Methodology for Forecasting Urban Economic Growth in the Yangtze River Delta Region of China

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Abstract: Cities in the Yangtze River Delta region of China are the core and important bearers of regional economic development. Based on the economic growth theory, the economic growth models of eight trillion GDP cities in the Yangtze River Delta region are estimated and established under the assumptions of production factors and inflationary change paths, and economic data from 1996 to 2020 are used to forecast the total economic scale and growth trend of each city up to 2035. The results show that (1) the constructed economic growth model has a high fitting ability, and according to the current economic growth path, the speed of each city to achieve the set economic goals mainly depends on the rate of capital accumulation under the stability of labor supply; (2) if the growth rate of fixed capital accumulation in each city can be maintained at an average annual rate of 3%-5%, the sum of economic aggregates of the eight cities will likely reach 30 trillion yuan in 2035.If the growth rate of fixed capital accumulation in each city can be maintained at an average of 3%-5%, the total economic volume of the eight cities will reach 30 trillion yuan in 2035, among which, Shanghai's total economic volume may exceed 5 trillion yuan around 2024, Suzhou's GDP may reach 3 trillion yuan in 2030, Nanjing and Hangzhou are expected to exceed 2 trillion yuan during the 14th Five-Year Plan, and Nantong, Wuxi, Ningbo and Hefei may achieve 2 trillion yuan in 2030-2035. -Nantong, Wuxi, Ningbo and Hefei will probably achieve the target of RMB 2 trillion in 2035. In order to achieve the set economic growth target as early as possible, the cities in the Yangtze River Delta region should accelerate the synergistic development, expand the scale of regional effective investment, stabilize the labor supply, and strengthen the innovation drive.

1. Introduction

At present, the world is experiencing a great change unprecedented in a century, the world economy is full of various uncertainties and instability, the important goal of China's economic development in the coming period is to strengthen the long-term balance of stable growth and risk prevention, under the conditions of effective risk prevention, to promote economic growth and achieve the great rejuvenation of the Chinese nation[1-3].

As an important economic center in China, the Yangtze River Delta region is in the best development period in history. The Yangtze River Economic Belt Development Strategy, Yangtze River Delta Integrated Development Strategy and other major national development strategies have brought significant policy opportunities for the economic and social development of the region[4-7]. The Yangtze River Delta region is extremely active in economic development, with the total regional economy accounting for about a quarter of the country. Eight of the 24 trillion GDP cities in China are located in the region, namely Shanghai, Nanjing, Wuxi, Suzhou, Nantong, Hangzhou, Ningbo and Hefei. These trillion GDP cities contribute more than 50% to the economic growth of the Yangtze River Delta region, and are important bearers and leaders of the economic development of the Yangtze River Delta region, playing a pivotal role in the economic and social development of the region. In recent years, the eight cities have stepped up their economic transformation, sought high-quality development, vigorously promoted innovation-driven and digital economy development planning, and deeply practiced the integrated development strategy of the Yangtze River Delta, making substantial progress in the process of integrated regional economic and social development[8-10].

The unprecedented policy windfall, strong economic development momentum, good ecological environment and innovative business environment have greatly enhanced the competitiveness and talent attraction of the cities, and the comprehensive economic competitiveness and sustainable competitiveness of the cities have been significantly improved.

The past 20 years have been a golden period of rapid economic growth in the Yangtze River Delta region. As shown by the economic aggregates of the eight trillion GDP cities, Shanghai has passed 4 trillion RMB, Suzhou has passed 2 trillion RMB, Nanjing and Hangzhou are just one step away from 2 trillion RMB, and the other four cities are striving towards the next trillion goal. China's second 100-year goal and the 2035 vision have both placed new demands on the region's economic growth. So, when will the cities' economic output cross the next trillion dollars threshold by 2035? How high will the cities' economic aggregates reach by 2035? What are the basic conditions needed to achieve the economic aggregate target? Answering these questions will help clarify the focus of economic growth and facilitate the formulation of policies by local government departments.

