.3709 | 0 | None * | 283.2954 | 228.2979 | 0 |
| At most 1 * | 189.0957 | 169.5991 | 0.0031 | At most 1 * | 188.2801 | 159.5297 | 0.0005 | At most 1 * | 219.211 | 187.4701 | 0.0004 |
| At most 2 * | 142.614 | 134.678 | 0.0157 | At most 2 * | 141.8261 | 125.6154 | 0.0035 | At most 2 * | 164.3036 | 150.5585 | 0.0066 |
| At most 3 | 98.2934 | 103.8473 | 0.1101 | At most 3 * | 97.59074 | 95.75366 | 0.0371 | At most 3 * | 118.0495 | 117.7082 | 0.0476 |
### Table 6.8  Test results for model 2

|     | FSI  | PMI  | HPI  | SSEC | R    | REXC | USFFER | GRFRA | C    |
|-----|------|------|------|------|------|------|--------|-------|------|
| CE1 | 1    | 0    | 0    | -2.5449 | 0.0861 | -8.0724 | 8.3769 | -1.5264 | 248.7177 |
|     |      |      |      | (1.2544) | (0.6497) | (4.8925) | (6.1446) | (2.5380) | (2.8985) | (125.6570) |
| CE2 | 0    | 1    | 0    | 0.7215 | 2.0334 | 0.5989 | 6.0052 | -2.6368 | 0.2926 | -123.0957 |
|     |      |      |      | (0.4302) | (0.2228) | (1.6778) | (2.1072) | (0.8704) | (0.9940) | (43.0923) |

|     | D(FSI) | D(PMI) | D(HPI) | D(SSEC) | D(R) | D(REXC) | D(USFFER) | D(GRFRA) |
|-----|--------|--------|--------|--------|------|--------|-----------|----------|
| CE1 | -0.0117 | -0.0081 | 0.0091 | 0.2034 | -0.0030 | -0.0337 | 0.0015 | 0.0252 |
|     | (0.0113) | (0.0177) | (0.0088) | (0.0659) | (0.0047) | (0.0061) | (0.0011) | (0.0117) |
| CE2 | -0.0884 | -0.2255 | 0.0464 | 0.1830 | -0.0071 | -0.1024 | 0.0053 | 0.0584 |
|     | (0.0335) | (0.0524) | (0.0259) | (0.1950) | (0.0138) | (0.0181) | (0.0032) | (0.0345) |
from the vector of co-integration, expressed as PMI variables normalized to 1 with the structure quantitative relationship of the other explanatory variables.

The bottom portion of Table 6.8 displays estimates of the adjustment coefficient for CE1 and CE2 (brackets indicate standard deviations). Table 6.8 displays the results for standardizing the equations for two co-integration relations. Since our analysis focuses on co-integration of financial pressure and explanatory variables and their long-term equilibrium, we concentrate on FSI and other variables. After finishing the CE1, it can be expressed as Eq. (6.17).

\[
FSI_t = -248.72 + 2.54HPI_t + 6.31SSEC_t - 0.086R_t + 8.072REXC_t - 8.377USFFER_t + 1.526GRFRA_t
\]

Equation (6.17) shows co-integration between FSI and other explanatory variables and represents a long-term equilibrium formed by the co-integration vector. However, Table 6.8 reveals relatively large standard deviations for R, ERXC, and GRFRA, and parameter estimates exhibit no statistically significant influence. That can be explained as the influence of short-term fluctuations in economic variables on long-term equilibrium relationships when they are subjected to external shocks during a financial crisis. With regard to short-term market fluctuations, there are factors and possibilities for deviating from co-integration at each moment \( t \). That is, economic variables often are unbalanced during short-term observation. Therefore, to consider disequilibrium in the model, the degree to which the variable deviates from its long-term equilibrium during short-term fluctuations can be measured by increasing or decreasing the order difference (\( \Delta FSI_t \)). Then the deviation can be corrected to approximate theorized long-run equilibrium, so that parameter estimation of the co-integration equation can move toward the long-term mean. For this reason, we introduce the VEC model to simulate the change in this long-run equilibrium when it deviates from short-run equilibrium.

