

## Research Article

# Financial Time Series Model Based on Least Squares Support Vector Machine Predictive Control Algorithm in Financial Market

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China's financial market also faces some outstanding problems, namely, obvious structural imbalance in the size of the financial market, on the one hand, the absolute dominance of the size of the indirect financing market, mainly the bank lending market and on the other hand, the imbalance in the size of the direct financing market and the indirect financing market. At the same time, there is also a structural imbalance of the financial market among regions in China. How to verify the objective existence of such structural imbalance in different regions and measure the difference in the level of financial market development among regions is the focus of this paper. This paper constructs a financial market development level indicator system from three dimensions, equity market, bond market, and lending market, and measures the financial market development level by using inter-provincial panel data from 2001 to 2020 through neural network algorithm, time series model, and support vector machine algorithm, and analyzes the regional heterogeneity of financial market development on this basis. The results show that the overall market level of the financial industry in the eastern coastal region of China is the highest, but the intra-regional differences are also the most obvious; the overall market level of the financial industry in the northeastern region of China is the lowest, and the differences with the eastern region rise significantly; the market level of the financial industry at the provincial level in the central and eastern regions shows an all-time decreasing trend, while the western and northeastern regions of China show a convergence, then divergence, and then convergence trend. Therefore, differentiated financial policies should be implemented according to the stage of regional development in order to enhance the financial development level of each economic region and gradually narrow the regional financial development gap.

## 1. Introduction

Under the premise that the goal of economic development is shifting from high-speed development to high-quality development, financial development and financial deepening may become an appropriate breakthrough for the transformation of the economy from capacity-intensive to quality-intensive. Studies by foreign scholars on western developed countries show that financial development can have a significant positive impact on the economic growth of a country. But this positive impact is due to the highly developed financial system and sound financial system. China's current financial market and financial system are not very sound, and the role of the financial system on economic growth is not particularly significant. In the context of the

current deepening financial reform, exploring the relationship between financial development and economic growth remains a valuable issue for the economy to achieve stable and healthy development at this stage [1]. On the other hand, the current global economic downturn has led to the introduction of quantitative monetary easing policies in various countries. Quantitative monetary easing may stimulate economic growth, but historical experience also shows that excessive release of liquidity can sow the potential risk of inflation. Inflation brings purchasing power risk and distorts commodity prices, while large fluctuations in capital flows as well as asset prices can cause macro-financial risks, which may have a huge impact on China's financial openness and stability, and thus affect the process of high-quality development of our economy; but moderate inflation

may also affect market investment in the short-term through monetary and real interest rates. Therefore, the financial time series model of least squares support vector machine predictive control algorithm has an uncertain effect on the financial development for economic growth. Therefore, it is of practical significance to study the relationship between financial development and economic growth from the perspective of financial time series models of the least squares support vector machine predictive control algorithm [2].

Although China's financial system is very unsound, high savings in China still support economic growth for forty years, and it has become one of the important components of China's market economy as it has been effective in promoting corporate financing and helping the development of enterprises. However, China's financial market is also facing some outstanding problems, namely, the obvious structural imbalance in the size of the financial market, on the one hand, the absolute dominance of the scale of the indirect financing market, mainly bank lending market and on the other hand, the imbalance between the scale of the direct financing market and the indirect financing market. At the same time, there is also a structural imbalance of the financial market among regions in China. How to verify the objective existence of this structural imbalance in different regions and to measure the differences in the level of financial market development among regions is the focus of this paper [3].

## 2. Research Background

The academic community has conducted in-depth discussions on the composition and influencing factors of financial markets. Richard pointed out that interest rates are the key indicator of financial markets [4]. Further, Calvo et al. explored the link between exchange rates and financial crises and found that exchange rates are a key factor in the stability or otherwise of financial markets [5]. Billah et al. argue that markets that can be accounted for by rates of return, in addition to interest rates, are an important component of financial markets [6]. Then, money and bond markets based on interest rates, equity markets based on yields, and foreign exchange markets based on exchange rates are important components of financial markets. This is widely used in academic circles; for example, Yang Zirong et al. mainly use the relevant variables in the credit market and the stock market as the core indicators of financial development, Szczygielski et al. point out that the stock market plays the role of direct financing in the financial market, Yan et al. measure the financial structure and financial development of China through the stock market and the credit market, and Yang Ke et al. consider the stock, bond, and exchange rate markets as important components of the financial market [7]. Scholars select suitable sub-markets to study according to different topics, e.g., Yin Zhentao et al. explored the relationship between competition avoidance and financial innovation in the credit market, Wu Shinnong et al. used the stock market and bond market to construct a financial market security index, and Li Minbo et al. screened

indicators from the bond market, equity market, money market, and foreign exchange market to construct a financial market stress index in China. Regional financial markets are an important component of the national financial market, but the influence of national indicators needs to be excluded when comparing the differences between different regional financial markets, such as the foreign exchange market which is more national in nature [8]. Lin et al. use the credit, bond, and exchange rate markets as key objects to measure global systemic financial risk, and it is for this reason that the foreign exchange market is not appropriate as an indicator of inter-provincial financial market development. For this paper, it is particularly important to find an indicator system that reflects the inter-provincial characteristics [9].

