Research Article

Correlation Analysis between Financial Development Level and City Size Based on Mutual Information Algorithm

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Urbanization is the accompaniment of industrialization and modernization, a symbol of the progress of human civilization, and it has always been the focus of social attention. With the transfer of rural population to cities, the secondary and tertiary industries continue to produce agglomeration effects, and the urbanization process is accelerated. The level of urbanization has gradually become an important indicator to measure the degree of regional development, which has led to the exploration of the inner dynamics of urbanization. Finance is the core of modern economy, and urbanization is an important driving force for modern economic and social development. Research on the relationship between financial development and urban scale should also receive widespread attention. On the basis of reviewing and sorting out the related research results of urbanization and financial development, this paper makes an in-depth analysis of urbanization and financial development, respectively, aiming to have a systematic, comprehensive, and objective analysis of the interaction between urbanization and financial development. On this basis, combined with the current situation of our country's financial development and urbanization, the internal relationship between the two is discussed. Based on the mutual information algorithm, this paper selects indicators that are representative of urbanization level, financial development, and economic development. By using the mutual information theory to analyze and rank the social and economic factors related to financial factors, it reveals the most relevant and accurate financial forecast. Then, it also discusses whether there is a cointegration relationship between urbanization and financial development and economic growth in our country and the causal relationship between them and analyzes the reasons on this basis.

1. Introduction

In the process of human civilization development and economic growth (see Figure 1), urbanization has played a very important role in promoting it. Urbanization contains people's longing and yearning for a better life and has always been widely concerned by scholars from all walks of life. Since the beginning of the twenty-first century, the process of urbanization around the world has developed vigorously. In cities that only occupy less than 1% of the Earth's area, the population has reached 50% of the world's total population. According to the statistics of the United Nations, about 3.5 billion people in the world already lived in cities before 2000 and enjoyed the fruits of urban civilization. The urbanization level of developed countries has basically reached a mature stage, and the urbanization rate of some countries has even exceeded 80%. With the continuous development of society, the urbanization rate index of a city is playing a pivotal role in economic and social development. The level of urbanization development has become one of the important symbols to measure the economic development of a country or region and whether people's living standards have improved. Urbanization is an overview of the process of urban development [1, 2]. Urbanization is actually a process of social development and an accompanying phenomenon of the Industrial Revolution. Generally, it refers to the increase in the number of cities and towns and the expansion of the scale of cities and towns in the geographical space caused by the development of social productive forces in the process of industrialization and the transfer and agglomeration of rural population to cities and towns.

FIGURE 1: Correlation between financial development level and city size.

With the deepening of reform and opening up, while China's economy continues to grow and its society is prosperous and stable, China's urbanization process has also made great progress. The pace of urbanization has been accelerating and the development momentum is good, providing China's economic growth, strong guarantee. However, due to the large population base in China, the level of urbanization in China is still relatively low from a global perspective. Therefore, in the future, the process of urbanization in China will continue and will continue. As the core of modern economy, finance has played a major role in promoting economic growth. In terms of promoting urbanization, the role of financial development cannot be ignored. The financial industry uses its own advantages to adjust infrastructure and economic structure and other aspects of support to promote the development of urbanization. The use of finance, the direction of credit, and the rural credit market may have a great impact on the development of urbanization. The urban economy occupies a dominant position in the national economy and becomes the main position for the advancement of society, as well as a process of continuous development in which the economic relations and lifestyles of the cities are widely penetrated into the countryside.

Nowadays, all aspects of society have paid great attention to the impact of urbanization and financial development. So now researchers and urban workers are faced with an urgent issue of how to do better and faster to promote the process of urbanization [3, 4]. For the subject of urbanization process, many scholars have carried out research from the perspective of industrialization process, agricultural population transfer, contribution of the tertiary industry, and so on. But an indispensable link in the process of urbanization, finance, has not received enough attention. In the process of urbanization, it is far from enough to rely on the state financial support, bank loans, and land transfer to obtain funds for construction. It is necessary to use various financial markets and tools for efficient resource allocation to achieve the purpose of promoting urbanization [5, 6].