### 6.5.4 The VEC Model

The VEC model is derived from Sargan’s (1964) study of wage growth and prices. The representation theorem subsequently proposed by Engle–Granger (1987) combines Hendry’s (1978) research into VEC models with the co-integration concept. Equation (6.18) holds if only two variables are used to show this theorem.

\[
\begin{bmatrix}
Y_t \\
X_t
\end{bmatrix} = \begin{bmatrix}
\alpha_{10} \\
\alpha_{20}
\end{bmatrix} + \begin{bmatrix}
\beta_{11} & \beta_{12} \\
\beta_{21} & \beta_{22}
\end{bmatrix} \begin{bmatrix}
Y_{t-1} \\
X_{t-1}
\end{bmatrix} + \begin{bmatrix}
\epsilon_{1t} \\
\epsilon_{2t}
\end{bmatrix}
\]

Equation (6.18) represents a vector autoregressive model (VAR model). When \( Y \) and \( X \) are first-order integrals—that is, I (1)—there is co-integration between \( Y \) and \( X \). \( Y \) and \( X \) can be expressed as \( Y_t = \alpha + \beta X_t + \mu_t \). Per Engle–Granger, when there
is co-integration between X and Y by I (I), the VAR model can be expressed as an error correction model (EC model); Conversely, if X and Y can be represented by EC model, then Y and X are co-integrated. If Y and X are co-integrated, the error between Y_t and E(Y_t) = \alpha + \beta X_t cannot be large. Thus there should be a mechanism for adjusting from \mu_t = Y_t - E(Y_t) = Y_t - \alpha - \beta X_t to 0 to long-term equilibrium. In this manner, if the stable long-term relation is set to Y_t = \alpha + \beta X_t + \mu_t, the principle governing a typical EC model can be expressed as follows. In this way, if the long-term stationary relation is set to Y_t = \alpha + \beta X_t + \mu_t, the principle governing EC model can be expressed as Eq. (6.19), a first-order error correction model.

$$\Delta Y_t = \gamma_1 \Delta X_t - \gamma (Y_{t-1} - \alpha - \beta X_{t-1}) + \epsilon_t \quad (0 < \gamma < 1).$$ (6.19)

When X and Y move at the same level which puts \Delta X_t = 0, \Delta Y_t = 0 in a long-term situation, so Eq. (6.19) can be expressed as Y_t = \alpha + \beta X_t with regard to the long-term average. In the short run, however, Y_{t-1} - \alpha - \beta X_{t-1} > 0. That is, Y_{t-1} > \alpha + \beta X_t. In turn, that means when Y_{t-1} has exceeded the long-term expectation with \alpha + \beta X_{t-1}, then Y_t in the next period t will be smaller than Y_{t-1}(\Delta Y_t < 0). In contrast, when Y_{t-1} < \alpha + \beta X_{t-1}, since Y_{t-1} does not reach the expected level \alpha + \beta X_{t-1} in the long run, Y_t in the period from t_1 to t will exceed Y_{t-1}(\Delta Y_t > 0). The short-term correction mechanism accelerates movement to the long-term mean. This is the principle underlying the error-correction mechanism in Eq. (6.19).

\[ Y_{t-1} - \alpha - \beta X_{t-1} \] in Eq. (6.19) is the error correction term. \gamma is the adjustment coefficient, which represents the speed of adjustment toward long-term equilibrium. The closer \gamma is to 1, the faster the adjustment. Thus 1/\gamma is the adjustment period. According to Eq. (6.19), some linear combination of these variables is stationary if there is co-integration between variables. Such long-term equilibrium is achieved by through constant adjustment of short-term fluctuations. The EC model is a short-term unbalanced model. If error correction is carried out, each variable returns to long-term equilibrium relationships.

Further, let the estimated value of \beta_i be \hat{\beta}_i (i = 1, 2, \ldots, n), and take the short-term imbalance model as the definition of EC model. Then, the typical EC model is formalized as Eq. (6.20).

$$\Delta Y_t = \gamma_1 \Delta Y_{t-1} + \sum_{i=1}^{n} \hat{\gamma}_i \Delta X_{i,t-1} - \gamma (Y_{t-1} - \hat{\beta}_1$$
$$- \sum_{i=2}^{n} \hat{\beta}_i X_{i,t-1}) + \epsilon_t \quad (0 < \gamma < 1)$$ (6.20)

Per the principle governing EC models, the two-dimensional vector is extended to multiple variables to specify the model. There are two ways to set up EC models. One is to estimate CE when the co-integration vector is known. Another is to specify a theoretical EC model, and then deduce the practical operational EC model. Since we have selected the co-integration vector and performed the co-integration test,
we continue to use the co-integration vector to specify the co-integration vector error correction model (VEC model) that describes financial stress. Influenced by the Johansen co-integration test of Model 2, we select it as the deterministic trend specification. That is, CE includes an intercept but no trend and exhibits no deterministic trend and intercept term in VAR. Moreover, when we extend discussion to the VAR(1) model with eight variables, we can directly use the relevant information of co-integration vectors from Table 6.6 and Table 6.7 and specify VEC model as Eq. (6.21).

