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Construction and analysis of regional financial stability index in China: Regional system status, difference measure and spatio-temporal variation

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Abstract

In the course of its steady development, China's financial landscape confronts an array of risks and challenges. Against the backdrop of China's sustained commitment to regional coordinated development strategies, the imperative of achieving coordinated financial stability across regions becomes paramount for fostering macro-financial stability. This study addresses this imperative by formulating a regional financial stability index grounded in the provincial financial stability index. The ensuing analyses encompass the delineation of regional financial stability status, the quantification of disparities, and the scrutiny of temporal and spatial dynamics. Our findings reveal a relatively high level of regional financial stability in China, with a modest overall variance between national and regional financial stability. Notably, the financial stability of the eastern region assumes a pivotal role in influencing the nationwide financial stability landscape. The regional financial stability index demonstrates dynamic evolutionary features characterised by temporal fluctuations and discernible spatial differentiation patterns. Drawing upon these insights, the article proffers a set of targeted policy recommendations, with

practical implications for fortifying macro-financial stability not only in China but also in other nations.

KEYWORDS

change of time and space, Markov regime switching model, regional financial stability, Theil index

JEL CLASSIFICATION

E44, G10, R12, R58

1 | INTRODUCTION

China's financial trajectory reflects consistent development with enhancements in the financial market, standardisation of institutions, advancement in infrastructure, and improved efficacy of financial services for the real economy. Government policy guidelines support financial stability, exemplified by the draft 'Financial Stability Law of the People's Republic of China' by the People's Bank of China on 6 April 2022, awaiting public scrutiny.

Despite commendable progress, China's financial sector faces pressures from domestic and foreign sources, including global trade protectionism and the U.S.-initiated 'trade war', impacting the global economy and financial markets. Domestically, challenges include structural overcapacity, high corporate leverage, rising non-performing loan ratios, and cross-industry, cross-market and cross-regional risks, threatening financial stability. Comprehensive understanding of these challenges is crucial for targeted policy responses.

In 2023, the Central Financial Work Conference of China underscored the imperative of advancing regional coordinated development and proactively addressing major financial risks to forestall the emergence of regional and systemic financial vulnerabilities. This marked a pivotal moment following the formal establishment of the State Council Financial Stability and Development Committee by the end of 2017. Notably, in 2020, the decision was made by the Committee to institute Financial Committee Offices across all provincial-level administrative regions, serving as local coordination mechanisms that bolstered financial collaboration between central and local authorities. The year 2023 also witnessed China's elevation of the State Council Financial Stability Committee to the Central Financial Committee, concurrent with the establishment of the National Financial Supervision and Management Bureau based on the former China Banking and Insurance Regulatory Commission (CBIRC). This restructuring initiative facilitated the creation of a local financial supervision system, predominantly comprising local branches of central financial regulatory bodies. Furthermore, the Central Economic Work Conference of 2021 articulated the imperative of robustly implementing the regional coordinated development strategy, aimed at fostering synchronised growth across the eastern, central, western and northeastern regions while optimising the overall regional economic framework. Macrofinance's sustainable progression requires harmonised cooperation within and across regions. Financial risks in one region affect not only local stability but also broader regions, emphasising the significance of regional financial stability. China, amidst population mobility and industrial realignment, must prioritise coordinated regional finance development. Proactive measures are necessary to avert and resolve local financial risks, ensuring

the seamless transmission of financial well-being and contributing to stable financial systems domestically and internationally.

In essence, delving into the realm of regional financial stability in China bears immense significance, not solely for the nation itself but also for global financial stability by mitigating regional financial risks and fostering a robust and sustainable financial landscape. Consequently, this article delves into the intricacies of China's regional financial stability, encompassing the development of a regional financial stability index, an assessment of the current state of regional financial stability in China, an exploration of variances, and an examination of spatiotemporal shifts. Ultimately, drawing from the findings of this study, targeted policy recommendations are put forth to uphold and fortify regional financial stability.

Compared to existing research, this article offers several noteworthy contributions. First, while much of the literature concerning China's financial stability index primarily concentrates on macro and provincial levels, such as the works by Wang and Ren (2021) on constructing China's macro-financial stability index and Wang and Dai (2002) on constructing China's provincial financial stability index, this article shifts the focus to China's regional financial stability by introducing the China regional financial stability index. Second, there is a dearth of research examining the status analysis, difference measurement, spatiotemporal changes and similar aspects concerning China's regional financial stability. For instance, Dong (2018) employed the principal component analysis method to devise and assess China's regional financial stability index for the year 2016, concluding that the eastern region exhibited relatively robust financial stability. In contrast, this article adopts the entropy method to construct the provincial financial stability index, subsequently expanding to construct the regional financial stability index spanning the years 2015–2022, while also conducting thorough analyses of status, differences, and spatiotemporal changes. The findings of this article diverge from Dong (2018), revealing a less favourable financial stability picture in the eastern region. This disparity can be attributed to variances in indicator systems and the extended research period considered in this article, rendering the results more widely applicable and generalizable.

The remaining structure of this article is delineated as follows: Section 2 provides a comprehensive review, summary, and critique of the existing literature; Section 3 focuses on constructing the China regional financial stability index; Section 4 employs the Markov regime-switching model to identify and analyse the status of the regional financial stability index; Section 5 conducts a detailed difference measurement and analysis of the regional financial stability index; Section 6 delves into the spatiotemporal changes analysis of the regional financial stability index; and finally, Section 7 encapsulates the primary conclusions drawn from the study along with the ensuing policy implications.

2 | LITERATURE REVIEW

Financial stability measurement methods include indirect measures, such as Z-score (Altman, 1968), default distance, and SRISK (Acharya et al., 2012; Brownlees & Engle, 2017), and direct measures synthesising indices through indicators (Morales & Estrada, 2010). Scholars in domestic research primarily adopt direct measurement methods, constructing financial stability indices using various approaches (Li & Zhao, 2022; Wang & Dai, 2002; Wang & Ren, 2021). Research on regional financial stability indices is limited, with scholars utilising methods like principal component analysis (Dong, 2018) and weighted averages (Guo et al., 2018).

To understand regional differences, scholars use measures like the Gini coefficient and Theil index. Markov models, particularly Markov regime switching models, are applied for state identification in financial stability (Guo et al., 2020; Li & Liang, 2021; Ren & Liu, 2022). Spatial and temporal change analysis, common in other disciplines, is increasingly used in economic and financial assessments (Ding et al., 2021; Gu et al., 2013; Peng & Chang, 2013).

The research gap in regional financial stability is addressed by proposing the construction of a regional financial stability index using a Markov regime switching model, assessing regional differences with the Theil index, and analysing spatial and temporal changes. Closing these gaps enhances research comprehensiveness and deepens understanding of regional financial stability dynamics.