Given the economic status of the eight trillion GDP cities in the Yangtze River Delta region, this paper takes these cities as research objects, establishes an economic growth model for each city through estimation, conducts prediction and analysis of the economic growth path of each city until 2035, and analyzes the conditions and paths to achieve the total economic target.

2. Model design

2.1. Economic growth forecasting methods and model construction

2.1.1. Overview of economic growth forecasting methods

Economic growth forecast is the assessment and measurement of economic development trend. Economic development trends are an important basis for formulating economic policies, and accurate forecasts of future economic growth are beneficial to the formulation and implementation of economic policies and economic development strategies.

In general, economic growth forecasts are predictions and measurements of future economic states that have not yet occurred. However, due to the influence of statistical system, data release rules and other factors, macroeconomic data widely have the problems of inconsistent statistical frequency, missing data, differences in release time, etc. Thus, forecasts can be further classified into Forecasting, Back-casting, Now-casting according to the relationship between the point in time to be forecasted and the actual point in time. -Forecasting is the usual sense of forecasting, where the actual point in time is earlier than the forecast point, such as forecasting the economic growth trend of the next five years in the current year. When the forecast point is in the same time zone as the actual point, it is a Now-casting, such as forecasting the size of GDP in the third quarter of the same year in September of the same year. In the case of lagged data release, the actual point in time of the Back-casting is later than the point in time to be forecasted, such as forecasting the size of GDP in the third quarter of the same year in October of the same year. In terms of forecast horizon, Back-casting and Now-casting are mainly used for short-term forecasting in the case of inconsistent data frequency and data release, while forecasting can be used for short-term and medium- to long-term economic forecasting, depending on the forecasting model and methodology used.

There are two major types of economic growth forecasting methods: subjective empirical assessment methods and quantitative modeling forecasting methods. Subjective empirical assessment has high error and relatively low accuracy. Quantitative modeling forecasting methods based on objective data use quantitative statistical models to characterize potential economic growth paths and make forecasts based on the constructed economic growth paths under certain assumptions, which often have better short-term forecasting ability because they are based on sufficient theoretical and realistic data. Throughout the studies, the choice of quantitative models depends on the type of economic growth forecasting. Specifically, most of the backward-looking and real-time forecasts use mixed-frequency models, such as Bridge Model, MIDAS model, factor model, and mixed-frequency vector autoregressive (VAR) model, which can better deal with the problems of inconsistent data frequencies, missing data, and publication time differences. For short- and medium-term forward forecasting, the commonly used methods include (linear and nonlinear) single-equation autoregressive (AR) models, multi-equation vector autoregressive (VAR) models, and dynamic stochastic general equilibrium (DSGE) models, which are based on the dynamic correlation structure of the estimated economic variables themselves or between them, and usually have high forecasting accuracy, but the model forecasting error increases with longer forecasting periods, thus These models are only suitable for short- and medium-term forecasting. For long-term forecasting of economic growth, the mainstream method is based on the economic growth theory and the set production function, and the long-term economic growth model is estimated from the perspective of production factors, and the long-term economic growth rate and scale are forecasted under the assumption of the path of change of production factors, and the long-term growth model (LTGM) developed by the World Bank belongs to this type of method. Combined with the purpose of the study, this paper will build a long-term economic growth model based on the production function for analysis and forecasting, drawing on the long-term growth model developed by the World Bank.

2.1.2. Long-term economic growth model

Theoretically, labor and capital are the fundamental determinants of long-run economic growth. Assuming that city i produces according to the following Cobb-Douglas type production function, integrating labor and capital under certain production technology, total output in period t can be expressed as:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta} \tag{1}$$

shows the economic output; K and L are fixed (material) capital stock and labor supply (human capital), respectively; A denotes the level or ability to integrate capital and labor for production (or total factor productivity); technical parameters α,β measure the contribution of capital and labor to output, respectively. The production function shown in this equation is simple in form and more realistic in its description of the economy. However, economic output is often significantly affected by some atypical disturbances, such as economic and financial crises, public health events, political events, institutional reforms, etc. Therefore, equation (1) is more strictly adjusted as follows.