In terms of the dimensions of the selection of measurement indicators, Yang et al. measured the financial market by the share of deposits in GDP, stock market turnover ratio, and bank reporting coverage ratio [10]. Kulish et al. measured the level of regional financial development in terms of the ratio between the scale of capital goods (including bonds, stocks, and funds) transactions and GDP in the process of studying the impact of regional financial development and economic fluctuations on income distribution [11]. At the level of the choice of the measurement method, scholars would measure through the theories calculated by Tobin's  $q$ -theory calculus, Tobin's correlation theory, and other calculations, all of which provide some support for this study [12].

In general, the financial market development level measurement needs to focus on the bond market, equity market, money market, and foreign exchange market [13]. The selection of sub-markets for the inter-provincial financial market development level mainly focuses on the first three markets, but it should be noted that the money market belongs to the ranks of the short-term market, while the bond and equity markets belong to the medium- and long-term market. Therefore, it is more appropriate to study the money market from the perspective of the lending market, i.e., it is more feasible to consider the impact of the medium- and long-term interest rate market changes on the financial market development [14]. At the level of indicator selection, existing studies do not construct a complete indicator system for financial market measurement and are not uniform at the level of market selection and indicator selection, and there are fewer relevant studies on regional differences in inter-provincial financial market development, so this study will measure the level of inter-provincial financial market development and further analyze the regional differences.

## 3. Materials and Methods

### 3.1. Basic Theory

**3.1.1. Least Squares Method.** The least squares method is a mathematical tool widely used in the fields of error estimation, uncertainty, system identification and forecasting, prediction, and other data processing. The first asteroid was discovered by the Italian astronomer Biazzi in 1801. After 40 days of tracking Piazzi Ceres and looking toward the Sun, he

would lose his position. Scientists around the world used Piza's diagram to find Ceres, but most of those who looked for Ceres came up empty in their calculations. Only Gauss (24 years old at the time) calculated the orbit of Ceres (Ceres), which was confirmed by the observations of the Austrian astronomer Heinrich Erbos, so that astronomers could predict the exact position of Ceres [15]. Many astronomical discoveries were made, including Halley's comet. In his Book of Celestial Motions, published in 1809, Gauss used the method of least squares. In fact, in 1806, the French scientist Legendre invented independently the "method of the smallest equation," but it was not known to the world.

The least square method (also known as the least quadrilateral) is a mathematical optimization method. It multiplies the square of the error by the series to get the most accurate function of the data. The unknown data can be easily obtained with the least quadratic method and the sum of the error values between the data delivery and the actual data can be minimized. The least square method can also be used to correct curves, while other optimization problems can be expressed in the form of energy minimization or entropy maximization.

A simple linear fit was performed with the least square number. However, how close the estimated parameters are to the true parameters of the overall, and whether there are other better estimates, involves least squares estimation or least variance of the estimate (or best), linear and unbiased, or BLU for short. This is the main reason why ordinary least squares are widely used to estimate econometric models. Ordinary least squares estimation has the three properties mentioned above. They are shown in Figure 1.

**3.1.2. Financial Markets.** The financial market is also known as the capital market, i.e., the money market and the capital market, i.e., the financial market. It implies the "integration of finance," i.e., the supply and demand for money in the business life of an economy using various financial instruments to regulate activities. Financial markets trade various instruments, such as stocks, bonds, and deposits. Finance refers to financial resources, which usually include direct and indirect funding. Direct financing is a financial measure between the supply and demand of financial resources, i.e., the direct provision of financial resources through financial markets to institutions and individuals who have surplus funds in society. Indirect financing is a financial resource provided by banks, as well as financial resources provided by banks and other financial institutions. Financial markets have a direct and far-reaching impact on all aspects of economic activity, individual wealth, corporate behavior, and economic efficiency that directly depend on financial market activities [16].

The composition of financial markets is very complex. It is a large system of different markets. However, depending on the maturity of the instruments traded, financial markets are divided into money markets and capital markets. The foreign exchange market is a short-term money market (less than one year) and the capital market is a long-term money market (more than one year). The money and capital

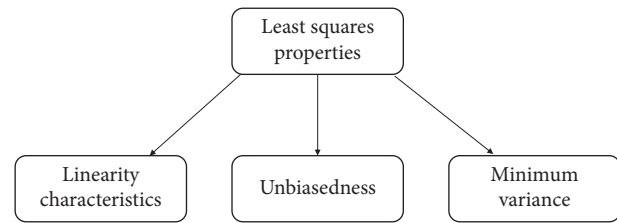


FIGURE 1: Least squares properties.

markets can be further subdivided into many different sub-markets. The foreign exchange market includes the inter-bank market, the repo market, the commercial foreign exchange market, the market for bank deposits and debt securities, the short-term government bond market, and the large amount of negotiable deposit money. The capital markets include the medium- and long-term credit and securities markets. The medium- and long-term credit market represents the credit market between financial institutions and firms [17]. The securities market is the market for financing through the issuance and sale of securities and includes the bond and stock markets, the fund market, the insurance market, and the financial and leasing markets. The formation of financial markets is shown in Figure 2.