3 | REGIONAL FINANCIAL STABILITY INDEX CONSTRUCTION

3.1 | Provincial financial stability index construction

Drawing on the established construction standards outlined in the works of Wang and Ren (2021) and Wang et al. (2023) for the Chinese financial stability index, alongside the authoritative delineation of the eight major risks—non-performing asset risk, liquidity risk, bond default risk, shadow banking risk, external shock risk, real estate bubble risk, government debt risk, and internet finance risk—this study undertakes the formulation of a provincial financial risk indicator system (as depicted in Supplementary Table 1). To ensure the integrity and accessibility of data, fundamental indicator data from 31 provinces, municipalities, and autonomous regions (excluding Hong Kong, Macao, and Taiwan) were meticulously curated, covering a span of 32 quarters from 2015 to 2022. Subsequently, the entropy weighting method was employed to construct the provincial financial risk index.

To mitigate logarithmic issues, this chapter employs data processing techniques to eliminate zero values and restrict data within the range of $[0,1]$. The specific calculation method is detailed below.

First, standardise the data using the following methods for handling positive and negative indicators.

$$x_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \tag{1}$$

$$x_{ij} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \tag{2}$$

In this context, x_{ij} represents the ith sample of the jth indicator, with $i = 1,2,\cdots,m$ and $j = 1,2,\cdots,n$. $\max\{x_{ij}\}$ and $\min\{x_{ij}\}$ denote the maximum and minimum sample values of the jth indicator, respectively.

Subsequently, the transformed index values are represented as R_{ij}, and from these values, the importance level of the jth indicator, denoted as the coefficient of variation G_j, is calculated.

$$R_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{3}$$

$$G_j = 1 + \frac{\sum_{i=1}^{m} R_{ij} \times \ln R_{ij}}{\ln m} \tag{4}$$

Finally, the weights of the selected indicators are determined.

$$\omega_j = \frac{G_{ij}}{\sum_{j=1}^{n} G_{ij}} \tag{5}$$

3.2 | Regional financial stability index construction

This article endeavours to construct a regional financial stability index derived from the inter-provincial financial stability index. Acknowledging the profound influence of financial and economic development on regional financial stability, the study opts for the 'financial-related ratio'—specifically, the ratio of the loan balance of financial institutions to GDP—as a metric to gauge the extent of financial development, as illustrated in Formula (1). This chosen indicator aligns more closely with the prevailing characteristics of China's financial system, predominantly characterised by the banking credit system.

$$\text{Financial} - \text{related ratio} = \frac{\text{Loan balance of financial institutions}}{\text{GDP}} \tag{6}$$

In accordance with the directives outlined in the opinions of the Central Committee of the Communist Party of China and the State Council on Promoting the Rise of the Central Region, the Opinions of the State Council on the Implementation of Certain Policies and Measures for the Development of the Western Region, and the spirit of the report from the 16th Party Congress, alongside insights provided in the Report of the People's Bank of China on the Operation of China's Regional Financial Stability, China's economic regions (excluding Hong Kong, Macao and Taiwan) have been categorised into four primary regions: the eastern, central, western and northeastern regions, as delineated in Supplementary Table 2.

Leveraging the provincial financial stability index, this study proceeds to construct regional financial stability indexes for the aforementioned regions, utilising the 'financial-related ratio' as the weighting mechanism.

4 | REGIME STATE ANALYSIS OF REGIONAL FINANCIAL STABILITY INDEX

4.1 | Markov regime switching model

The ultimate purpose of compiling a regional financial stability index is to measure and assess the degree of stability of financial markets. Therefore, it is extremely important to be able to

correctly identify the degree of stability of financial markets. In this article, the Markov Regime Switching model proposed by Hamilton (1989) is used to measure the state of the regional financial stability index in China.

The Markov regime-switching model possesses the following characteristics:

1. *Independence from subjective thresholds*: These models do not depend on setting stability threshold values based on individual preferences to evaluate risks, nor do they necessitate predicting the specific timing of high-risk occurrences. This eliminates the influence of subjective factors.
2. *Clear state identification*: The models can distinctly identify the state in which observed samples are situated through smooth transitions, accurately specifying the timing of financial system stability states.
3. *Dynamic state analysis*: Financial stability states are part of a dynamic process where static models may fall short in state analysis. However, the Markov regime-switching model effectively utilises state transition variables to elucidate the dynamic changes of financial stability indicators, thereby precisely determining financial stability states.

Markov regime switching model is one in which a variable is transferred between different regimes according to a Markov chain. Instead of subjectively establishing a guarded value of financial stability to determine its stability, MS-VAR model determines its stability state by the smoothed transition profile of the financial stability index. Markov transition models can capture the characteristics of the studied variables in different states, that is, the observed time series vector y_t is determined by the unobservable discrete state variable s_t:

$$y_t = \beta_1(s_t)y_{t-1} + \ldots + \beta_p(s_t)y_{t-p} + v(s_t) + e_t \tag{7}$$

where, s_t is the regime variable, and the study problem is divided into m regimes (states) according to the regime of $s_t = 1, 2, \ldots, m$. $e_t \sim NID(0, \sum s_t)$ is the residual distribution. The intercept $v(s_t)$ and the vector coefficient matrix $\beta_{x=1,\cdots,p}$ change with the transition of the regime state s_t, reflecting the nonlinear characteristics of the model.

In addition, the probability of regime switching is:

$$p_{ij} = \Pr\left(s_{t+1} = j | s_t = i, \sum_{j=1}^{m} p_{i,j} = 1\right) \ \forall i,j \in \{1, 2, \cdots, m\} \tag{8}$$

The Markov transfer matrix is given by:

$$P = \begin{bmatrix} p_{1,1} & \cdots & p_{1,m} \\ \vdots & \ddots & \vdots \\ p_{m,1} & \cdots & p_{m,m} \end{bmatrix} \tag{9}$$

where, P satisfies the regularity constraint, that is, for any $i = 1, \ldots, m$, there is $\sum_{j=1}^{m} p_{i,j} = 1$.

4.2 | Stability test

To ensure the accuracy and efficacy of the empirical research, a smoothness test was performed on China's regional financial stability index prior to the construction of the MS-VAR model. The results of this test are presented in Supplementary Table 3. As observed in the table, the *P*-values associated with the four major regional financial stability indices in China all fall below the critical value of 5%. This rejection of the null hypothesis indicates that the regional financial stability index constructed in this study exhibits a satisfactory level of smoothness.

4.3 | Empirical results

Based on the log-likelihood estimation, AIC, SC and HQ indicators, the two-regime and the lagged zero-order MSIAH(2)-AR(0) model are selected in this article. The empirical results are obtained for the filtering probability, smoothing probability, and prediction of the two-regime for the four major regions, respectively. The smoothing probability $P[S_t] > 0.5$ is used as a criterion for judging the interval in which the sample is located, and the regime properties and distribution characteristics of the financial stability indices of each region are summarised based on the empirical results.