As an important driving force of urbanization, finance has attracted more and more attention for its special functions in integrating regional resource advantages and optimizing the distribution of production factors [7, 8]. The construction and development of urban public facilities have obvious stages, especially our country is at the peak of urbanization development, the scale of cities is expanding rapidly, and urban residents have an urgent need for urban public facilities. The managers of various cities mainly rely on financial investment, land transfer, bank loans, and other channels to raise funds for the construction of urban public facilities. Due to the huge investment and long cycle of urban public facilities, it is far from enough to rely solely on bank loans and land transfers [9, 10]. Therefore, international experience must be learned to broaden the financing channels for urban public facilities projects.

To sum up, in the existing literature, there is much related literature on financial development and urbanization. However, there is less literature focusing on China's financial development to promote the level of urbanization in prefecture-level cities, and the selected financial indicators are compared with each other [11, 12]. There are few studies on the mechanism of financial development affecting the urbanization process at the same time. Based on the existing literature, this paper strives to comprehensively and objectively present the impact and mechanism of prefecture-level city financial development on urbanization and then study the correlation analysis between financial development level and city size based on mutual information algorithm [13, 14].

2. Mutual Information Algorithm

In the process of building a complex network, there are two key steps that affect the entire network structure: one is the selection of network nodes. This paper focuses on network modeling based on financial data through the understanding and application of complex network concepts [15, 16]. The influence relationship between financial development and city size is complex, showing the characteristics of an obvious network system. At the same time, there are various reasons that affect the relationship between financial development and city size, such as the impact of volatility, the spread of emergencies, and the mutual constraints of competition and synergy [17, 18]. These reasons make the

modeling of the correlation characteristics between network nodes much more difficult, and some basic linear correlation analysis methods such as principal component analysis or covariance matrix have been unable to accurately quantify the relationship between complex network nodes. In order to meet the actual needs and to better describe the relationship between network and nodes, this paper uses mutual information entropy as a method to describe the relationship [19, 20].

Entropy originally originated from the concept of thermodynamics, which measures the degree of disorder of the system and is a quantitative measure of the disorder of molecular thermal motion in the system [21, 22]. This disorder can be characterized by the total number of microstates Ω corresponding to a certain macrostate. The more the microstates a system has, the greater the degree of chaos, and the greater the entropy value. The second law of thermodynamics is also known as the law of increasing entropy. In the natural state, entropy can only increase, not decrease. Therefore, the entropy value of the whole society is constantly increasing [23, 24].

Shannon introduced entropy value into the field of information theory and formed information entropy. In information theory, information is composed of a source, a channel, and a sink. The message is generated from the source, encoded in a certain way, and transmitted through the channel, and the sink compiles the received message. Thus, the message is known to the sender, but not to the entire communication system and to the recipient [25–27]. The amount of information is a measure of the size of the message. If the amount of information of the message is obtained, the uncertainty of the message is relieved. Shannon defines the average amount of information of a source as information entropy, which is based on the probability distribution of the occurrence of samples. He transforms the probability distribution of random events into a representation of information, indicating the amount of self-information contained in an event.

In information theory, mutual information entropy is a useful measure of information that refers to the degree of correlation between two sets of events. The measurement of mutual information entropy needs to consider the entropy value of the joint information stripped in the case of the sum of the two event entropy values, which is expressed in the form shown in Figure 2.

The concept of mutual information (represented by T) comes from information theory, which represents the uncertainty about another symbol set that is eliminated after receiving one symbol set, and is a measure of the statistical correlation of random variables. Using mutual information theory to analyze and sort socioeconomic factors related to financial factors can reveal the factors most relevant to accurate financial forecasting. Therefore, it can accurately eliminate factors that contribute less to economic forecasting and thereby reducing the complexity of modeling with economic forecasting and improving the prediction accuracy.