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta}\varepsilon_{it} \tag{2}$$

where ε it denotes the disturbance affecting economic output. Further taking the natural logarithm of both sides of the above equation simultaneously yields:

$$\ln Y_{it} = \ln A_{it} + \alpha \ln K_{it} + \beta \ln L_{it} + \eta_{it}, \eta_{it} = \ln \varepsilon_{it} \tag{3}$$

According to equation (3), the economic growth rate from period t to t+1 (log) is:

$$\ln(\frac{Y_{i+1}}{Y_{it}}) = \ln(\frac{A_{i+1}}{A_{it}}) + \alpha\ln(\frac{K_{i+1}}{K_{it}}) + \beta\ln(\frac{L_{i+1}}{L_{it}}) + \frac{\eta_{i+1}}{\eta_{it}} \tag{4}$$

In equation (4), there are four main sources of economic growth: increase in productive capacity, capital deepening, increase in labor force, and increase in factor contribution. Scientific and technological innovation brings about a change in social production methods, thus increasing production capacity and factor contribution, but it is difficult to have an impact on production efficiency in the short term due to the relative solidification of social production methods.

At the same time, for a city, geospatial constraints can cause relatively slow changes in labor supply, and with the possibility of technological advances reducing the contribution of labor output, the economic growth effect of labor supply changes may be diminished. Therefore, to promote steady economic growth, it is important to enhance the stability of the labor market while increasing the rate of capital accumulation.

Considering that the output contribution of production factors will show time-varying characteristics due to technological innovation and institutional change, etc., more generally, α,β is set as time-varying, so equation (3) can be expressed as:

$$\ln Y_{it} = \ln A_{it} + \alpha_{it}\ln K_{it} + \beta_{it}\ln L_{it} + \eta_{it} \tag{5}$$

Based on Hauzenberger et al, a binary regression model with time-varying coefficients can be developed from equation (5) as follows.

$$\ln Y_{it} = \ln A_{it} + \alpha_{it}\ln K_{it} + \beta_{it}\ln L_{it} + \sigma\lambda_{it}, \eta_{it} = \sigma\lambda_{it}, \lambda_{it} \sim N(0,1) \tag{6}$$

From equation (6), the model is a homoskedasticity model. where σ is the standard deviation of residuals. Since macroeconomic variables often exhibit time-varying volatility characteristics due to shocks from institutional changes and atypical events, the residual standard deviation of the model is set to be time-varying, i.e., σ is set to σit, which yields.

$$\ln Y_{it} = \ln A_{it} + \alpha_{it}\ln K_{it} + \beta_{it}\ln L_{it} + \sigma_{it}\lambda_{it} \tag{7}$$

By estimating equation (7) using time series data of each place to obtain the optimal estimates of A, α, and β, and establishing a model of economic growth for each place, and then assuming the future change paths of capital and labor force, the scale and trend of future economic growth can be predicted. However, under the current statistical rules, only annual time series data can be obtained for the above model estimation, and together with the missing data, the actual sample size of available data is small. Under such circumstances, the estimation results of the parameters in Eq. (7) may not be optimal estimates regardless of whether Bayesian inference or traditional frequency school estimation methods are used, which will result in a poor model fit. Therefore, this paper provides a technical treatment of the time-varying parameter model of Eq. (7). First, Monte Carlo simulation sampling method is applied to obtain the posterior estimates of the model parameters, and then the mean 2.5% quantile of the sample period of the effective sampling of the three parameters is taken as the minimum value and the 97.5% quantile as the maximum value, while constraining the parameter nonnegativity, and the idea of simulated annealing algorithm is used to improve the fit of the model to the actual observations as the goal, and the combination of parameters with the smallest sum of squares of residuals is screened to estimate The optimal estimates of the model parameters are selected, and the corresponding economic growth models are established and used for economic growth forecasting.

2.2. Model estimation and economic growth forecast

2.2.1. Model estimation

2.2.1.1 Data selection and variable setting

The economic growth model shown in Eq. (7) involves three economic variables as economic output, capital stock and labor supply, respectively. Based on data availability, economic data from 1996 to 2020 are used in this paper. All relevant data are obtained from the statistical yearbooks of each municipality unless otherwise specified.