\[
\Delta FSI_t = \gamma_1 \Delta FSI_{t-1} + \gamma_2 \Delta PMI_{t-1} + \gamma_3 \Delta HPI_{t-1} + \gamma_4 \Delta SSEC_{t-1} \\
+ \gamma_5 \Delta R_{t-1} + \gamma_6 \Delta REXC_{t-1} + \gamma_7 \Delta USFERR_{t-1} + \gamma_8 \Delta GRFRA_{t-1} \\
- \gamma (FSI_{t-1} - \hat{\beta}_1 - \hat{\beta}_2 PMI_{t-1} - \hat{\beta}_3 HPI_{t-1} - \hat{\beta}_4 SSEC_{t-1} \\
- \hat{\beta}_5 R_{t-1} - \hat{\beta}_6 REXC_{t-1} - \hat{\beta}_7 USFERR_{t-1} - \hat{\beta}_8 GRFRA_{t-1}) + \epsilon_t
\]

(6.21)

Where parameter \( \gamma_i (i = 1, 2, \ldots, 8) \) is called the parameter of long-run influence and is intended to reflect the effect of short-term changes due to explanatory variables on the formation of financial stress. \( \gamma \) is the adjustment coefficient \((0 < \gamma < 1)\), also known as the feedback effect. The bracketed \( \hat{\beta}_i (i = 1, 2, \ldots, 8) \) is the short-run influence coefficient, and the difference between bracketed \( FSI_{t-1} \) and variables \((t-1)\) indicates a deviation adjustment to short-run equilibrium. It expresses deviation from long-term equilibrium and is expressed as \( EDT \). For example, \( EDT > 0 \) indicates that variables in the preceding period exceed equilibrium, and negative adjustments are needed. \( EDT < 0 \) indicates the value of each variable in the preceding period is below equilibrium, and positive adjustments are needed.

\( \hat{\beta}_1 \) is a constant estimate, and \( \epsilon \) is a random error term. Since all variables in Eq. (6.21) are I(1), the t-test can be used to evaluate predicted results. After substituting 195 data points of each variable, CE with a value of 1 and estimated results for the VEC model with error correction appear in Table 6.9. Table 6.10 displays results for the model’s correlation tests.

The conjecture results include four parts. The first represents the long-run parameter estimate of the \( CE \) (Table 6.9). The second represents the short-run parameter estimate of the error correction term (the column headed D(FSI) in Table 6.9), where the corresponding value of CointEq1 is the adjustment coefficient estimate of the error estimate term with \( \gamma = 0.028 \) (upper part of Table 6.9). The third part is correlation test results for a single equation in the model (Table 6.10). The fourth is the overall correlation for the model (lower portion of Table 6.9). Since we focus on FSI, the error correction related to D(FSI) in the second portion of Table 6.9 is embedded into the first part of CE in Table 6.9, and the error correction model of the co-integration vector about FSI is obtained after sorting, as shown in Eq. (6.22).

VEC Model-Substituted Coefficients:

\[
\Delta FSI_t = 0.03(FSI_{t-1} + 1.46 PMI_{t-1} - 1.49 HPI_{t-1} - 3.34 SSEC_{t-1})
\]
### Table 6.9 Estimated results for the VEC model

Included observations: 193 after adjustments Standard errors in () & t-statistics in []

| Co-integrating Eq: | Coint Eq1          |
|-------------------|--------------------|
| FSI(-1)           | 1.000000           |
| PMI(-1)           | 1.462102 (0.90687) [1.61225] |
| HPI(-1)           | -1.490025 (0.68492) [-2.17547] |
| SSEC(-1)          | -3.341766 (0.34696) [-9.63168] |
| R(-1)             | 0.961786 (2.61515) [0.36777] |
| REXC(-1)          | 0.707907 (3.28116) [0.21575] |
| USFFER(-1)        | 4.521694 (1.38648) [3.26128] |
| GRFRA(-1)         | -1.098637 (1.57770) |
| C[−0.69635]       | 68.73925 (73.4587) [0.93575] |