### 3.2. Research Methodology

**3.2.1. Algorithm of Support Vector Machine.** Support Vector Machine (SVM) is a learning monitoring method which can be used to label, correct, and search for sample anomalies. The main idea is to create a hyperplane in a selected fabric so that the distance between each point and each point is optimal. There are many ways to go where. In the 1990s, before deep learning was available, vector supports became most popular at the time because they could solve nonlinear classification problems and predict them very accurately. The vectors supported in the responder are, on the one hand, linear death gas pedals and, to a lesser extent, nonlinear death gas pedals, called linear death gas pedals. The winning one proposes the idea of maximizing the segmented circle to create a better sense of prediction. On the other hand, traditional two-symbol algorithms often stop the iterative algorithm after finding the antidote [18].

The advantage of support vector machine is that it is still valid in high-dimensional spaces and can still be used when the dimensionality of the space is larger than the number of samples. Some feature points cannot be linearly separated in two-dimensional space, but after dimensional augmentation, a hyperplane can be perfectly found to reasonably separate the two types of sample points. Support vector, using basic functions instead of computation, solves the complex computation problem, effectively overcomes the huge local miniature problem, and solves the linear separation problem in low-dimensional space. At the same time, support vector machines are versatile in that they can select different kernels as decision functions and construct different hyperplanes to obtain different classification results, allowing researchers to get the desired classification method according to their requirements [19].

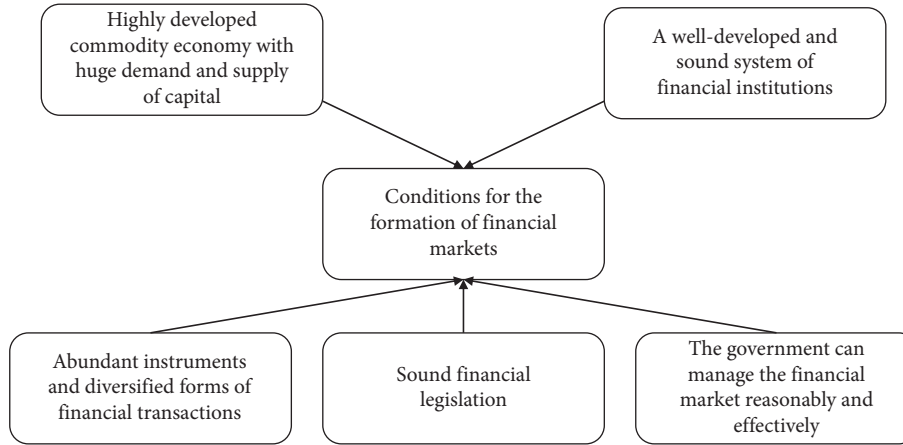


FIGURE 2: Conditions of formation of financial markets.

**3.2.2. Time Series Model.** Time series analysis is a theory and method for computing mathematical models based on time series calculated from an observation system. Usually, curves are combined and parameters (e.g., nonlinear multipliers) are calculated. Time series are often used in national macroeconomic management, integrated planning of regional development, business management of enterprises, forecasting market opportunities, meteorology, hydro-meteorological forecasting and prediction, earthquakes, prevention and control of diseases and predicted skulls, prevention and control of environmental damage, and balance of marine ecosystems [20].

The purpose of the “time-rice” model is, first of all, to objectively describe a system based on the time series transmitted to the observed system. Changes in the time series can be explained if the mechanisms occurring in the time series are understood using the values of more than two variables. Time series are usually interpolated with correlation models that predict the future values of the time series. In a time series, the input variables can be adjusted so that the system development maintains its target values. This means that controls are needed to predict that the process will deviate from the target. This is shown in Figure 3.

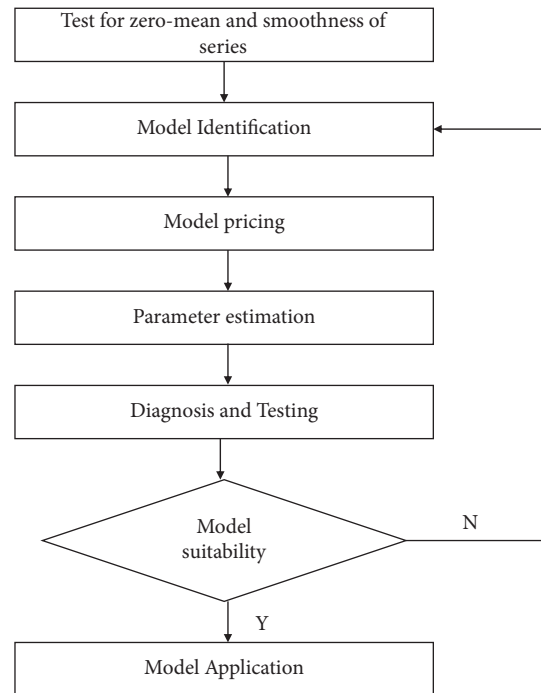


FIGURE 3: Overview diagram of time series model.

**3.2.3. Generalized Regression Neural Network Research Method.** The generalized regression neural network (Radial Basis Function Neural Network, or RBFNN) is a most typical three-layer forward neural network structure, which, in addition to having the information processing of traditional neural networks, uses radial basis functions in its implicit layer for nonlinear mapping of input data, which is then passed to the next layer after linear computation. The structure of the radial basis neural network is shown in Figure 4.