Shannon defines entropy (entropy: average amount of information) in information theory as the probability of occurrence of discrete random events. The greater the

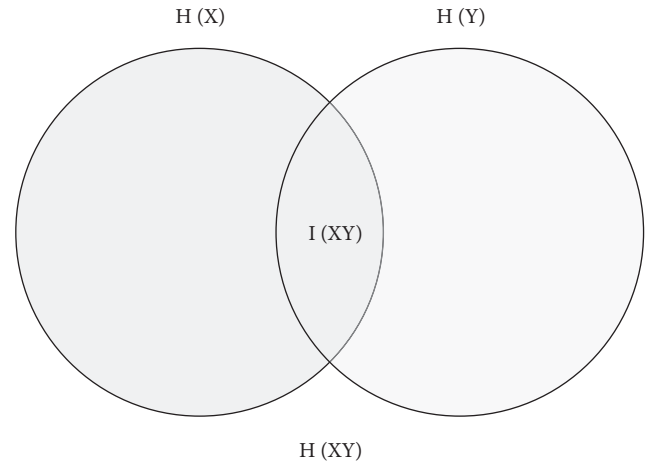$$H(X) \qquad H(Y)$$

$$I(XY)$$

$$H(XY)$$

Figure 2: Information entropy diagram.

uncertainty of the event, the greater the entropy. The more orderly a system is, the lower the entropy is. The information entropy of different industries is shown in Figure 3. In the case of one variable, entropy is calculated as

$$H = -\sum_{j} P_j \log_2 P_j, \qquad (1)$$

where H represents the entropy, that is, the average value of the amount of information, and P_j is the probability of the jth information appearing. Correspondingly, the entropy of a two-dimensional distributed dataset can be expressed as

$$H_{ij} = -\sum_{i} \sum_{j} P_{ij} \log_2 P_{ij}, \qquad (2)$$

where P_{ij} is the joint probability distribution of events i and j, and the two-dimensional mutual information can be expressed as

$$T_{ij} = H_i + H_j - H_{ij}. \qquad (3)$$

If the two variables are completely independent, the value of T_{ij} is 0; otherwise T_{ij} is positive. We use u, i, and g to represent the number of papers published by Chinese universities, Chinese companies, and the Chinese government, respectively, and the three-dimensional mutual information is expressed as follows:

$$T_{uig} = H_u + H_i + H_g - H_{ui} - H_{ug} - H_{ig} + H_{uig}. \qquad (4)$$

It is noted that the uncertainty of the measurable variable is determined by the mutual information T, so the mutual information is used as a dynamic index to measure the degree of closeness between subjects. The larger value of two-dimensional mutual information such as T_{ui} indicates the cooperation between universities and enterprises. The three-dimensional mutual information is a measure of the self-organization of the system, and it is negatively correlated to explain the self-organization of the relationship network due to the lack of central coordination. When the value of T_{uig} is negative, it indicates that the three-dimensional relationship has played a self-organizing role in the system though it consists of the closer partnership.
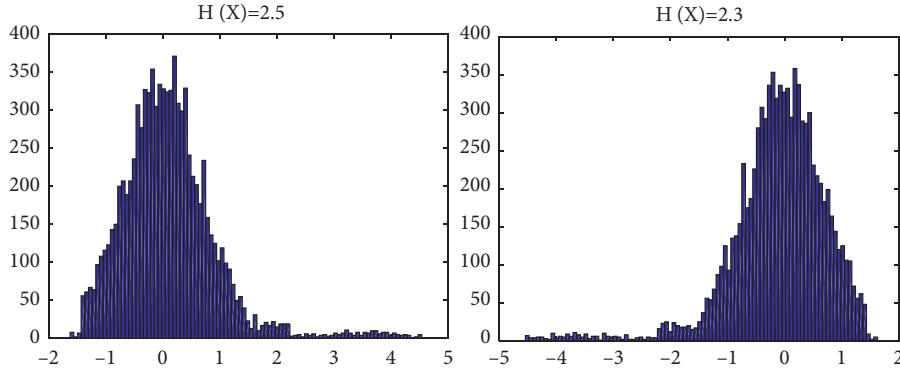
FIGURE 3: Information entropy of different industries.