(1) Economic output

As a general practice, the total economic output of each municipality is measured using constant price GDP, and the nominal GDP of each municipality is deflated by the GDP deflator (100 in 1996) to obtain the constant price GDP of each municipality. The GDP deflator of each municipality is calculated using the GDP index of each municipality (100 in the previous year) and the nominal GDP growth rate.5 The GDP index of each municipality is obtained from the WIND information terminal.

(2) Labor supply

Different from the studies targeting the national level, due to the cross-regional mobility of labor, the labor supply of a region consists of the local internal working-age population6 and the inflow of labor from outside the region. Therefore, considering natural and frictional unemployment, in order to objectively reflect the labor supply and utilization status of each municipality, this paper uses the number of employees in the whole society as a proxy for labor supply.

(3) Fixed capital stock

The available statistics do not publish the fixed capital stock data of each municipality, so it needs to be estimated, and the commonly used method is the Perpetual Inventory Method (PIM). Referring to OECD [5] and Donckt et al [6], the (net) capital stock in period t under the Perpetual Inventory Method is.

$$K_{it} = (1-\delta)K_{it-1} + F_{it} \tag{8}$$

where Fit denotes the new fixed capital in constant prices in city i in period t, δ is the fixed capital depreciation rate, and δKit-1 is the depreciation amount. The fixed capital stock at the end of period t is equal to the capital stock at the beginning of period t minus the capital consumption in period t, plus the new fixed capital added by the investment. Assuming that the initial capital stock is Ki0, equation (8) can be rewritten as

$$K_{it} = (1-\delta)^T K_{i0} + \sum_{j=1}^{T} \quad F_{it-(j-l)} \tag{9}$$

From this, it can be seen that three pieces of information are required to estimate the capital stock: initial capital stock, constant price capital formation and fixed capital depreciation or depreciation rate.

a) Initial capital stock

Assuming that the share of industrial capital stock in the capital stock of the whole society is the same as the share of value added in the total GDP, the average balance of net fixed assets of all independently-accounted industrial enterprises in each city in 1996 is divided by the GDP share of industrial value added in each city, and the average balance of all net fixed assets in each city in 1996 is roughly projected and taken as the initial capital stock of each city.

b) Fixed capital formation

Fixed asset investment forms material fixed capital. The amount of completed fixed asset investment in each municipality is used to obtain the actual amount of completed fixed asset investment each year by deflating the amount of completed fixed asset investment by the fixed asset investment price index. Due to the reform of the statistical system, only the year-on-year growth rate of fixed asset investment has been published since 2018. Based on the year-on-year growth rate data, the data on the total amount of fixed asset investment completion in each municipality from 2018 to 2020 are filled.

Due to the absence of fixed asset investment price indices at the local and municipal levels, the fixed asset investment price indices of the provinces where the local and municipalities are located are used instead. The fixed asset investment price indices of Shanghai, Jiangsu, Anhui and Zhejiang during 1996-2019 are available from the WIND information terminal, but the data for 2020 are missing. To fill in the 2020 data, in view of the high correlation between GDP deflator and fixed asset investment price index, a linear regression model is established between GDP deflator and fixed asset price index of three provinces and one city to obtain the fixed asset investment price index of each place in 2020 by backpropagation.

On this basis, assuming that the construction cycle of fixed asset investment is three years, the annual fixed capital formation of each city is expressed as the average of the actual fixed asset investment of each city in the past three years, i.e.

$$F_t = (I_t + I_{t-1} + I_{t-2})/3 \tag{10}$$

Where, It denotes the amount of constant price fixed asset investment completed in year t.

c) Fixed capital depreciation amount and depreciation rate

In fixed capital estimation, the measurement of depreciation rate is one of the highly controversial and difficult points. Here, this paper does not directly estimate or assume the depreciation rate, but based on the income approach perspective of national income accounting and the principle that depreciation of fixed assets is a component of GDP, assumes that the proportion of depreciation of fixed assets in each city except Shanghai is the same as the proportion of GDP of each city in the province, estimates the annual depreciation of fixed assets in each city, and then uses 1996 as the base period of The GDP deflator of each city is then discounted to obtain the depreciation amount of fixed assets in constant prices for each city from 1996 to 2020.