(continued)
Table 6.9 (continued)

| Error Correction | D(FSI) | D(PMI) | D(HPI) | D(SSEC) | D(R) | D(REXC) | D(USFFER) | D(GRFRA) |
|------------------|--------|--------|--------|---------|------|---------|-----------|----------|
| Coint Eq1        | 0.028234 (0.00541) | -0.019346 (0.00848) | -0.009535 (0.00408) | 0.267566 (0.03035) | -0.001430 (0.00214) | 0.003846 (0.00303) | -0.000291 (0.00505) | 0.013152 (0.00537) |
|                  | (5.22006) | (-2.33494) | (-2.33494) | (8.81560) | (-0.66790) | (-1.27083) | (-0.58458) | (2.44893) |
| D(FSI(-1))       | -0.409591 (0.11266) | -0.140210 (0.17603) | 0.018472 (0.08506) | 0.660493 (0.63221) | -0.066220 (0.04458) | -0.006841 (0.06304) | 0.009336 (0.01037) | 0.232136 (0.11187) |
|                  | (-3.63563) | (-0.97650) | (0.21717) | (1.04475) | (-1.48527) | (-1.0852) | (0.90602) | (2.07510) |
| D(PMI(-1))       | -0.032053 (0.05394) | -0.259669 (0.08429) | -0.005447 (0.04073) | 0.456677 (0.30270) | 0.020024 (0.02135) | -0.000758 (0.03018) | 0.020623 (0.00496) | 0.043770 (0.05356) |
|                  | (-0.59421) | (-3.08081) | (-0.13375) | (1.50866) | (0.93801) | (-0.02512) | (4.15481) | (0.81717) |
| D(HPI(-1))       | -0.079850 (0.09762) | -0.110216 (0.15253) | -0.069801 (0.07370) | -0.695469 (0.54780) | 0.001361 (0.03863) | 0.020160 (0.05462) | 0.007512 (0.00898) | 0.014029 (0.09693) |
|                  | (-0.81798) | (-0.72259) | (-0.94706) | (-1.26957) | (0.36910) | (0.36910) | (0.83632) | (0.14473) |
| D(SSEC(-1))      | 0.026797 (0.01949) | 0.004176 (0.03045) | -0.021382 (0.01471) | -0.173082 (0.10935) | 0.007978 (0.00771) | -0.007286 (0.01090) | -0.000741 (0.00179) | -0.007116 (0.01935) |
|                  | [1.37517] | [0.13715] | [-1.45335] | [1.03455] | [0.66825] | [-0.04136] | [-0.36776] | [-0.36776] |
| D(R(-1))         | 0.262972 (0.18487) | -0.150509 (0.28886) | 0.156589 (0.13958) | -1.210035 (1.03741) | -0.206888 (0.07316) | 0.036685 (0.10344) | -0.08944 (0.01701) | -0.237218 (0.18357) |
|                  | [1.42248] | [-0.52105] | [0.12188] | [-1.16640] | [-2.82876] | [0.35466] | [-0.52579] | [-1.29226] |
| D(REXC(-1))      | -0.144631 (0.16016) | 0.749054 (0.25025) | 0.073301 (0.12092) | -1.273975 (0.89786) | 0.052320 (0.06383) | -0.305878 (0.08461) | -0.005086 (0.01474) | -0.023871 (0.15903) |
|                  | [-0.90303] | [2.99318] | [0.60618] | [-1.41748] | [0.82546] | [-3.41331] | [-0.34509] | [-0.15010] |
| D(USFFER(-1))    | -0.045717 (0.68029) | 1.023456 (1.06296) | 0.66944 (0.51362) | 3.723804 (3.81751) | 0.267098 (0.26922) | -0.048329 (0.38063) | 0.637868 (0.06260) | 0.536789 (0.67550) |
|                  | [-0.06720] | [0.96284] | [1.30435] | [0.97545] | [0.99212] | [-0.12697] | [10.1900] | [0.79465] |

(continued)
Table 6.9  (continued)

| Error Correction | D(FSI)     | D(PMI)     | D(HPI)     | D(SSEC)    | D(R)       | D(REXC)    | D(USFFER)  | D(GRFRA)   |
|------------------|------------|------------|------------|------------|------------|------------|------------|------------|
| D(GRFRA(−1))    | −0.009993  | −0.006094  | 0.023263   | 1.050719   | −0.004770  | −0.063930  | −0.001147  | −0.323775  |
|                  | (0.07825)  | (0.12226)  | (0.05908)  | (0.43909)  | (0.03097)  | (0.04378)  | (0.00720)  | (0.07770)  |
|                  | [−0.12772] | [−0.04984] | [0.39378]  | [2.39294]  | [−0.15403] | [−1.46024] | [−0.15934] | [−4.16720] |
Table 6.10  Tests of the model’s overall correlations