In the unsupervised learning part, the data are clustered by using a clustering algorithm such as K-means to obtain the centroid of the radial basis function in the hidden layer, and then the width vector of the radial basis function is calculated by using the centroid information, and the width vector is calculated by the following formula:

$$\sigma_j = \frac{c_{xy}}{\sqrt{2h}} \quad (1)$$

where  $c_{xy}$  is the maximum distance before the centroid and  $h$  is the number of nodes.

After that, the input data are related to the scattering through the implicit layer and the output layer, respectively, and the output  $x_i$  of the first node  $j$  of the input sample in the implicit layer is calculated by the following equation:

$$\phi(x_i, j) = \exp\left(-\frac{1}{2\sigma_j^2}x_i - c_i\right), \quad (2)$$

where  $c_j$  and  $\sigma_j$  are the centroid and width  $m$  vector of the first node in the hidden layer, respectively.

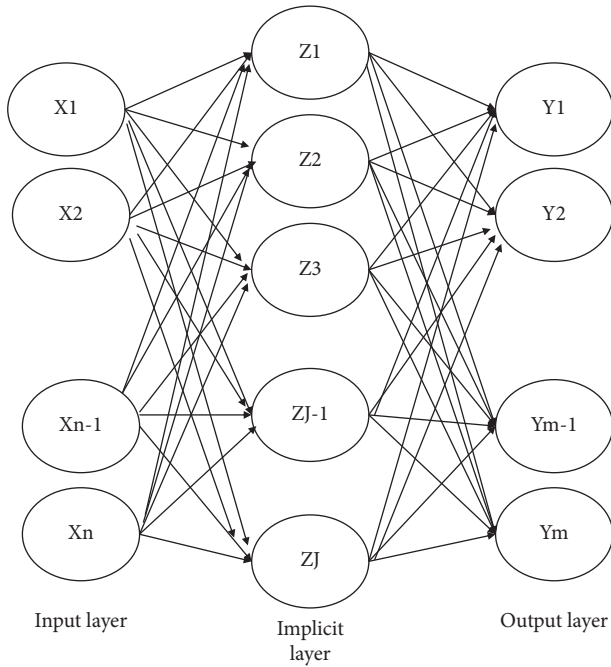


FIGURE 4: Structure of generalized regression neural network.

The output of  $x_i$  the first node of  $j$  the input sample in the output layer is calculated by the following equation:

$$y_m = \varphi(\phi(x_i, j) * w_m), \quad (3)$$

where  $w_m$  is the weight of the  $\varphi$  node and is the activation function.

In the supervised learning part, it is mainly a process of continuous correction of the parameters in each layer, this process is mainly through the error function to calculate the gradient value of each parameter, and then use the traditional gradient descent method such as stochastic gradient descent (SGD) to continuously correct the parameters, taking the output layer for linear calculation of the weights as an example, the update formula is as follows:

$$w_t = w_{t-1} - u * \frac{\sigma E}{\sigma w_{t-1}}, \quad (4)$$

where  $E$  is the error function and  $u$  is the learning rate.

In addition to the above methods, the centroids and width vectors of the hidden layer can be directly generated randomly, after which they are updated according to the gradient correction formula of the supervised learning process.

## 4. Results and Discussion

**4.1. Spatial and Temporal Distribution of Financial Market Development Level in Each Province.** By measuring the level of financial market development in 31 provinces from 2001 to 2020, four representative years are selected to form interprovincial data spanning 20 years to explore the temporal evolution characteristics of the development history of China's financial market. The analysis of the spatial and temporal distribution of the financial market development

level of each province in the representative years (2001, 2007, 2013, and 2020) shows that: in 2001, only three provincial administrative units, Beijing, Shanghai, and Guangdong, had financial market development level values higher than 0.1, and the highest one, Beijing, was only 0.1258; in 2007, except for Shanxi, Jilin, Chongqing, Tibet and in 2007, except for Shanxi, Jilin, Chongqing, Tibet, and Ningxia, the value of financial market development level of other provinces was higher than 0.05, among which the value of Beijing exceeded 0.25; in 2013, the financial market development level higher than 0.15 has reached 5 provinces, among which both Beijing and Guangdong have exceeded 0.25; in 2020, the financial market development level higher than 0.2 reached 12 provinces, and higher than 0.25 reached 7 provinces. All provinces have a financial market development level higher than 0.05. Overall, the development level of China's financial market has been steadily improving over the past 20 years, but there are always differences in the development level among regions, but the developed eastern region is always in a distant lead.

**4.2. Trends in the Evolution of Financial Market Sub-Dimensions.** The equity market shows obvious up and down fluctuations in the development process, and after reaching the highest point in 2016, it has shown a downward trend in recent years; the development level of bond market continues to improve after 2014, but it declined in 2017, recovered in 2018, and reached a new high in 2020; the lending market has been developing rapidly since 2010, and maintains a continuous rapid growth trend. As can be seen, there are various factors that influence the further development of finance, especially national policies and industry norms, and the development of each specific dimension is not entirely consistent.