In the process of identifying and screening factors related to financial development level and city size, each financial data series is used as an explanatory variable X, namely:

$$X = [x_1, x_2, \ldots, x_n]. \tag{5}$$

Each potential correlation factor data series is used as the condition variable Y, namely:

$$Y = [y_1, y_2, \ldots, y_m] \tag{6}$$

The magnitude of mutual information between Y and X reflects the degree of association between potential association factors and city size. In order to make each condition variable and explanatory variable more statistically significant, it is necessary to discretize each variable in the variable domain, that is, to convert the numerical sequence of each variable into a probability distribution interval. The joint entropy of two industries is shown in Figure 4. After discretization, the mutual information between the explanatory variable X and the condition variable Y can be obtained by

$$I(X, Y) = -\sum_{i=1}^{N_i} \left[\frac{M_i}{M} \log \frac{M_i}{M} \right]$$
$$\qquad - \left\{ -\sum_{u=1}^{N_j} P(y_u) \left[\sum_{v=1}^{N_i} \frac{M_{uv}}{M} \log \frac{M_{uv}}{M} \right] \right\}. \tag{7}$$

In the formula: M is the sum of all values of the explanatory variable X and the condition variable Y; N_i is the number of intervals of the explanatory variable X; M_i is the number of values of the explanatory variable X in the ith interval; N_j is the condition variable; Y $P(yu)$ is the probability that the condition variable Y falls in the uth interval; Mu_v is the number of values that the explanatory variable X falls into the v th interval when the condition variable Y falls in the uth interval.

Suppose that there are p financial data sequences constituting the dataset:

$$X_D = [x_1, x_2, \ldots, x_p]. \tag{8}$$

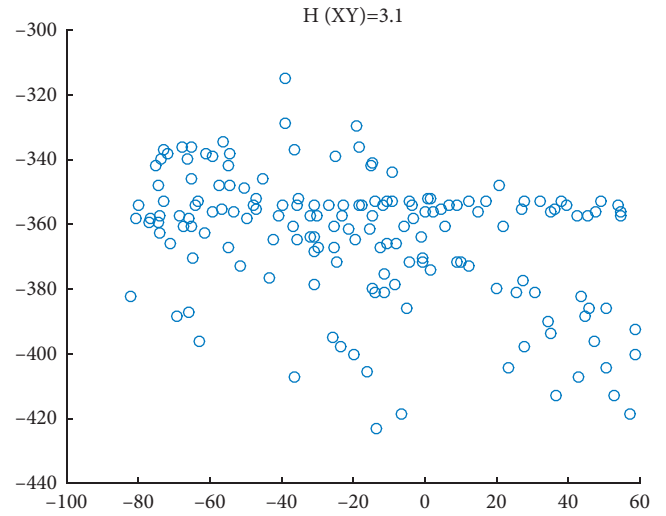The data sequences of l potential associated factors constitute the dataset:

FIGURE 4: Joint entropy of two industries.

$$Y_D = [y_1, y_2, \ldots, y_l] \tag{9}$$

The mutual information between financial development level and urban development can be expressed as

$$I_k = \begin{bmatrix} I(X_1, Y_1) \ldots I(X_1, Y_j) \ldots I(X_1, Y_l) \\ \ldots \\ I(X_i, Y_1) \ldots I(X_i, Y_j) \ldots I(X_i, Y_l) \\ \ldots \\ I(X_p, Y_1) \ldots I(X_p, Y_j) \ldots I(X_p, Y_l) \end{bmatrix}, \tag{10}$$

where

$$X_i \in X_D, Y_j \in Y_D. \tag{11}$$

The average value of mutual information between Y_j and $X_1, X_2, \ldots, X_p$, that is, the average mutual information, can be expressed as

$$\overline{I(X, Y_j)} = \frac{1}{p} \sum_{i=1}^{p} I(X_i, Y_j), \quad j = 1, \ldots, l. \tag{12}$$

For urban development indicators, the average mutual information can be used to evaluate the strength of the

correlation between the potential correlation factor Y_j and financial development: the greater the average mutual information, the stronger the correlation between the two. Sort the related factors whose average mutual information is greater than 0 to form a list of related factors, and select the top strong related factors in the list.