|                | R-squared   | Adj. R-squared | Sum sq. resid | S.E. equation | F-statistic | Log likelihood | Akaike AC | Schwarz SC | Mean dependent | S.D. dependent | Determinant resid covariance (dof adj ...) |
|----------------|-------------|----------------|---------------|---------------|-------------|----------------|-----------|------------|----------------|---------------|------------------------------------------|
| R-squared      | 0.353492    | 0.325383       | 325.3415      | 1.329722      | 12.57575    | -324.2460      | 3.453327  | 3.605473   | -0.001036      | 1.618945      | 0.454198                                  |
| Adj. R-squared | 0.141190    | 0.103851       | 794.3057      | 2.077710      | 3.781249    | -410.3812      | 4.345920  | 4.498066   | 0.009845       | 2.194799      | 0.309977                                  |
| Sum sq. resid  | 0.051005    | 0.009744       | 185.4571      | 1.003952      | 1.236167    | -270.0080      | 2.891275  | 3.043421   | -0.050881      | 1.008879      | -2077.815                                 |
| S.E. equation  | 0.503640    | 0.482059       | 10245.10      | 7.461894      | 23.33731    | -657.1400      | 6.903006  | 7.055152   | -0.050829      | 10.36833      | 22.37114                                  |
| F-statistic    | 0.081714    | 0.041789       | 50.95276      | 0.526229      | 2.046669    | -145.3373      | 1.599350  | 1.751496   | -0.004974      | 0.537582      | 1.471006                                  |
| Log likelihood | 0.109278    | 0.070551       | 101.8525      | 0.744007      | 2.821756    | -212.1758      | 2.291977  | 2.444123   | 0.001440       | 0.771728      | 6.788773                                 |
| Akaike AC      | 0.436280    | 0.411770       | 2.754636      | 0.122355      | 17.80037    | 136.2124       | -1.318264 | -1.166117  | -0.001865      | 0.159533      | 3.591348                                  |
| Schwarz SC     | 0.227897    | 0.194327       | 320.7784      | 1.320364      | 17.80037    | 6.788773       | 3.439202  | 3.591348   | -0.021295      | 1.471006      |                                          |

6 Measuring Financial Stress and Vector Error Correction from a Global Flow...
\[\begin{align*}
+ 0.96R_{t-1} + 0.71R{\text{EXC}}_{t-1} + 4.52USFFER_{t-1} - 1.1RFRA_{t-1} \\
+ 68.74 - 0.41FSI_{t-1} - 0.03PMI_{t-1} - 0.08HPI_{t-1} \\
+ 0.03\Delta SSEC_{t-1} + 0.26\Delta R_{t-1} - 0.15\Delta R{\text{EXC}}_{t-1} - 0.05\Delta USFFER_{t-1} \\
- 0.01\Delta GRFRA_{t-1}
\end{align*}\] (6.22)

6.6 Empirical Analysis of Financial Stress

6.6.1 Analysis of Long-Run Relationship of CE

An estimate of the adjustment coefficient \(\gamma\) of CE (6.22) is 0.03 and statistically significant. The adjustment coefficient \(\gamma = 0.03\) means that, with other difference variables unchanged, FSI changes (\(\Delta FSI = FSI_t - FSI_{t-1}\)) in period \(t\), eliminating the 3% disequilibrium in the earlier period. \(0 < \gamma < 1\) indicates a stable long-term relation between FSI and other variables. Their co-integration restricts changes between FSI and other variables, and short-term fluctuations gradually will approximate long-term stability. The adjustment period of \(1/\gamma = 33.3\) indicates the feedback effect is about 33 months.\(^9\)

We observe three aspects of the impact on financial stress: changes in the domestic real economy, fluctuations in financial markets, and external shocks. We first discuss the estimated value of long-term parameters in the first part of CE in parentheses in Eq. (6.22), which reflects FSI’s short-term deviation of each variable on long-term equilibrium at time \(t\). PMI represents the impact of changes in the real economy on FSI. We speculate that the correlation between the real economy and FSI is positive. For every percentage point rise in PMI(-1), FSI will rise 1.46. Although the t-statistic (1.61) is not high, it possesses a degree of statistical significance. The relatively high parameter estimation value of HPI(-1) (-1.49) indicates that changes in real estate prices exert a greater impact on financial stress in China.

Volatility in China’s stock market exerts the greatest effects on financial stress. SSEC(-1) has significant effects on FSI and exerts long-term pressure on financial stress. Its long-term supercharging effect is \(-3.34\), and estimated values of SSEC are statistically significant. The positive sign of \(R\) indicates its shock effect on the long-term equilibrium of financial stress, but the effect is not highly significant (t-statistic is low in Table 6.9). There are two explanations. First, \(R\) (highest and lowest spreads in interbank interest rates) indicates that changes in interest rates were not fully embedded in Chinese markets and did not fully reflect actual market risk. Second, positive long-term parameter estimates of \(R\) indicate the influence of \(R\) on financial stress. Higher spreads mean tighter financial policies and intensify financial stress.