In Figure 5, "Evolution of the mean value of financial markets in each dimension from 2001 to 2020," the equity market in all regions of China was underdeveloped before 2006, and the role of regional financial markets was relatively low in the traditional economic model based on the real economy, coupled with China's residents'. The overall development of the equity market remained slow due to the limited awareness of the population in China. Entering 2006, the completion of the equity share reform as well as its further deepening, China's stock market entered an unprecedented bull market. At the same time, the first wave of brokerage firms, pension funds and insurance funds poured into the stock market, driving the first step of the stock market up, i.e., the rise in 2006. The entry of foreign capital, the issuance of QFII, a large number of new fund offerings and the follow-up of private savings power in the stock market in the later part of the year led to the emergence of a bull market in China in 2007. Since April 2007, inflationary pressures began to appear in China, and China implemented a policy of double-high reserves and interest rates, further contracting our monetary policy and suppressing the momentum of the stock market's excessive rise, which, together with the lifting of the ban on IPOs in China and the withdrawal of foreign capital, brought the stock market back



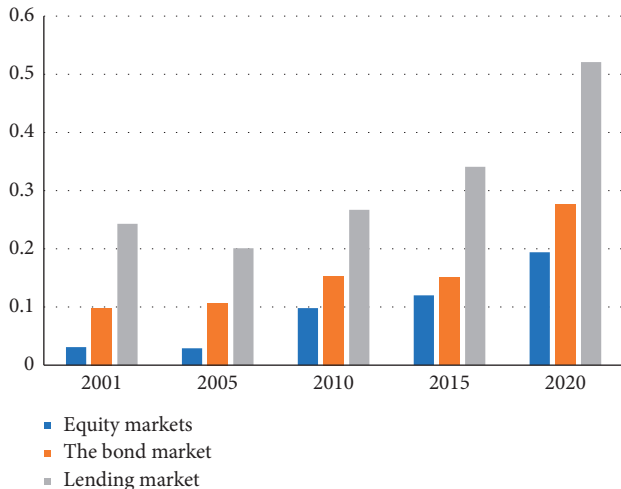


FIGURE 5: Evolution trend of financial market mean in each dimension from 2001 to 2020.

down. However, the major cause of the massive decline in the equity market in 2008 relative to 2007 came from the impact of the international financial crisis, which directly led to the decline in the level of equity market development in various regions of China in 2008. After 2009, China's equity market entered a cyclical fluctuation, driven by two fusion of over-the-counter matching discs in 2015, the rising PE of GEM, high leverage brought about the overvaluation of the equity market, under the strong de-risking of the regulator, the equity market in China was basically stable in the later period as shown in Figure 5.

As for the bond market, the steady development of the bond market was achieved after 2007 by gradually expanding the scale. In 2007, due to the overheating of our economy, there was a greater risk of inflation, which was able to reduce the economic risk of the market to a greater extent. The General Bureau of the State Council in 2009 issued a number of opinions on the current financial to promote economic development. In the process, he clearly proposed to increase the scale and actively expand the debt of enterprises such as bonds and debt financing instruments and good corporate short-term and medium-term paper money. In addition, in 2009, the provincial local governments not only issued bonds, but also promoted the development of the bond market. In addition to the impact of economic fluctuations in the later period, infrastructure construction is an important influence on the level of local bond development. It can be found that the higher the economic level, the better the bond market development, mainly because the government relies only on fiscal revenue to develop urban construction, which is seriously insufficient to meet the needs of rapid development, and can only get financial support by issuing local bonds. The better the economic level of the region, the greater the demand for infrastructure, and the local government needs to issue bonds to better solve the funding gap; while the general economic level of the region, based on the principle that bonds are not higher than the fiscal revenue, it is difficult to issue more bonds. By comparison, it can be found that the bond market tends to

develop to a greater extent in the following year when the equity market is overheated.

The lending market reflects the scale of market capital application. With the acceleration of China's infrastructure construction and real estate industry construction, coupled with industrial support from different regions, and accompanied by the liberalization of China's medium- and long-term loan interest rates in 2005, the lending market in all regions of the country gained rapid development. In 2008, the U.S. subprime mortgage crisis swept the world, the lending business of China's financial institutions was also significantly affected, manifesting as a significant decline in the development level of the lending market; after experiencing the international financial crisis, the lending market in 2009 showed a retaliatory rebound, with a steep increase in the scale of lending, promoting the development level of the lending market in that year; after 2010 to the present decade, the development level of China's lending market has basically been rising year by year, and this rising trend has not weakened, and the lending market still has sufficient vitality.

**4.3. Regional Financial Market Variability Analysis.** This paper measures the regional disparity in the development level of financial markets and its subgroup decomposition disparity from 2001 to 2020 for the national and four major economic regions. The specific measurement results are shown in the detailed analysis below.

**4.3.1. Intra-Regional Gap and Its Evolution.** According to the Dagum Gini coefficient method, the results of the Gini coefficient measurement of the level of financial market development of China's national and four major economic regions from 2001 to 2020 are shown in Figure 6.

The Gini coefficient of the national financial market development level: First, the Gini coefficient of the national financial market development level in China always remains high and is basically higher than that of the four major economic regions in China, with values ranging from 0.1762 to 0.2811. This indicates that, compared with the four economic regions, the financial market development level among the 31 provinces in China is more different, and the development of the national financial market is more unbalanced. Second, the Gini coefficient of China's national financial market development level shows a fluctuating change of "rising, then falling, then rising," and has been increasing since 2005. This indicates that although China's financial market is developing in general, the difference in the level of financial market development among the 31 provinces in China is also widening, and the development of the national financial market shows a significant imbalance.