3. Relationship between Financial Development Level and City Scale

Urbanization and financial development are both important factors that promote a country's economic development. There is a subtle relationship between the improvement of urbanization level, the deepening of financial development, and the rapid development of economy. Urbanization and financial development affect the impact of economic development, and economic development plays an important role in the process of financial development and urbanization. Urbanization is the premise of financial existence and development, and financial development can promote the process of urbanization. As the core force of modern urban development, finance is the manifestation of urban economic value movement. With the development of urban economy, finance also deepens; in turn, the continuous deepening of finance plays an indispensable role in regulating the economic development of a city. All in all, there is a relationship between financial development and urbanization, and both are a dynamic and related process.

3.1. Financial Development Helps to Expand the Scale of Cities. The linkage between financial development and urbanization process is fully reflected in the development of financial theory. With the agglomeration of population and the development of social productivity, the number of cities continues to increase, and at the same time, the scale of cities under construction has also continued to expand. The rural population was liberated from the land and concentrated in the cities. The regional economic growth mode has changed from the economic growth mode, which is mainly based on the primary industry (agriculture) to the secondary and tertiary industries. Finally, the tertiary industry plays a pivotal role in the economic structure. These processes show the evolution of the nature and morphology of the territory both spatially and structurally. Intuitively, the population gathers in cities, and the increase of urban population is the most significant sign reflecting the degree of urbanization.

3.2. Financial Development Is Conducive to the Adjustment of Urban Industrial Structure. Through the asset-return evaluation of the assets of various industrial sectors and regions, the capital market plays a role in inducing the flow of capital (assets) from sunset to sunrise industries, from sectors with low competitiveness to sectors with high competitiveness, and from disadvantaged areas. The role of concentration in advantageous areas: As a result, the city's industrial sectors and regional structures have been continuously rationalized and advanced. At the same time, existing cities have accelerated their own development pace in the adjustment of industrial structure, and in the process, many new cities supported by industries have appeared, and the process of urbanization has been further promoted.

3.3. Financial Development Is Conducive to Improving the Efficiency of Capital Allocation. An important function of the financial system is to allocate capital to projects with the highest marginal efficiency of capital. With the improvement of urbanization, the role of cities in social and economic development will continue to increase. Therefore, in general, the degree of urbanization is also an important indicator of the degree of economic development of a country. The process of converting savings into investment by the financial system, on the one hand, obtains corresponding remuneration for the owners of idle funds (residents) and, on the other hand, provides the capital demanders (enterprises or urban public construction) with urgently needed funds for production and operation, which is helpful. In order to promote the development of enterprises and the completeness of urban public facilities, they also received corresponding remuneration for their own financial services. Its existence can effectively collect and utilize social idle funds. Before the emergence of financial institutions, the storage method of idle funds is usually hoarding at home, and owners of idle funds often face two major problems: one is the danger of theft, loss, and natural damage of the hoarded funds; the second is the possibility of depreciation of the hoarded funds. The emergence of financial institutions can provide owners of idle funds with a safe place to store funds. Not only does it avoid the risk of theft, loss, and natural damage for owners of idle funds, but also the rewards offset some of the effects of inflation. Therefore, the financial system gathers idle funds in the society, reduces the burden for the owners of idle funds, brings convenience for capital turnover, and improves their income level.