Based on the outcomes presented in Figure 1 and Table 1, the model delineates a dual-zone system for the financial stability index in eastern China. The smoothing probability analysis reveals that Zone 2 exhibits a higher frequency, a greater number of samples, and an average

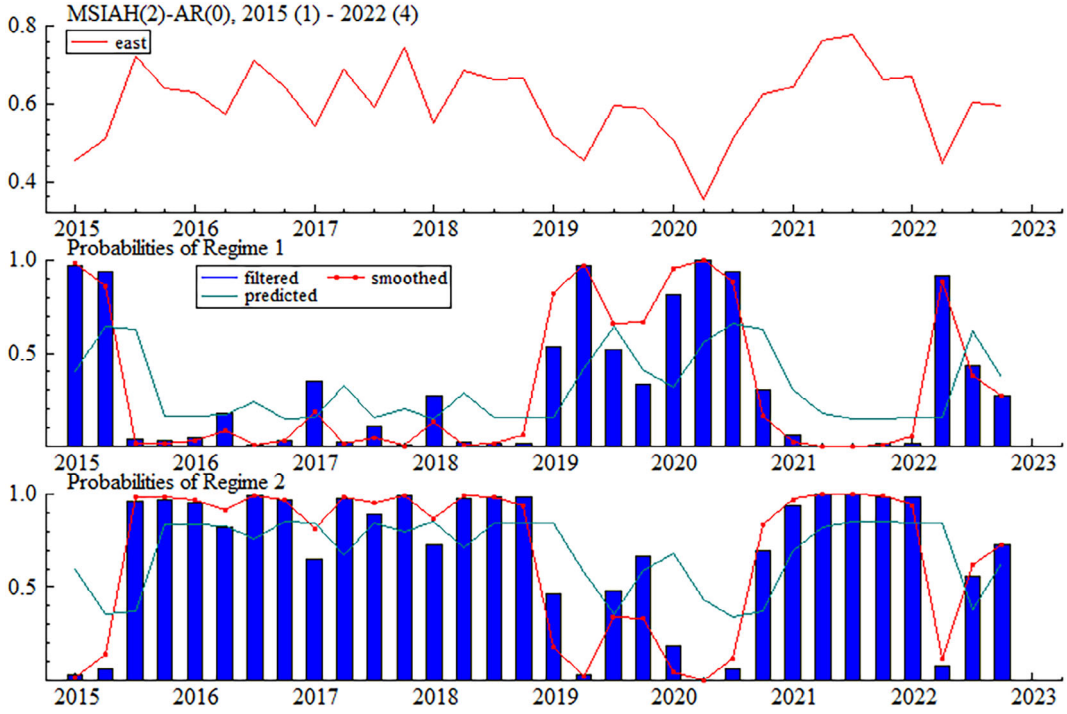

FIGURE 1 Empirical results of financial stability index in eastern region. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Properties and distribution characteristics of regimes of eastern financial stability index.

Properties	Regime 1 (low stability)	Regime 2 (high stability)
Sample intervals that fall within the regime	2015Q1–2015Q2 2019Q1–2020Q3 2022Q2	2015Q3–2018Q4 2020Q4–2022Q1 2022Q3–2022Q4
Sample size	10.0	22.0
Frequency	0.2970	0.7030
Average duration	2.93	6.93
Regime switching probability	0.6585	0.8557

duration that surpasses Zone 1. Furthermore, the probability of zone shift within Zone 2 is higher compared to Zone 1. A closer examination of the descriptive statistics within the zoning system reveals that the sample mean of Zone 1 is 0.49, lower than that of Zone 2 (0.65), while the standard deviation of Zone 1 is 0.07, higher than that of Zone 2 (0.06). Consequently, Zone 1 is categorised as 'low stability', and Zone 2 is classified as 'high stability'. Notably, the standard deviation of Zone 1 (0.07) surpasses that of Zone 2 (0.06). This finding reinforces the classification of Zone 1 as a 'low-stability' zone, while Zone 2 is designated as a 'high-stability' zone. This observation implies that the financial stability index in eastern China tends to spend more time in 'high stability' zones and exhibits a lower likelihood of transitioning to 'low stability' zones.

Similarly, the financial stability indices for central China (Supplementary Figure 1 and Supplementary Table 4), western China (Supplementary Figure 2 and Supplementary Table 5), and northeast China (Supplementary Figure 3 and Supplementary Table 6) undergo a parallel regional analysis. The findings reveal that the financial stability indices for central, western and northeastern China exhibit analogous characteristics to those observed in eastern China. Specifically, the duration of the 'high stability' regime constitutes a greater proportion of the total study period compared to the 'low stability' regime. Additionally, the status of the 'high stability' regime surpasses that of the 'low stability' regime. Moreover, the 'high stability' regime demonstrates greater stability than its 'low stability' regime.

In summary, the financial stability indices across China's diverse regions collectively showcase favourable performance, with the 'high stability' regime prevailing for a more substantial duration, exhibiting a higher status, and demonstrating greater overall stability than the 'low stability' regime. This implies that, on the whole, China's regional financial stability indices manifest robust performance and exhibit a higher degree of stability in financial status.

4.4 | Regional regime analysis

4.4.1 | 2015: Shift from 'low stability' to 'high stability'

In the initial and second quarters of 2015, the eastern, central, western and northeastern regions all faced a period of 'low stability' in financial development. However, a notable shift occurred in the third quarter of 2015 as all four regions transitioned from the 'low-stability' zone to the 'high-stability' zone.

This transformation coincided with a challenging period for China's regional financial stability in 2015, marked by increased complexities in liquidity management, heightened financial activities, and a corresponding rise in regulatory difficulties. The challenges were met with concerted efforts from the central bank, the government, and other sectors, leading to a more stable and healthy financial landscape. In 2015, there was a substantial increase in the scale of RMB loans and non-financial enterprises' bond and stock financing. Concurrently, entrusted loans, trust loans and undiscounted bank acceptances financing experienced significant declines, restructuring the social financing structure within the banking sector and reducing financial risks. In 2014, local governments initiated trial bond issuances, and this practice expanded in 2015, with the scale of local government bonds exceeding 700 billion Yuan in June. The latter part of 2015 witnessed heightened secondary market activity for local government bonds, with increased transaction volumes and a diverse range of investors. Additionally, the international currency market experienced improvements with the launch of the Renminbi cross-border payment system (CIPS), the International Monetary Fund's decision to include the Renminbi in the SDR currency basket, and the People's Bank of China's announcement to enhance the mechanism for forming the mid-price of the Renminbi exchange rate against the US dollar. These developments injected vitality into the international financial system and created a favourable external environment for China's financial stability. Consequently, the collective transition of the four major regions from 'low stability' to 'high stability' in 2015 underscored the resilience and adaptability of China's financial system amid a challenging and dynamic economic landscape.

4.4.2 | 2016–2018: Stay 'high stability'

From 2016 to 2018, the eastern, central, western and northeast regions consistently achieved 'high stability' in financial development.