The Gini coefficient of financial market development level in China's four major economic regions is seen: First, the Gini coefficient values of financial market development level in China's four major economic regions are mainly expressed as Eastern region > Western region > Northeastern region > Central region. It can be seen that, in the process of China's financial market development,

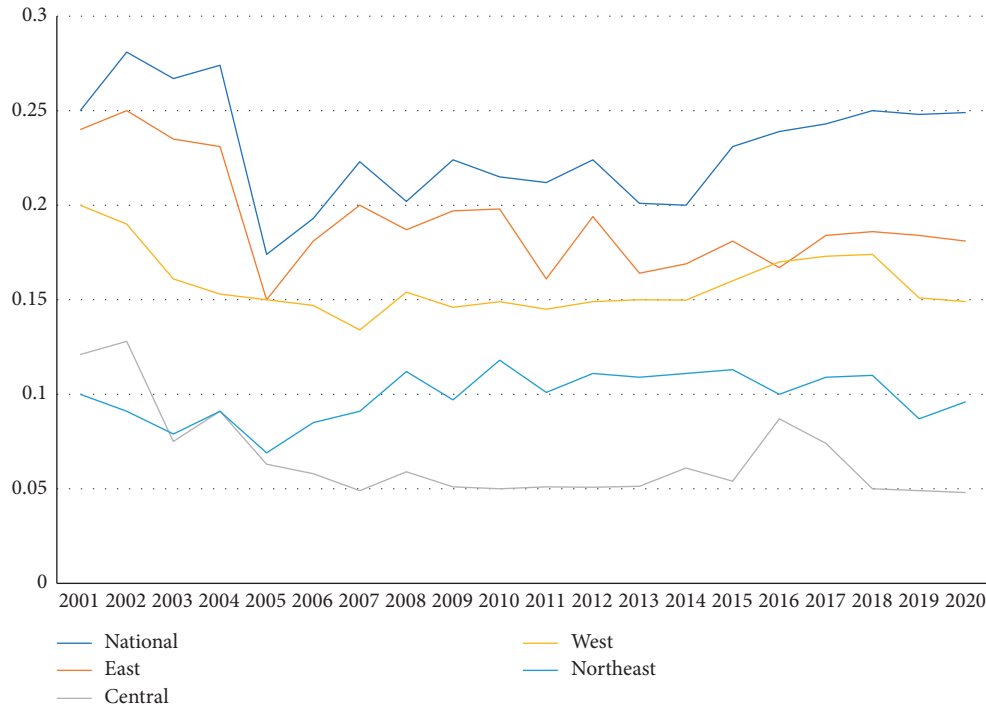


FIGURE 6: Gini coefficient of financial market development level of national and four major economic regions.

although the development level of the eastern region has always maintained a leading position, but the difference in the level of financial market development among its internal provinces is also relatively greater, and the problem of financial market development imbalance is also relatively more prominent. Second, the Gini coefficients of financial market development levels in China's four major economic regions show different trends of evolution. The magnitude of the volatility of the Gini coefficient of financial market development level in each region (the difference between the maximum and minimum values of each economic region during this period) is in the order of Eastern region (0.1043) > Central region (0.0787) > Western region (0.0756) > Northeast region (0.0527). Specifically, the Gini coefficient of the development level of the financial market in the east shows a fluctuating upward and downward trend, the Gini coefficient of the development level of the financial market in the central region shows a fluctuating and continuous downward trend, the Gini coefficient of the development level of the financial market in the western region shows a trend of first decreasing and then slowly increasing and then decreasing, and the Gini coefficient of the development level of the financial market in the northeast region remains basically unchanged in a small fluctuation.

In the process of continuous development of China's financial market, although the financial markets in different regions have achieved greater development, the financial market development gap between provinces within each region shows different evolutionary trends. In general, the differences in financial market development levels among provinces in the eastern, central, and western regions show a trend of significant decline, then a slight increase, and finally

a gradual decrease, while the gap in financial market development levels in the northeast region has always been the smallest among the four major economic sectors, with little change over the past 20 years. Although the central region started its economic development late, it has developed quickly and effectively in the last decade, with a high degree of industrialization and a steadily increasing level of financial market development. The eastern region, on the other hand, is in the center of China's financial market development and has more provinces, which results in a large value of provinces with a high level of financial market development, while provinces with a low level of financial market development have a more sluggish financial market development, and the polarization phenomenon is most obvious in this region.

4.3.2. Inter-Regional Disparity and Its Evolution.

According to the Dagum Gini coefficient method, the results of the Gini coefficient measurement of the financial market development level among the four major economic regions in China from 2001 to 2020 are shown in Figure 7.