3.4. Population Agglomeration under the Effect of Urban Agglomeration. With the continuous deepening of urbanization, the secondary and tertiary industries have been vigorously developed, and the labor force entering the secondary and tertiary industries has also continued to increase, which has promoted the spatial migration of the population from the countryside to the city, making the number of urban population grow rapidly. It is in this population effect that the urban life of residents is also affected. First of all, the income level of the rural surplus labor force entering the city has been greatly improved compared with before. Therefore, the part of the income used for consumption has also increased, which will inevitably promote the income growth of other people in the city. The "consumption" ~ income effect affects the increase in people's demand for consumption. Hence, the increase in people's demand for financial services and money stimulates the development or growth of the financial industry. Secondly, with the population expansion brought by urbanization, it is bound to increase the demand for infrastructure construction and investment in urban public service facilities. The funds required for urban construction, public

transport coverage construction, and public service facilities construction are only a small part of the government's own investment. However, most of the remaining funds are still needed. In fact, the financing from financial institutions can ensure the smooth implementation of the project. Therefore, the improvement of the financial industry provides a strong guarantee for the funds required for the construction of urban infrastructure and public service facilities. Thirdly, the increase of the urban population scale is limited, and urban housing prices have always been high. Moreover, the real estate industry is an industry with large capital demands. Therefore, both real estate companies and residents are dependent on the development of the financial industry. To a certain extent, it has promoted the continuous deepening and development of finance.

3.5. The Impact of Urban Diffusion Benefits on Financial Development. The function of urban agglomeration is for diffusion. If it is only for agglomeration, without diffusion, such agglomeration cannot be sustained. In order to avoid the dual structure of urban and rural areas and coordinate the development of urban and rural areas at the same time, cities must drive the development of surrounding areas on the basis of their own development. It can be seen that accumulation is only a means, and diffusion is the real purpose. When the agglomeration of production factors, industries, and population reaches a certain scale and exceeds the requirements of economies of scale, urbanization will enter the diffusion stage. At this time, the promotion of financial development by the diffusion effect of cities is mainly reflected in the following: first, the transfer or expansion of production factors and industries to surrounding areas and the allocation and utilization of production factors are carried out on a larger scale, and the structure of the financial industry is further improved, with tweaks and upgrades. Second, to build an economic cooperation system with a larger space, banks and other financial institutions face a wider market, and the development scope of the financial industry expands. The x and y variation are shown in Figure 5, which means y varies from 0 to 3.8 while x increases from 1 to 4.

4. Empirical Research

In addition to the level of financial development, there are many factors that affect the level of urbanization. From the above analysis, we can know that the level of economic growth is an important factor affecting the level of urbanization. There are many indicators to measure the level of economic growth. Per capita GDP figures are less likely to be in error than gross GDP figures, because some errors that affect estimates of GDP levels also affect estimates of population, so errors are offset. This paper collects a total of 23 indicators from 283 prefecture-level cities between 2003 and 2015, including the explained variables, explanatory variables, the lagged terms of the explained variables, the squared terms of the explanatory variables, and the panel data of the control variables. The data sample capacity has a
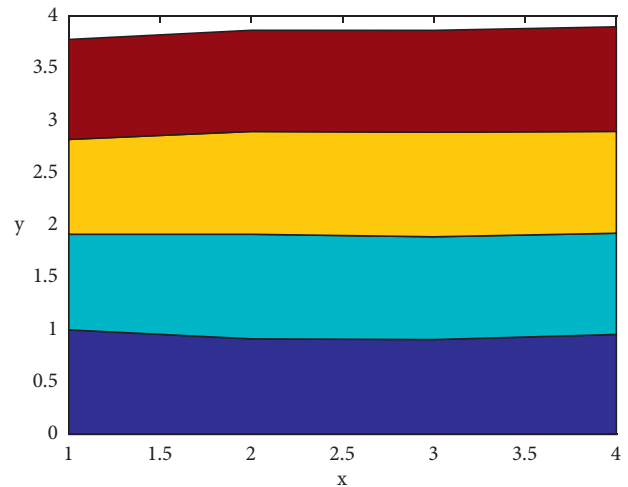

FIGURE 5: x and y variation.

total of 84617 valid values. The selection of sample cities and their indicators is mainly based on consideration of differences in the level of financial development and urbanization rate and the availability of data. All data come from the National Bureau of Statistics-China Urban Statistical Yearbook and the Wind database. What this paper wants to study is the mutual influence between the degree of financial development, the level of economic growth, and the change of industrial structure on the growth rate of urbanization. The correlation is shown in Figure 6.