The initiation of the 13th 5-Year Plan in 2016 marked a period of robust economic and financial development, accompanied by steady growth in social financing and low interest rates. Ongoing reforms from 2016 onwards addressed the rapid increase in macro leverage, mitigating some financial risks and steering towards a more stable financial direction. Substantial progress in preventing and resolving financial risks occurred in 2018, with measures curbing macroeconomic leverage growth, addressing high-risk institutions, and robustly rectifying Internet financial risks. Supervisory policies effectively managed volatility in the financial market and asset prices. The issuance of the 'Plan for Promoting the Development of Inclusive Finance (2016–2020)' on 31 December 2015, played a pivotal role in guiding inclusive finance development and contributing to its rapid progress over the subsequent 3 years. Institutions and policy guidelines for financial stability, coupled with dedicated efforts from the Government, central bank, and relevant departments, effectively controlled financial risks. Consequently, both China as a whole and its regions maintained a 'high degree of stability' in financial development from 2016 to 2018.

4.4.3 | 2019: Regional difference

In the initial and second quarters of 2019, the eastern, central, western and northeast regions experienced a period of 'low stability'. However, notable variations emerged in the third and

fourth quarters. Specifically, the eastern and northeast regions remained in 'low stability', while the Central region transitioned to 'high stability'. The Western region exhibited 'low stability' in the third quarter and maintained this status in the fourth quarter.

In 2019, improvements in financial asset quality were observed in the eastern, central and northeast regions, with a decline in the non-performing loan (NPL) ratio contributing positively to financial stability. Conversely, the Western region experienced an increase in the NPL ratio. Despite this, the Western region pursued poverty alleviation goals, with certain provinces engaging in financing through debt instruments under precision poverty alleviation objectives, supporting financial stability development. Loan sizes increased in the eastern and central regions but declined in the western and northeast regions. Overall, financial operations across all regions demonstrated general stability in 2019, with enhanced regional development coordination and effective prevention and control of major risks. However, due to regional disparities in risks, the zoning system reflecting regional financial stability differed. From a filter probability perspective, the difference in probabilities between 'low stability' and 'high stability' was minimal, approaching 0.5, highlighting the dynamic nature of regional financial stability during this period.

4.4.4 | 2020–2021: Shift from 'low stability' to 'high stability'

In the first three quarters of 2020, all four regions of China—the eastern, central, western and northeastern regions—were categorised under a 'low stability' regime. However, by the fourth quarter of 2020, a transition occurred across these regions from a 'low stability' regime to a 'high stability' regime.

This transition coincided with the onset of the COVID-19 pandemic, which profoundly impacted both the Chinese and global economic and financial landscapes. The COVID-19 pandemic precipitated a severe global economic downturn, disrupting industrial and supply chains, resulting in widespread closures and production halts. The healthcare sector faced unprecedented strain, while international trade and investment contracted. This turmoil led to volatility and instability in commodity and stock markets. China's economy contracted by nearly 6.8% in the first quarter of 2020, accompanied by a temporary rise in the macro leverage ratio. Small and medium-sized enterprises encountered significant survival challenges, leading to an uptick in default risks and concentration of financial risks, posing a substantial threat to financial stability. In response, the Chinese government swiftly implemented active and effective control measures. These measures included ensuring adequate liquidity, implementing accommodative fiscal and monetary policies, providing support to small and medium-sized enterprises through discounted loans, and addressing the pandemic's impact on financial markets. Concurrently, measures were taken to address high-risk financial institutions, introduce new regulations on asset management, and formulate detailed rules. The combined effect of these measures resulted in effective control and resolution of key financial risks by the end of 2020. This transitioned regional financial stability from a 'low stability' regime to a 'high stability' regime.

Moving into 2021, all four regions maintained their 'high stability' status in financial development.

China integrated epidemic prevention and control with economic and social development, ensuring sustained and healthy financial system development. At the macro level, effective macroeconomic policies led to a significant decrease in the macro leverage ratio. Capital market reforms deepened with the establishment of the Beijing Stock Exchange, and progress was made in drafting the 'People's Republic of China Financial Stability Law', strengthening the

financial safety net. Micro-level risk resolution efforts continued for enterprises such as the 'Tomorrow Group' and HNA group, resulting in a notable decrease in high-risk institutions. P2P lending platforms ceased operations, and regulatory oversight of various financial activities adhered to legal frameworks. The conclusion of new asset management regulations further bolstered stable and healthy development in the asset management industry. Overall, 2021 saw positive strides in financial work, with manageable financial risks, steady financial system development, and sustained 'high stability' across all four regions throughout the year.

4.4.5 | 2022: Fluctuations in financial stability status

In the financial landscape of the first quarter of 2022, all four regions of China—the eastern, central, western and northeastern regions—were positioned in a state of 'high stability'. However, this stability shifted in the second quarter of 2022, as all regions transitioned from 'high stability' to 'low stability'. The subsequent quarters, the third and fourth of 2022, witnessed a varied scenario: the eastern, central and western regions returned to a state of 'high stability', while the northeastern region remained in a state of 'low stability'.

The initial quarter of 2022 maintained financial stability across the four regions, aided by effective financial risk prevention and control measures and an uptick in total credit issuance. However, challenges emerged in the second quarter as global economic growth decelerated, inflation persisted at elevated levels, and international financial markets experienced notable volatility, notably impacting the US dollar and commodities. Despite improvements in COVID-19 prevention and control within China, disruptions persisted in supply chains, particularly in cities like Shenzhen and Shanghai. Additionally, geopolitical tensions such as the Russia-Ukraine conflict further exacerbated financial market volatility, posing challenges to regional financial stability. In response, the People's Bank of China intensified the implementation of prudent monetary policies, maintained reasonable liquidity levels, and enhanced financial services' capacity to support the real economy. Efforts were also made to address risks at small and medium-sized banks, reform financial operations of platform enterprises, and control financial risks effectively, leading to the transition of the eastern, central and western regions from 'low stability' back to 'high stability'. However, the northeastern region exhibited relatively weaker performance in economic development indicators such as investment growth, import–export volumes, loan growth rates and non-performing loan ratios, albeit showing a decreasing trend. Challenges persisted in industrial structure adjustment and upgrading, necessitating strengthened financial services to optimise industrial structure, address development challenges, and enhance people's livelihoods. Overall, 2022 saw fluctuations in financial stability across the regions, with the eastern, central and western regions oscillating between 'high stability—low stability—high stability', while the northeastern region experienced a transition from 'high stability' to 'low stability'.

5 | VARIANCE MEASURES OF REGIONAL FINANCIAL STABILITY INDEX

5.1 | Theil index

Economic development across regions is inherently influenced by national development strategies and human geography, leading to variations in financial development and its stability.