It can be seen that, firstly, the numerical importance of the inter-regional Gini coefficient indicates that there are obvious differences in the level of financial market development between regions. East and West > East, Northeast > East, Central > Central, West > West, Northeast > Central, and Northeast average Gini coefficient during the continental period. Secondly, between regions, the change in the Gini coefficient can be divided into two phases: the first phase, from 2001 to 2005, showed a downward trend upward, then downward, and then a large change in all regions,

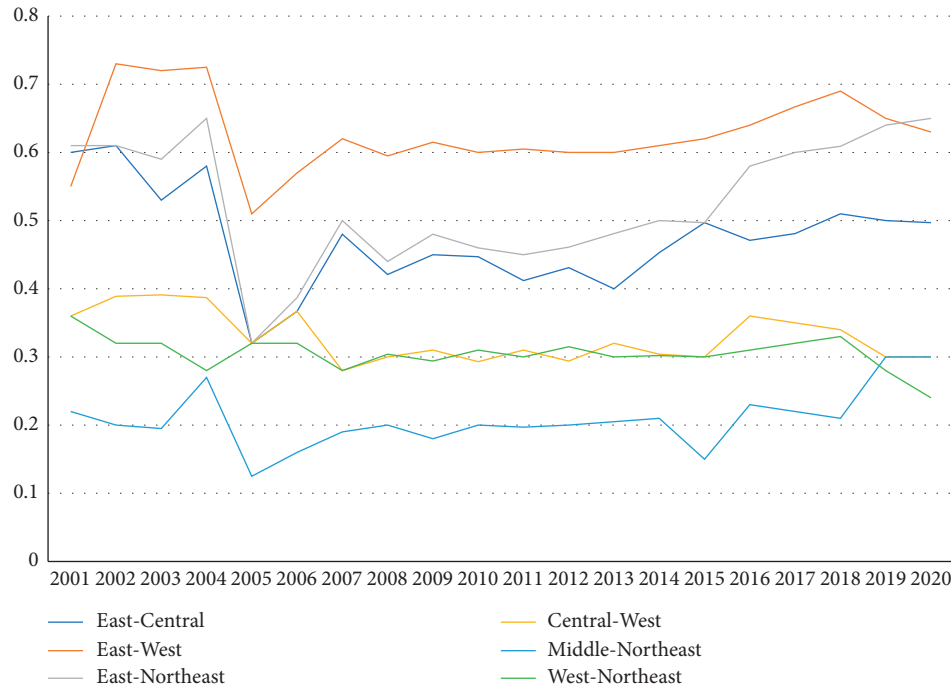


FIGURE 7: Inter-regional Gini coefficient of the level of financial market development in China's four major regions.

which indicates that most inter-regional disparities have clearly fluctuated; the second period (2006–2020) is characterized by a relatively stable, albeit slightly different, development of the regions during this period. The Gini coefficients of East and Central, East and West, and East and Northeast fluctuate gradually, while those of Central and West, Central and Northeast, and West and Northeast fluctuate from top to bottom and have a smaller range, and have basically not changed much in the past 15 years.

There is a big gap between the development level of the financial market in the East and that in the West, Central, and Northeast, which is much higher than that in the other three regions. From 2001 to 2005, the Gini coefficient between the east and the west changed a lot, increasing from 0.4389 to 0.7323, and was at its highest value in 2002; it ranged from 0.5228 to 0.6838 from 2005 to 2020, and reached its maximum value in 2018. The Gini coefficient between the eastern region and the northeastern region also changed dramatically between 2001 and 2005, between 0.3218 and 0.6488, and showed a significant upward trend from 2006 to 2020, indicating that the level of financial market development in the eastern region has gradually widened with that of the northeastern region in the past 15 years. Compared with the other two regions, the difference in the level of financial market development between the central region and the eastern region is not large, and although there is an upward trend in the past 15 years, the magnitude is relatively slow, so although there is a gap in the development of the financial market between the two regions, it is not an insurmountable distance. The trend of changes between East and West, East and Central, and East and Northeast is very consistent, which is highly correlated with the rapid development of financial markets in the East

and the relatively close development rate of financial markets in Central, West, and Northeast. Except for the obvious regional differences between the East and the other three regions, the other three regions are not as different from each other. Between the central region and the western region, the maximum value of the difference between 2001 and 2020 is 0.4191, and the minimum value is 0.2688, with a relatively stable change in the difference in general; between the western region and the northeastern region, except for the up and down trend of the difference between the two before 2009, the difference between the two in 2009 and after is almost on a horizontal line, and the difference between the regions for many consecutive years is kept. The difference between the central region and the northeastern region is the smallest, at 0.2261 in 2001 and 0.2935 in 2020, with a mere change of 0.0674 in the past two decades. The financial market is also actively approaching and learning from the eastern region, while the gap between the central region and the northeastern region is also gradually widening because the northeastern region has been experiencing a continuous economic downturn in recent years and the development of the regional financial market is also significantly lagging behind.

*4.4. Analysis of the Convergence of Financial Market Development.* The evolution of temporal stages and the evolution of spatial forms are the two most significant aspects of financial market development. The change of regional spatial pattern is an important measure of the evolution of regional differences, and the factors affecting the evolution of regional differences show different characteristics in different periods. In order to explain the level of



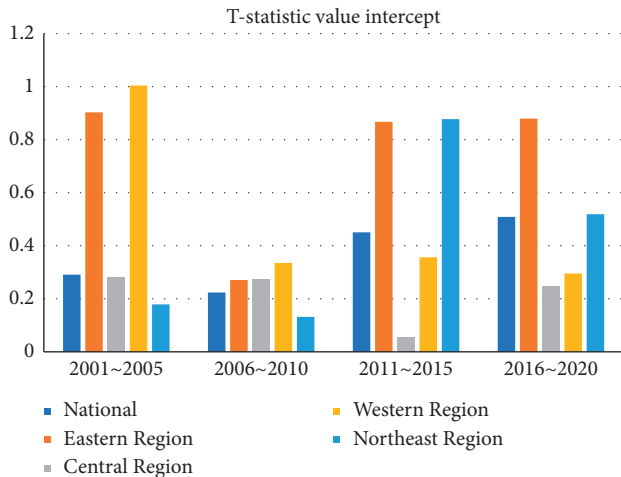


FIGURE 8: Convergent measurement results.