\(^9\gamma = 0.26\) from January 2004–September 2012, 0.08 from January 2004 to December 2015, and 0.03 from January 2004 to March 2020. The longer the sampled period, the smaller the \(\gamma\) value.
We now consider how external shocks affect financial stress. The positive sign of the estimate of $\text{REXC}(-1)$ indicates that appreciation in $\text{REXC}(-1)$ inhibits the long-term equilibrium of financial stress, but not significantly (low t-statistic). Again, there are two explanations. First, $\text{REXC}$ (RMB/USD exchange rate) indicates that changes in exchange rates were not fully embedded in Chinese markets and did not reflect actual market risk. Second, the long-term parameter estimate of $\text{REXC}(-1)$ is positive. That is, fluctuations in the RMB/USD exchange rate and financial pressure move in opposite directions. The greater the appreciation in the RMB, the greater the influence on financial pressure.

$\text{USFFER}(-1)$ exhibits a strong positive influence on China’s FSI. The statistical estimate (4.52) and t-statistic (3.26) are significant. Its positive influence can be explained in a practical sense that an increase in US interest rates during the previous period directs international capital flows to the US, reducing China’s capital inflows and increasing financial stress on China. This event also reduces China’s financial returns. Therefore, the question is one of balance between financial returns and risks.

$\text{GRFRA}(-1)$ exerts a negative influence on FSI. The increase in China’s FX reserves during the period reduced China’s financial stress about 1.01. The increase in FX reserves improves China’s external payment capacity. The financial risk of holding FX reserves and the impact on financial stress diminish. However, low t-statistics for $\text{REXC}(-1)$ and $\text{GRFRA}(-1)$ dissuade that speculation.

### 6.6.2 Analysis of Short-Run Relationship on Error Correction

According to the estimated short-term change parameters of the error correction term in Column $D(\text{FSI})$ in Table 6.9, the change in $\Delta \text{FSI}_{t-1}$ significantly reduces $\Delta \text{FSI}_{t}$ by 0.41. As with the long-term parameter, short-term fluctuations in various variables affect financial stress in three ways: changes in the domestic real economy, fluctuations in financial market, and external shocks. In the short-term estimates of volatility (Eq. (6.22), $D(\text{PMI}(-1))$, $D(\text{SSEC}(-1))$, $D(\text{REXC}(-1))$, and $D(\text{USFFER}(-1))$ differ from long-term parameter estimates. The effects on financial stress of short-term shocks originating in these variables differ from their long-term effects. Through these error corrections, FSI returns to a stable long-term state and maintains a normal range. Note also that parameter estimates of $CE$ exceed the error correction estimates.

The estimated value of $D(\text{PMI}(-1))$ is $-0.032$, and that of $\text{PMI}(-1)$ is 1.46. These variables reflect the real economy. Growth in the real economy also raises FSI. However, short-term revisions in the PMI exhibit less responsiveness to FSI. With regard to comprehensive short-term changes, the estimated parameter reflecting short-term fluctuation in real estate prices ($D(\text{HIP}(-1))$) is $-0.08$. Its negative sign is the same as for the coefficient for long-term influence ($\text{HIP}(-1)$), and its absolute value is below the estimated value of the long-term co-integration relation ($-1.49$).
That finding demonstrates the relation between FSI and the speed of short-term corrections in real estate prices.

The estimate for $D(SSEC(-1))$ is 0.03, and that for $SSEC(-1)$ is −3.34. An increase of 1 percentage point in stock prices reduces financial stress 3.34 percentage points. $D(SSEC(-1))$ is 0.03, reflecting the correction in deviation from long-term equilibrium. With regard to the short-run impact of the market on financial stress, the parameter estimate of $D(R(-1))$ is 0.263, which exceeds the short-run impact of other variables, and the estimate of long-run impact $R(-1)$ is 0.96. These two estimates share the same symbol and greatly influence FSI, but their parameter estimates are not statistically significant.

We now consider influences of the overseas economy, volatility in exchange rate, short-term volatility of FSI, and long-term co-integration between the parameters of the estimate different symbols. The $D(REXC(-1))$ is 0.15, showing the relation between short-term, and $REXC(-1)$ is 0.71, which reflects long-term co-integration. That is short of the RMB against the US dollar exchange rate changes on China’s financial pressure occur in the opposite direction. Short-term factors lead to appreciation in the exchange rate and less financial stress.