Regional disparities in financial stability not only manifest between different regions but also within individual regions. The Thiel Index, chosen for its ability to accurately reflect overall, inter-group, and intra-group variation in financial stability, along with the proportion of total variation explained by these factors, is employed in this article to measure the variation of regional financial stability indices. Following the approach outlined by Pan and Zheng (2020), Equations (10) and (11) are used to calculate the differences in financial stability indices for the entire country and the eastern, central, western and northeast regions.

$$T = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{Y_i}{\overline{Y}} ln \frac{Y_i}{\overline{Y}}\right) \tag{10}$$

$$T_k = \frac{1}{n_k}\sum_{i=1}^{n_k}\left(\frac{Y_{ki}}{\overline{Y}_k} ln \frac{Y_{ki}}{\overline{Y}_k}\right) \tag{11}$$

where, T denotes the overall financial stability index of the Thiel index, with values ranging from 0 to 1, The more the value tends to 0, the smaller the overall difference; T_k ($k = 1, 2, 3, 4$) denotes the Thiel index of the financial stability index of the east, central, west and northeast regions, respectively; i denotes the province; n denotes the total number of provincial administrative regions; n_k denotes the number of provinces and cities in the east, central, west and northeast regions, respectively; Y_i denotes the financial stability index of provincial administrative region i; Y_{ki} denotes the financial stability index of province and city i in region k; $\overline{Y}, \overline{Y_k}$ denotes the average value of the financial stability index of the overall and region k, respectively.

The Theil index of the financial stability index is further decomposed into the intra-regional variance Theil index T_w and the inter-regional variance Theil index T_b by Equations (12) and (13).

$$T = T_w + T_b \tag{12}$$

$$T = \sum_{k=1}^{4}\left(\frac{n_k}{n}\frac{\overline{Y_k}}{\overline{Y}}T_k\right) + \sum_{k=1}^{4}\left(\frac{n_k}{n}\frac{\overline{Y_k}}{\overline{Y}} ln \frac{\overline{Y_k}}{\overline{Y}}\right) \tag{13}$$

On this basis, the contribution of intra-regional variation and inter-regional variation to the total variation, D_w, D_b, is calculated, and this indicator can further study the sources of the overall variation in regional financial stability. The calculation formula is as follows.

$$D_w = T_w / T \tag{14}$$

$$D_b = T_b / T \tag{15}$$

5.2 | Difference analysis

The results of the Tel Index calculation are depicted in Supplementary Figure 4. The graph illustrates Theil index values for the entire country and its four major regions, predominantly falling between 0 and 0.015. Particularly noteworthy are the central and northeastern regions,

where Theil index values tend towards 0, signifying minimal differences overall. Additionally, the national Theil index closely follows a pattern akin to that of the eastern and western regions, demonstrating a distinct three-stage fluctuation in financial stability differences characterised by an initial decline, followed by an increase, and then another decline. Notably, two significant inflection points stand out: the fourth quarter of 2017 and the second quarter of 2020. Preceding the fourth quarter of 2017, Theil index values for the country and the eastern and western regions experienced a declining fluctuation, indicating a gradual narrowing of financial stability differences, reaching their lowest point in the fourth quarter of 2017. From this point until the second quarter of 2020, Theil index values exhibited an increasing fluctuation, showcasing a widening of financial stability differences. The impact of the COVID-19 pandemic accelerated these differences in 2020, reaching a peak in the second quarter. Subsequently, as the pandemic was brought under control and financial markets recovered, a significant downward trend in Theil index values ensued, leading to a narrowing of differences. Conversely, Theil index values for the central and northeastern regions remained relatively stable, fluctuating modestly between 0 and 0.0002, significantly lower than national and eastern and western regional levels. The Theil index for the eastern region notably surpassed the national Theil index, indicating a substantial contribution to overall financial stability differences, while the contributions from the central and northeastern regions were comparatively minor. Therefore, the financial stability trend of the eastern region becomes pivotal in determining macro-financial stability trends, making it a focal point for efforts aimed at reducing financial stability differences.

From Supplementary Figure 5, it's evident that the total differences in financial stability index align closely with intra-group differences, showcasing a consistent trend. Meanwhile, inter-group differences typically remain below 0.001 across most time periods, indicating a consistently low level. This observation underscores that intra-group differences, specifically among the eastern, central, western and northeastern regions, consistently play a dominant role in total differences. Conversely, inter-group differences have a relatively minor impact on the overall differences in financial stability.

Supplementary Figure 6 illustrates the comparative impact of inter-group and intra-group disparities. The data reveals a consistent pattern where throughout the study timeframe, the influence of intra-group disparities consistently surpasses that of inter-group disparities. Specifically, internal differences among the four major regions account for more than 70% of the total differences observed. Notably, between 2015 and 2017, intra-group differences exhibited an oscillating upward trajectory while inter-group differences demonstrated a fluctuating decline. This led to a continual reinforcement of the explanatory power of intra-group disparities regarding total differences. In the subsequent period from 2017 to 2020, there was a continuous decline in the contribution of intra-group differences, juxtaposed with a rising contribution from inter-group differences. This gradual shift indicates a diminishing proportion of total differences being elucidated by internal differences among the four major regions, with a concomitant increase in the explanatory role of differences between these regions. Noteworthy is the substantial spike of nearly 130% in the contribution rate of inter-group differences observed between 2018 and 2020, underscoring the escalating significance of fostering coordinated regional financial stability to uphold overall financial stability. Post-2020, a sudden surge in the contribution of intra-group differences alongside a descending trend in inter-group differences underscores the imperative of concurrently focusing on promoting coordinated regional financial stability and enhancing internal financial risk management to uphold financial stability within regions.

6 | ANALYSIS OF THE SPATIAL AND TEMPORAL VARIATION OF REGIONAL FINANCIAL STABILITY INDEX

6.1 | Analysis of regional financial stability index over time

6.1.1 | Line graph of change over time

The line graphs of the financial stability index over time for the four regions of East, Central, West and Northeast are shown in Figure 2.

The graph illustrates that the western region consistently maintains the highest level of financial stability among the four major regions, while the eastern region consistently records the lowest level. Across the period from 2015 to 2022, the financial stability indices for the eastern, central, western and northeastern regions manifest a fluctuating trajectory characterised by alternating phases of growth and decline. Specifically, in 2015, a phase of accelerated growth is evident, succeeded by a period of horizontal fluctuation spanning 2016 to 2018, peaking in the fourth quarter of 2017. Subsequently, from 2019 to 2020, a downward fluctuation trend is observed, exacerbated by the impact of the COVID-19 pandemic, leading to the nadir of financial stability indices across regions in the second quarter of 2020, followed by a subsequent recovery. However, in the years 2021–2022, a renewed downward trend in financial stability indices is apparent. Overall, spanning the years 2015–2022, the financial stability indices for the four major regions demonstrate a fluctuating developmental pattern.