development of our financial markets from a convergent temporal perspective, taking into account the geographical factors that influence the level of development of financial markets in different provinces, as well as the reduced impact due to the heterogeneity of the results, we will try to introduce a matrix of distances spatial geographical latitude and longitude of the spatio-temporal model fusing the measurements of the relevant indicators and the level of development of each Chinese financial market. The relevant parameters were also studied. The study period is divided into four phases: 2001–2005, 2006–2010, 2011–2015, and 2016–2020, with convergence measures as shown in Figure 8.

## 5. Conclusion

Looking at the level of financial market development in China from an overall perspective, it is found that the spatio-temporal correlation convergence feature is obvious and the development of financial market is also in the convergence stage during the period under examination. That is, the correlation coefficient estimates for each period greater than zero show that the less developed regions are catching up with the developed regions. In other words, the level of development of financial markets in each region (i.e., the central region) is growing slower, and the regions with a lower level of development of financial markets (i.e., the periphery), and therefore the level of development of financial markets, is gradually decreasing over time. The correlation of the convergence speed coefficients shows that the speed of convergence first decreases and then increases in the considered time period. Among them, the maximum convergence rate has peaked according to the relevant parameter estimates for the period from 2016 to 2020, which indicates that, since the economy entered the new normal, a series of policies and measures such as the comprehensive deepening of economic system reform, strategic adjustment of the economic structure, and the promotion of coordinated regional development have been implemented with significant effects, and the rate of convergence of the level of

development of China's financial markets has increased significantly.

From a partial perspective, the degree of convergence and the speed of convergence of development levels in different regions are obviously different. As with the country as a whole, the eastern region showed convergence during the period under review, with the correlation coefficient of the level of financial market development estimated to be greater than zero for the four periods, with a “V” shaped trend. By looking at the convergence rate, it is found that the eastern region is higher than the national region for the period 2001–2015. This also implies that the eastern region caught up faster than the national level and experienced strong economic development during this period. This is because the eastern direction of economic policy gives it the advantage of gradually establishing an integrated coastal economic zone, which will concentrate the central force of economic development and accelerate the process of regional integration; from 2016 to 2020, China's economy has entered a new normal. The eastern region also shows a convergence trend, and its convergence rate is much lower than the national level. This suggests an urgent need to improve the dynamics of economic development with the decaying effect of the marginal pull on the higher level of development of financial markets in the eastern region and with the slowing down of financial markets in the regions with lower levels of development to catch up.

Similar to the eastern region, in all four periods, the financial market development level in the central region also converged, but the rate of convergence is much higher than the national average and the other three regions. The economic pull effect of the higher level of financial market development in the region is obvious. The reason for this phenomenon is that after the implementation of the Central Rising Strategy, the central region has given full play to its latecomer advantage and fully learned from the experience of developed regions, so that the financial markets in its relatively lagging regions can develop in a coordinated and rapid manner, gradually narrowing the gap with the regions with higher levels of financial market development.

In contrast, the situation in the western region is completely different from the first two regions, with a continuous trend of convergence and differentiation in the level of financial market development. Its level of development converged significantly between 2001 and 2005, diverged between 2006 and 2010, and then converged again, but at a slower pace. This convergence increased significantly after the economy entered the new normal. The main reason for the two convergence states before and after maybe the western development strategy in the early stage and the formation of the comprehensive economic zone of the Great Southwest and Great Northwest in the latter stage, which led to the rising proportion of investment in the western region and the increasing degree of opening to the outside world, thus driving the rapid development of the regional economy and deepening the degree of coordinated regional development, as well as making the less developed regions in the western region continuously converge with the developed

regions in terms of the level of financial market development, forming a radiation effect.

The level of financial market development in the Northeast region first shows a slight convergence feature from 2001 to 2005 and then shows an obvious divergence from 2006 to 2015 and then convergence feature from 2016 to 2020. The first convergence is in line with the economic development level of the Northeast region, i.e., the Northeast region implements the revitalization strategy and presents a catch-up state from the less developed regions to the developed regions, while the economic development in the eastern region slows down at this time and the economic gap narrows, and the difference in the regional financial market development level is slightly reduced again by this influence. The divergence of financial markets in the Northeast region was particularly obvious during the period from 2006 to 2010, which led to a significant reduction in the degree of convergence in the development of the country's financial markets during this period. With the implementation of the Northeast revitalization strategy, the continuous optimization of the economic structure and the acceleration of the modernization of industrial transformation contributed to the development of the Northeast economy. In recent years, the economic downturn in the Northeast is evident, and the level of financial market development, which also presents a small downward trend within it, reflected in the "measured regression," is the different characteristics of the financial market development in the Northeast, replacing the convergence from 2016 to 2020.

## Data Availability

The dataset can be accessed upon request.

## Conflicts of Interest

The authors declare no conflicts of interest.

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