$D(USFFER(-1))$ demonstrates the short-term impact of the Federal Reserve Board policy rate on China’s financial stress. Its estimate (−0.05) is less than the long-term impact (4.52) indicated by $USFFER(-1)$, and their signs differ. In the short term, an increase in US policy rate objectively reduced stress from international financial markets, but with regard to long-term co-integration, increases the US policy rate elevate China’s financial stress. With regard to long-term and short-term effects, when the US policy rate rises 1%, financial stress in China increases about four percentage points.

The −0.01 estimate of $D(RFRA(-1))$ indicates that acquiring more FX reserves reduced FSI by 0.01 in the hypothetical short-term revision. The estimate of $RFRA(-1)$ in CE is −1.1, and signs of the two estimates are identical. Compared with the short-term impact of $RFRA$ in the error correction term, the long-term equilibrium impact of the increase in FX reserves on China’s financial stress exceeds the short-term impact.

There is a common problem in the short-term parameter estimation of VEC models: the parameter estimation of short-term change is less statistically significant than that for long-term equilibrium. There are two reasons. First, there are too many variables in the model based on the concept of financial stress, which has an effect on passing the t-test when making statistical estimates. Second, taking a first-order difference for each variable makes it is easy to reduce statistical significance. However, whether a single coefficient is statistically significant is not the focus of the VAR model. Its primary considerations are the stationarity and significance of the whole system. Table 6.10 displays overall results for the VAR model.
6.6.3 Analysis of Impulse Responses on Financial Stress

Results for the VEC model explain the influence of variables on long-term equilibrium and short-term fluctuations in financial stress. However, changes in coefficients in the model manifest only a local dynamic relationship. To systematize the model we want to know the dynamic changes in variables within the VAR model after it is affected by a unit of random disturbance, the total influence on other variables, and the duration of the impact. For further impulse response analysis we used a VEC model to observe standard deviations in disturbances caused by random impact on current and future values of endogenous variable. We seek to reveal the impact on China’s financial stress from the real economy, real estate prices, and changes in the securities market, interest rate differentials, exchange rate changes, the US policy rate, and change in such variables as FX reserves. The duration of impact for each variable on FSI differs, although the short-term correction calculated as $\gamma$ is about 33 months. The duration of the impact is set at 30 months. Figure 6.9 reveals the impact of each variable in the VEC model on financial stress and its duration.

![Diagram of impulse influence](image)

*Fig. 6.9* Diagram of impulse influence. *Note* Horizontal axis represents months
Figure 6.9 displays the change in impact of shocks on financial stress (FSI) by each variable over 30 months. We first note the impact of the financial stress index itself. The change in response of FSI to FSI is 1.3297 in the first month. Table 6.10 displays data derived from inference results for the model (1.3297 in the S.E equation). FSI exhibits a strong response to new information about its own standard deviation. In the first five months of the examined period, its random disturbance term exhibits great influence, reaching its maximum the first month after impact and stabilizing after falling from 0.6602 in the sixth month.

The shock of PMI on PSI is relatively brief, but it had a big initial impact, rising from −0.034 in the first month to 0.26 in the second. A small relapse occurred, and it was close to 0.2631 in the sixth month and remained stable. The initial shock of HPI on FSI (response of HPI to FSI) is large, rising from 0.032 the first month to 0.149 in the third. The duration of impact is about 11 months and stabilizes at 0.171.

The duration of SSEC’s impact on FSI (response of SSEC to FSI) is about 10 months. It also exhibits a large effect during the first two months, dropping from 4.017 in the first month to 0.18 in the second and recovering to 0.929 in the third. It then fluctuates slightly and remains at 0.425 after entering the eleventh month. The response of R to FSI is weak, dropping from 0.03 initially to 0.0027 in the second month, then returning to 0.033 and leveling off at 0.03 after the ninth month.

Figure 6.9 reveals that REXC has a negative impact on FSI (response of REXC to FSI). The relevant interpretation is that appreciation in the RMB brings appreciation to FSI, increasing financial stress. Its impact was great, especially during the initial four months, dropping from 0.3388 to 0.2644 in the second month followed by repeated fluctuations. The impact (0.0345) persists about six months and then persists at that level.

The impact of USFFER on FSI is distinctive. First, the change from a negative to a positive influence is clear at the start of the period, from −0.009 the first month to −0.004 in the second, and then turning positive (0.002) in the third month. Second, influence of the US policy rate persists the longest, about 12 months, and stabilizes at 0.02.

GFRFA exhibits a negative impact on FSI (response of GFRFA to FSI) throughout the period. In fell from −0.363 the first month to −0.139 in the second, then rose and leveled off after the sixth month, remaining at −0.276.