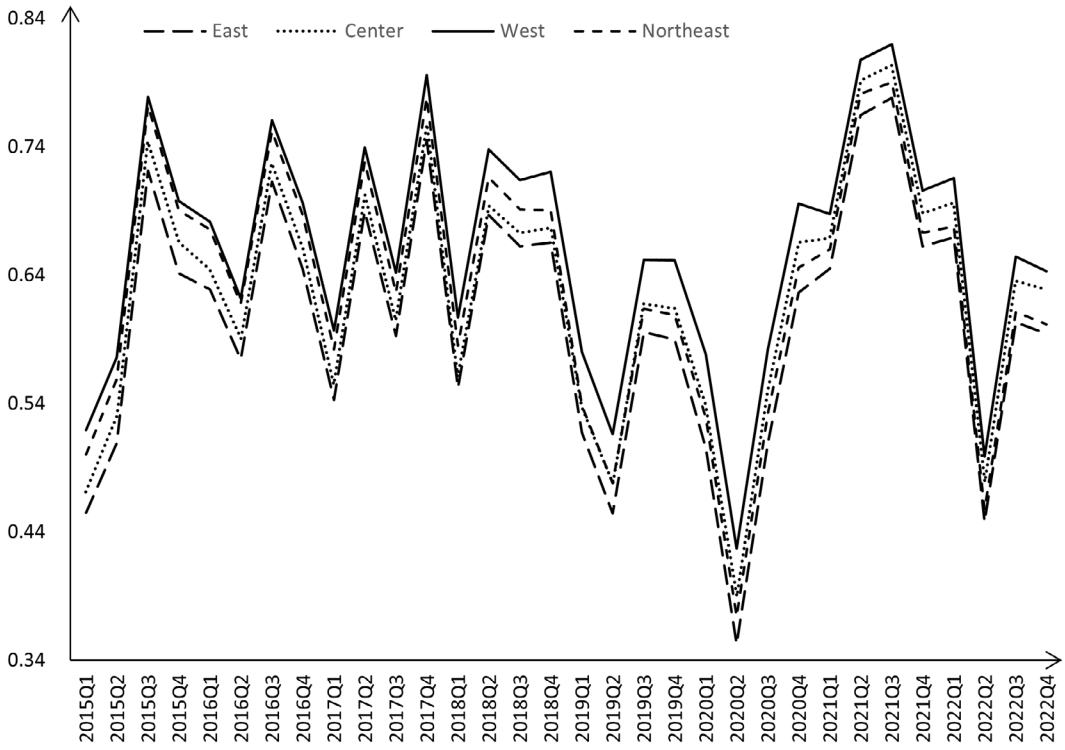

FIGURE 2 Changes in regional financial stability index levels.

6.1.2 | Nuclear density map

To further study the dynamic trend of the regional financial stability index over time, this article selects the kernel density estimation method to analyse the dynamic time-series evolutionary characteristics of the financial stability index.

Figure 3 depicts the interregional kernel density map, revealing several noteworthy observations. During the period from 2015 to 2022, the centroid position of the kernel density curve exhibited a directional shift. Specifically, it moved leftward from 2015 to 2016, then rightward from 2016 to 2017, followed by another leftward shift from 2017 to 2019, a subsequent rightward movement from 2019 to 2021, and finally, a leftward shift from 2021 to 2022. This temporal progression signifies a distinctive pattern in the overall regional financial stability index within China, characterised by an initial decline followed by an ascent, a trend that aligns with the illustrated pattern in Figure 2.

Furthermore, over the same period from 2015 to 2022, the primary peak's height in the kernel density curve exhibited a gradual upward trajectory, indicating a trend of sustained and incremental growth, with its peak in 2021 and a nadir in 2020. This observation implies a fluctuation in the financial stability index among different regions within China, characterised by an initial decline, subsequent rise, and subsequent decline.

Additionally, between 2016 and 2022, there was an occurrence of coexisting primary and secondary peaks in the kernel density curve, suggesting a degree of regional disparity in the financial stability index during these years. In contrast, 2015 showed a single peak, indicating absence of such disparity.

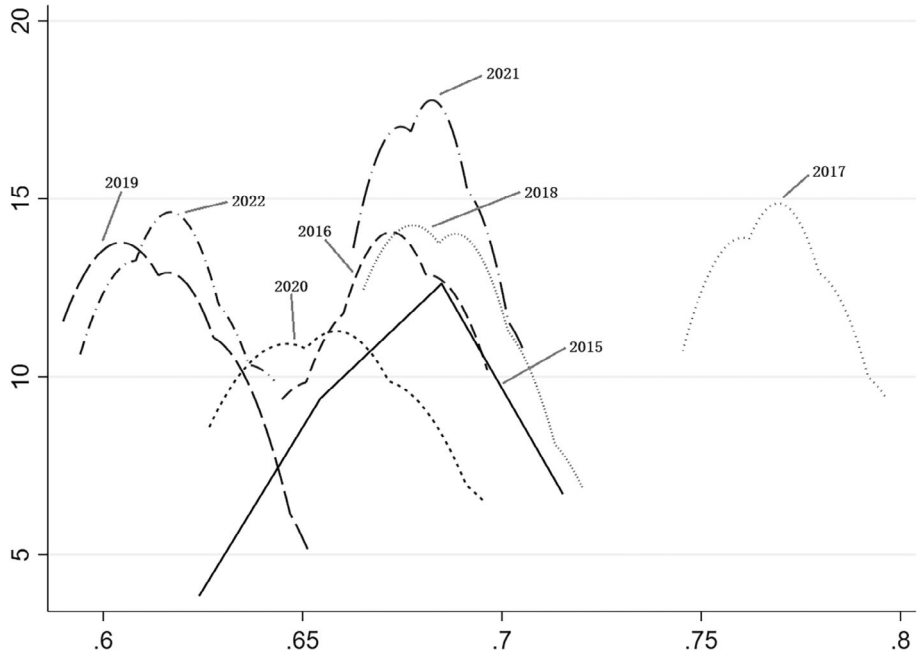

FIGURE 3 Regional financial stability index kernel density map.

Lastly, the distribution between 2015 and 2016 demonstrated a left-skewed distribution, with a larger left tail, indicating more regions below the average financial stability index during that period. Conversely, from 2017 to 2022, a right-skewed distribution emerged, with a larger right tail, indicating more regions above the average financial stability index. This transition from a concentration of low values to a concentration of high values across different regions underscores varying degrees of increase in financial stability indices from 2015 to 2022.

Supplementary Figures 7–10 presenting the kernel density analysis for the eastern, central, western and northeastern regions, respectively, reveal that the financial stability indexes of both inter-regions and individual regions (eastern, central, western and northeastern) exhibit dynamic evolutionary characteristics with fluctuations over time. These fluctuations pertain to the overall level of development, differences between cities and the degree of polarisation in each region.

6.2 | Evolution of the spatial and temporal patterns of regional financial stability indices

6.2.1 | Characteristics of the evolution of the global spatial pattern

Figure 4 and Supplementary Figure 11 illustrate the results of measuring the global Moran's I index for the financial stability index between regions and within each region for the period 2015–2022, using GeoDa software.

The results indicate that while there is a spatial dispersion and variation in the operation of regional financial stability, the mutual influence of the financial stability index between regions is not significant. Similarly, the spatial autocorrelation within each region's financial stability index is not significant. This suggests that the financial stability of provinces and cities within each region operates in a decentralised manner. The lack of significant spatial autocorrelation emphasises the need for differentiated and targeted governance for the financial stability of each region to strengthen the diffusion effect and promote coordinated development.