It can be seen that there is at least one cointegration relationship between the three indicators measuring financial development and the population urbanization rate. That is to say, the scale expansion, structural adjustment, efficiency improvement of financial development, and any combination of them all have a long-term and stable relationship with urbanization development. More specifically, when considering the impact of scale expansion, structural adjustment, and efficiency improvement on urbanization development separately, we can see that the coefficients of all aspects of financial development are negative, indicating that they are all positively related to urbanization development in the long run, and after combining them, some of the coefficients are positive. After simply adding up their coefficients, it is found that the overall coefficient is still negative; that is, there is a long-term positive correlation between financial development and urbanization. A possible reason for this is that multicollinearity between them makes the sign wrong. In addition, the number indicates that scale expansion financial development (FD), structural adjustment financial system (FS), and urbanization development are generally positively correlated. In particular, the scale expansion coefficients after the reform and opening up all of them were negative, and some were positive before the reform and opening up, which shows that the expansion of financial scale after the reform is opening up and promotes the urbanization process. The structural adjustment is negative in the whole range, which means that since our country began to issue foreign debts in 1979, the financial restructuring from indirect financing to direct financing is
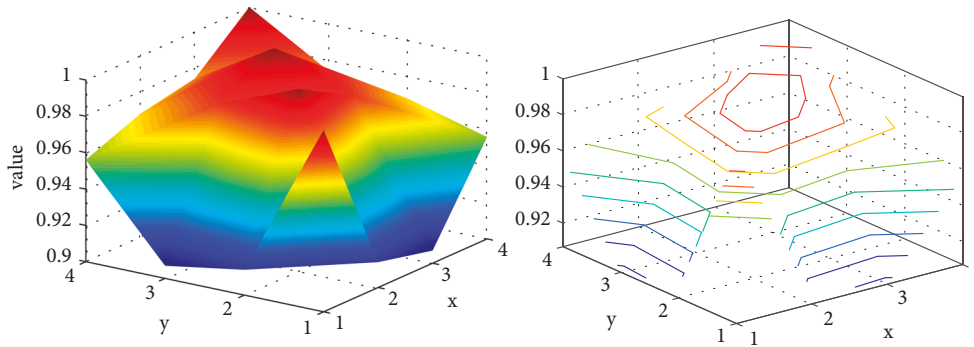
Figure 6: Correlation of the prediction.

the driving factor for the urbanization process. It cannot conclude that the capital allocation efficiency FE of financial institutions is a driving factor of the urbanization process. This is also due to multicollinearity between variables. We test the correlation of FD, FS, and FE separately; see Figure 7. It is found that there is indeed a high correlation between the various indicators of financial development. From this, we can conclude that the efficiency of capital allocation promotes the urbanization process.

Further introduce some macroeconomic indicators as control variables; namely, government fiscal expenditure, FDI, total investment in fixed assets, proportion of R&D investment, R&D investment. Joint significance test, and GMM regression results show that there is a significant U-shaped nonmonotonic relationship between the degree of financial deepening, the efficiency of financial development, the scale of financial development, and the urbanization rate. The impact of financial deepening on the urbanization rate is U-shaped, and its inflection point appears at about 6.4371, and the financial deepening is all values less than 1. Therefore, the impact of financial deepening on the urbanization rate is nonlinearly decreasing: with the financial deepening as the degree of urbanization increases, the degree of urbanization is gradually decreasing. The impact of financial development efficiency on the urbanization rate is in an inverted U shape, and its inflection point appears at about −1.52, and the financial development efficiency is a value greater than zero, so the impact of financial development efficiency on the urbanization rate is nonlinearly decreasing: as with the improvement of financial development efficiency, the degree of urbanization rate is gradually declining. The impact of the scale of financial development on the urbanization rate is U-shaped, and its inflection point appears at about 4.77, and the value of the scale of financial development is on both sides of the inflection point. Therefore, before the scale of financial development reaches 4.77, the urbanization rate increases with the scale of financial development; after the scale of financial development exceeds 4.77, the urbanization rate increases with the increase of the scale of financial development. We also note that, except for the total fixed asset investment, the control variables are all significant,
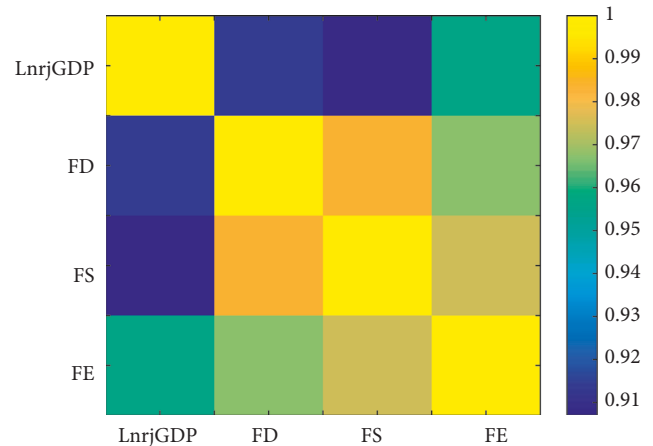