As observations above make clear, the variable effect of FSI is three-fold. First, its impact is greater during the initial four months of the period studied and gradually diminishes, as verified by CE in the VEC model. There the adjustment coefficient of γ is 0.03, and that 1/γ = 33.3, indicates feedback persists about 33 months. This finding urges authorities to impose time limits on policy responses. Second, all variables for the impact of FSI duration differ, commonly by six months. But the impact of HPI is approximately a linear uptrend, and persists 11 months. Real estate prices, a factor underlying China’s financial stress, rose continuously. The impact of USFFER is not large, but it persists 12 months. Third, among all variables SSEC exhibits the strongest impact (0.42). The impact of securities market changes on financial stress was greatest at this stage, followed by REXC (0.304), PMI (0.267),
HIP (0.171), and GRFRA (−0.277). The impact is always negative. Acquiring FX reserves reduces FSI.

6.7 Conclusions and Future Issues

To monitor systemic risks, this chapter observes GFF based on the mechanism of GFF, referencing FSIs released by IMF. The application of GFF monitoring can establish FCI and FSI, observe current short-run financial shocks, and build a model to measure long-run structural changes in GFF and systemic risks. This analysis is necessary for monitoring the impact of GFF composite factors on financial stress, predict its trends, and maintain national financial stability.

6.7.1 New Findings

Adopting the GFF perspective, we concluded that financial stress in China intensified after 2008 by observing changes in FSI. FSI was elevated from May 2009 to September 2010 and during 2017–2018. However, two subjects remain for discussion.

This chapter constructs a method for creating FCI and FSI. To monitor FSI and control financial pressure it constructed a VEC model to measure FSI. Examining co-integration between financial stress and related variables revealed long-run stationarity and short-term fluctuations among FSI and PMI, HIP, SSEC, R, REXC, USFFER, and GRFRA in China. Of these, changes in China’s stock market and real estate prices exerted the greatest impact on FSI, and USFFER(-1) exhibits a great impact on FSI. The impact of USFFER can be explained practically: higher US policy rates during a previous period directed capital to the US and intensified financial stress in China.

The estimated value of adjustment coefficient $\gamma(0.03)$ indicates a stable long-term relation between FSI and other variables that restricts changes in FSI and other variables. The feedback effect during the adjustment period persists about 33 months, sufficient time for authorities to take appropriate action.

$D(FSI(-1))$ will reduce $D(FSI)$ at a ratio of $−0.41$ from the estimate of the short-run variation in the error correction term. Although short-run fluctuation in R exceeds the effects of other variables on $D(FSI)$, it will elevate $D(FSI)$ 0.263 percentage points. $D(REXC(-1))$, reflecting short-run changes, is $−0.14$. Its statistical estimate is opposite the parameter estimate of the long-run impact. Appreciation in the RMB will increase financial stress in China.

Each variable exerted a great shock on FSI during the initial six months of the period studied and weakens gradually. The shock of changes in SSEC on FSI was strongest, and the impact of HPI displays nearly a straight uptrend for six months. Shocks from stock and real estate prices intensified in China during the period.
REXC also has magnified its impact on FSI, and its intensity is second only to SSEC, especially during the initial four months of the period studied. The impact of USFFER initially diminishes and then increases, with a maximum duration of 12 months. Findings suggest that fluctuations in securities markets and exchange rates exert the greatest influence on financial stress.

6.7.2 Future Work

Several issues remain for study. One is to construct a database to observe GFF and financial stress and improve the statistical index to observe GFF.

The second is to select explanatory variables in financial stress models and interpret predicted results. Constructing VEC models and monitoring financial stress statistical with regard to GFF are new efforts in this field of research. The selection of explanatory variables of financial stress should accord with economic theory and mathematical principles of VEC models. So far, the interpretation of VEC model results research literature focuses on statistical inference. Future, interpretation of statistical inference should be based more on economic theory.

The third future task is to integrate theories and methods from related disciplines to improve the study of GFF and financial stability. Network information science has made GFF borderless, and the speed and direction of fund flows are more complicated and changeable. Improving the ability to control financial system risks with regard to GFF analysis guarantees more stable and sustainable economic development. After completing long-term plans to assess risk tolerance, policy authorities should establish a corresponding statistical monitoring system. In particular, they should strengthen monitoring of financial products to manage decentralized risks, grasp timeliness, and enhance ability to defuse financial risks.

However, traditional single analysis cannot solve these problems and monitor suitably the needs of GFF, such as system risk, evolution, and transmission path. Practices drawn from statistics, economics, econometrics, information science, and financial engineering are needed to study how GFF changes and to develop methods to identify, monitor, and mitigate financial risks. New systematic theories and methods need to be constructed, and there is ample room for expansion from an international perspective.

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