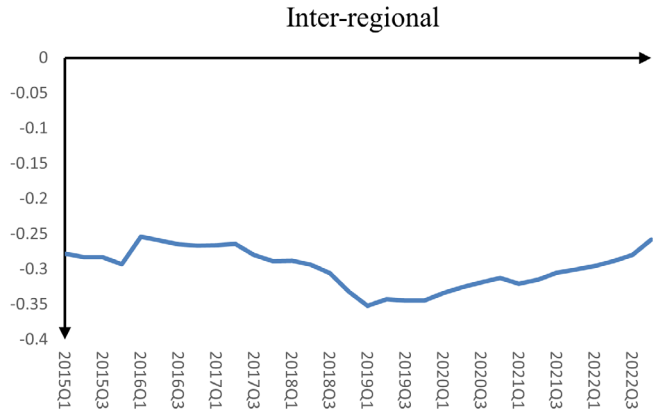

FIGURE 4 Evolution of the regional financial stability index Global Moran'I index. [Color figure can be viewed at wileyonlinelibrary.com]

6.2.2 | Characteristics of the evolution of local spatial patterns

To examine the changes in the local spatial divergence of the financial stability index in each region, this article summarises the local spatial pattern of each region based on the local Moran'I scatters plot of the financial stability index in each quarter from 2015 to 2022 as well as the Lisa set scatter plot.

Table 2 delineates the spatial distribution pattern of financial stability indices across China's four major regions. Analysis of the table reveals that, with the exceptions of the second quarter of 2015 and the fourth quarter of 2019, during which localised spatial agglomeration phenomena were not pronounced, the financial stability indices across China's regions exhibited discernible localised spatial agglomeration characteristics throughout other time periods. Notably, the evolution of China's regional financial stability indices was largely influenced by polarised effect zones and backward transition zones, representing states of spatially non-equilibrium correlated agglomeration. Specifically, the eastern region consistently showcased polarised effect characteristics across each time period, whereas the western region epitomised the backward

TABLE 2 Inter-regional spatial pattern distribution.

Period	**2015Q1**	**2015Q2**	**2015Q3**	**2015Q4**	**2016Q1**	**2016Q2**	**2016Q3**	**2016Q4**
H–H	0	0	0	0	0	0	0	0
L–H	East	0	East	East	East	East	East	0
L–L	0	0	0	0	0	0	0	0
H–L	West	0	West	West	West	West	West	West
Insignificant	2	4	2	2	2	2	2	3
Period	**2017Q1**	**2017Q2**	**2017Q3**	**2017Q4**	**2018Q1**	**2018Q2**	**2018Q3**	**2018Q4**
H–H	0	0	0	0	0	0	0	0
L–H	East	East	East	East	East	East	East	East
L–L	0	0	0	0	0	0	0	0
H–L	0	West	West	West	West	West	West	West
Insignificant	3	2	2	2	2	2	2	2
Period	**2019Q1**	**2019Q2**	**2019Q3**	**2019Q4**	**2020Q1**	**2020Q2**	**2020Q3**	**2020Q4**
H–H	0	0	0	0	0	0	0	0
L–H	East	East	East	0	East	East	East	East
L–L	0	0	0	0	0	0	0	0
H–L	0	West	West	0	West	West	West	West
Insignificant	3	2	2	4	2	2	2	2
Period	**2021Q1**	**2021Q2**	**2021Q3**	**2021Q4**	**2022Q1**	**2022Q2**	**2022Q3**	**2022Q4**
H–H	0	0	0	0	0	0	0	0
L–H	East	East	East	East	East	East	0	East
L–L	0	0	0	0	0	0	0	0
H–L	West	West	West	West	West	West	West	West
Insignificant	2	2	2	2	2	2	3	2

transition zone. Conversely, the central and northeastern regions displayed minimal spatial differentiation attributes. Consequently, prioritising attention to financial stability concerns in the eastern region and strategizing to harness the radiating effect of financial stability in the western region emerge as pivotal imperatives. Efforts should be directed towards bolstering financial stability across all regions and mitigating financial disparities interregionally.

Supplementary Table 7 delineates the spatial distribution pattern within the eastern region. Examination of the table reveals that the provincial-level financial stability indices in the eastern region, with the exception of the period spanning from the fourth quarter of 2016 to the second quarter of 2019, did not prominently display significant local spatial agglomeration phenomena. Nevertheless, they did exhibit certain local spatial agglomeration characteristics during other time intervals. Moreover, the local spatial differentiation features within the eastern region are predominantly typified by polarised effect zones and backward transition zones. Notably, the polarised effect zone is exemplified by Guangdong, showcasing polarised effect characteristics in 2015, 2016, and from 2020 to 2022. On the other hand, the backward transition zone, represented by Tianjin, manifested backward transition characteristics in the latter half of 2019 and from 2021 to 2022. The remaining seven provinces within the eastern region displayed negligible spatial differentiation attributes.

Supplementary Table 8 provides an overview of the spatial distribution pattern within the central region. A detailed analysis of the table reveals that the provincial-level financial stability indices in the central region, with the exception of the period from the fourth quarter of 2015 to the fourth quarter of 2016 and the final three quarters of 2017, did not prominently display notable local spatial agglomeration phenomena. However, they did exhibit certain local spatial agglomeration characteristics during other temporal intervals. The progression of financial stability indices in the central region is primarily shaped by polarised effect zones and backward transition zones. Specifically, the polarised effect zone is exemplified by Hubei Province, Hunan Province, and Anhui Province. Hubei Province exhibited significant polarised effect characteristics solely in the initial three quarters of 2015. Anhui Province showcased polarised effect characteristics from 2018 to 2020, while Hunan Province demonstrated polarised effect characteristics in the first quarter of 2017, the first quarter of 2019, and in 2020. On the other hand, the backward transition zone is predominantly represented by Jiangxi Province and Henan Province. Jiangxi Province displayed backward transition characteristics solely in the third quarter of 2018, whereas Henan Province showcased backward transition characteristics in the first quarter of 2020 and from 2021 to 2022. Notably, Shanxi Province did not exhibit significant spatial differentiation attributes.