Figure 7: Correlation matrix about economic growth and financial development.

and the signs and operating results are also in line with our expected direction. The urbanization rate was regressed using the FE estimation method and the traditional estimated method, respectively, but no external instrumental variables were used in the estimation. The joint significance test and regression results of each indicator show that, even without using external instrumental variables, there is still a significant nonmonotonic relationship between urbanization rate and financial development indicators. Due to the existence of lag terms, both FE and OLS estimates are inconsistent, so the coefficients estimated by these two methods are biased. With the reform of household registration and the influx of more and more rural people to engage in nonagricultural work, the proportion of nonagricultural population to the total population underestimates the level of urbanization. The ratio of urban population to total population is now more widely used to describe the level of urbanization.

All in all, the above model setting and estimation methods all show that there is a very robust U-shaped nonmonotonic relationship between financial development and urbanization rate. The prediction is shown in Figure 8,
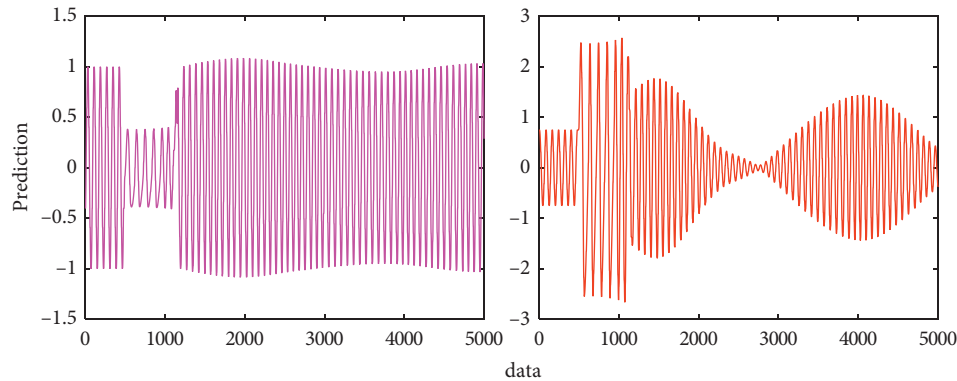
Figure 8: Prediction value.

which shows that the predicted value is consistent with the analyses.

5. Conclusion

The empirical results of the impact path of financial development on the proportion of urban built-up area: there is a significant U-shaped nonmonotonic relationship between the degree of financial deepening, the scale of financial development, and the proportion of urbanized built-up area; the degree of financial deepening, the degree of financial market activity, and the degree of financial development. There is a significant nonlinear relationship between size and urban unemployment. There is an inverted U-shaped relationship between financial deepening and unemployment.

However, since this paper does not study the cointegration relationship and long-term and short-term causality of panel data, the research in this paper cannot explain the causal relationship between financial development and urbanization at the provincial and municipal levels.

Data Availability

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

Conflicts of Interest

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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