Supplementary Table 9 delineates the spatial distribution pattern within the western region. Examination of the table reveals that the provincial-level financial stability indices in the western region showcased a certain degree of local spatial agglomeration phenomena at various stages. Notably, diffusion spillover zones, polarised effect zones, backward transition zones, and low-speed growth zones emerged in the evolution of financial stability indices within the western region. The diffusion spillover zone is primarily exemplified by Yunnan, Guangxi, and Guizhou, with a notable concentration observed in the years 2021 and 2022. On the other hand, the polarised effect zone is chiefly represented by Xinjiang and is concentrated between 2017 and 2019. Furthermore, the low-speed growth zone is prominently represented by Chongqing Municipality and Guizhou Province, with Chongqing Municipality exhibiting low-speed growth characteristics from 2016 to 2020, and Guizhou Province showcasing low-speed growth characteristics from the fourth quarter of 2016 to the fourth quarter of 2018. Moreover, the backward transition zone is predominantly represented by Qinghai, Gansu, and Yunnan, with Qinghai

Province displaying backward transition characteristics in the first two quarters of 2015, Yunnan exhibiting backward transition characteristics from the third quarter of 2015 to the second quarter of 2016, and Gansu Province showcasing backward transition characteristics from 2021 to 2022. Notably, the remaining seven provinces and municipalities not mentioned displayed negligible spatial differentiation characteristics. Of particular significance is the transition of Guizhou Province from exhibiting characteristics of a low-speed growth zone initially to a diffusion spillover zone during the study period, signifying an improvement in its financial stability status and enhanced diffusion and radiation effects on surrounding areas. Similarly, Yunnan Province transitioned from exhibiting characteristics of a backward transition zone to a diffusion spillover zone, indicative of improved financial stability status and enhanced diffusion and radiation effects on its neighbouring areas.

Finally, Supplementary Table 10 provides an overview of the spatial distribution pattern within the northeastern region. Analysis of the table reveals that the provincial-level financial stability indices in the northeastern region consistently exhibited certain local spatial agglomeration characteristics across each time period. Furthermore, the local spatial differentiation features within the northeastern region are primarily defined by polarised effect zones and backward transition zones. Notably, the polarised effect zone is predominantly represented by Heilongjiang Province and Liaoning Province. Heilongjiang Province showcased polarised effect characteristics in the initial three quarters of 2015 and from the second quarter of 2019 to the fourth quarter of 2020. Similarly, Liaoning Province exhibited polarised effect characteristics from 2015 to 2020. Conversely, Jilin Province consistently demonstrated significant spatial differentiation characteristics as a backward transition zone throughout each time period.

7 | CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 | Results, discussion and conclusions

In summary, this article constructs a regional financial stability index based on the provincial financial stability index and conducts state analysis, differential analysis, and spatiotemporal variation analysis of this index, drawing relevant conclusions. The scientific validity and rationality of the index construction are crucial, as the conclusions of this article are derived from the regional financial stability index.

In the state analysis, the research conclusions align with the actual macro-financial stability conditions in China, indicating a degree of scientific validity in the constructed regional financial stability index. However, Dong (2018) also constructed a regional financial stability index for China for the year 2016, concluding that the eastern region had better financial stability. In contrast, this article finds that the eastern region exhibits the poorest financial stability among the four major regions. Two possible reasons for this contradictory conclusion are: first, the difference in the financial stability indicator systems used. Dong (2018) primarily used risk indicators from the banking sector and included numerous macroeconomic indicators, while this article's indicator system focuses primarily on risk indicators and covers most risk areas. Second, Dong (2018) only covered the year 2016, which limits the credibility and generalizability of the conclusions, whereas this article spans 2015–2022, providing a broader research period and larger sample size, thus making the conclusions more reliable. Furthermore, compared to existing literature, this article provides a more comprehensive and detailed analysis of the regional

financial stability status in China, aiming to stimulate academic interest and exploration in this field. Therefore, the research conclusions of this article can be summarised as follows:

First, the duration of the 'high stability' regime of the regional financial stability index in China is longer than that of the 'low stability' regime, and transitions to the 'low stability' regime are infrequent. The regime of each regional financial stability index is generally synchronised and consistent with the overall macro-financial stability conditions, influenced by both macro and micro-financial stability factors, with provincial financial stability factors causing inter-regional regime differences.

Second, the overall difference in financial stability across the nation and regions is relatively small, with the eastern region playing a decisive role in macro-financial stability. Additionally, the contribution of intra-regional differences in the financial stability index is significant, dominating the total difference.

Third, the regional financial stability index exhibits temporal fluctuations in overall development levels, inter-provincial differences, and polarisation degrees. The central region's financial stability index shows significant volatility. Spatially, the operation of regional financial stability is dispersed and highly variable. During the research period, regions generally displayed certain local spatial agglomeration phenomena, with spatial differentiation characterised mainly by polarisation effects and lagging transitional zones.

7.2 | Policy recommendations

Based on the research findings, the regional financial stability index constructed in this study demonstrates significant scientific validity and applicability. To promote the coordinated and stable development of regional finance in China, the following policy recommendations are proposed.

The analysis reveals significant spatial dispersion and variability in regional financial stability. The eastern and northeastern regions exhibit more active financial activities but weaker financial stability, necessitating the optimization and adjustment of financial mechanisms. Conversely, the central and western regions have less developed financial markets but demonstrate greater financial stability, suggesting a need for targeted resource allocation and guidance. Enhancing financial supervision in the eastern and northeastern regions is essential to improve their risk resistance and maintain financial stability. Similarly, advancing the financial development of the central and western regions should focus on the quality of their development. Promoting the diffusion of financial activities from the eastern and northeastern regions to the central and western regions, and integrating financial stability capabilities across regions, will contribute to the continuous optimization of the financial landscape. An optimised financial layout can enhance regional financial stability, foster financial aggregation, and generate positive spillover effects, ultimately achieving coordinated regional financial stability and development.

For regions or provinces experiencing polarisation effects, support for financial cooperation with neighbouring areas is recommended to facilitate the dissemination of financial knowledge and technology, thereby enhancing regional financial development and stability. For regions in lagging transitional zones, attention should be given to leveraging their radiative role to boost surrounding areas with low financial stability through financial support and policy guidance. For regions in diffusion spillover zones, encouraging financial innovation and development is critical while using regional cooperation mechanisms to disseminate successful experiences and

high-quality financial resources to neighbouring areas. Regions experiencing slow growth should focus on infrastructure construction, improving financial services, strengthening financial education and training, and leveraging policy support to enhance financial stability.

In conclusion, to promote coordinated and stable regional financial development, it is necessary to strengthen financial coordination and cooperation both between regions and within provinces. This includes facilitating the rational flow and optimal allocation of financial resources and establishing regional financial risk monitoring and early warning mechanisms to prevent and mitigate regional financial risks. Additionally, formulating and implementing long-term financial development strategies that fully consider regional disparities and synergies will drive balanced development of the financial sector across and within regions.

8 | LIMITATIONS OF THE STUDY

First, the data are quarterly and not monthly, which limits the effectiveness and timeliness of assessing the state of financial stability. However, even with just quarterly data, the index presented in this article is highly effective in assessing and analysing the state of financial stability. With monthly data, this task could be undertaken far more efficiently.

Another limitation is that the indicators used in this study do not represent all of the possible factors that influence financial stability in China. There are other factors involved in influencing financial stability that were omitted and could have had an impact on the results of the Financial Stability Index. Hence, future research is encouraged to take into consideration other important indicators and to construct a more scientific and effective financial stability indicator system.

This article presents an analysis of a regional financial stability index, focusing on differential measurement and spatiotemporal variation analysis. Future research endeavours are anticipated to refine the methodologies utilised herein and to undertake broader and more comprehensive investigations into financial stability of China and other countries.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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