According to equation (8), the fixed capital stock of each municipality can be estimated by using the initial capital stock, new fixed capital formation and depreciation of fixed assets.

3. Data processing and regression analysis

3.1. Data modeling and analysis

For the collated economic data, regression models are built for analysis on a city-by-city basis. In each city model, according to equation (7), the natural logarithm is taken for all variables, the prior distribution consistent with Hauzenberger et al. is set, and the Monte Carlo simulation sampling MCMC method is used to repeat the sampling 1 million times, the first 500,000 times are used for pre-burning, and every 10 steps are recorded, and a total of 50,000 valid samples of the posterior estimates of the model parameters are obtained.

To find the optimal estimates of the model parameters, the mean value of the 2.5% quantile sample of the parameter posterior estimates is taken as the minimum value and the mean value of the 97.5% quantile sample is taken as the maximum value, while a non-negative constraint is imposed to ensure economic significance, and a 0.005 step is set to calculate the sum of squares of the model residuals under each parameter combination using the simulated annealing algorithm idea to filter out the parameter combination with the smallest sum of squares of residuals. In addition, as shown in equation (7), the model parameters are allowed to have structural mutations, and if the model fit is low for a certain time period, the simulation is repeated for that time period to estimate the optimal parameter combination for that time period. After the operation, the final parameter estimation results and the model fit are shown in Table 1 and Figure 1.

Table 1 Estimated economic growth models for each city

Cicy	Interval1	Model1	Interval2	Model2	Interval3	Model3
Shanghai	1996-2010	0.02K^1.04L^0.42	2011-2020	0.004K^1.41L^0.11		
Nanjing	1996-2012	1.45K^0.83L^0.03	2013-2017	0.95K^0.86L^0.05	2018-2020	0.93K^0.89L^0.01
Nantong	1996-2020	3.83K^0.6L^0.24				
Wuxi	1996-2013	0.65K^0.72L^0.41	2014-2020	0.75K^0.66L^0.48		
Suzhou	1996-2006	0.97K^0.88L^0.09	2007-2013	1.36K^0.87L^0.06	2014-2020	0.87K^0.9L^0.08
Hangzhou	1996-2014	12.8K^0.65L^0.02	2015-2020	24.04K^0.56L^0.05		
Ningbo	1996-2014	8.88K^0.68L^0.001	2015-2020	18.06K^0.59L^0.03		
Hefei	1996-2011	32.33K^0.48L^0.001	2012-2014	9.93K^0.6L^0.001	2015-2020	10.44K^0.57L^0.03

Table 1 shows the comparison of the trend of the fitted values (solid line) and the observed values (dashed line) of the real economic aggregate model for each city from 1996 to 2020. It can be clearly seen from the figure that for eight cities, the economic growth model constructed in this paper has a good fitting ability and can objectively reflect the potential economic growth path and pattern. Further, as shown in Table 1, there are obvious structural changes in the economic growth models of the other seven cities during the 25-year period from 1996 to 2020, and the output capital elasticity of Shanghai is about 1.04 and the labor elasticity is about 0.42 during the period from 1996 to 2010, while the output capital elasticity expands to 0.42 during the period from 2011 to 2020. The elasticity of output capital expands to 1.41 and the elasticity of labor shrinks to 0.11 in 2020, indicating that the dependence of Shanghai on capital increases and the dependence on labor decreases after 2011. The same situation also occurs in Nanjing and Suzhou, but the degree of change is less than that of Shanghai. Wuxi, Hangzhou and Ningbo show weakening output capital elasticity and increasing output labor elasticity. In general, the contribution of capital to output is higher than that of labor during the 13th Five-Year Plan period, with the elasticity of output capital in the range of 0.6-0.9 and the elasticity of output labor in the range of 0.01-0.5 for all seven cities except Shanghai. This result is consistent with China's long-standing investment-driven economic growth model. It is due to the high contribution of capital output that the three provinces and one city in the Yangtze River Delta have introduced various policies to actively expand effective investment in order to stabilize economic growth in early 2022.

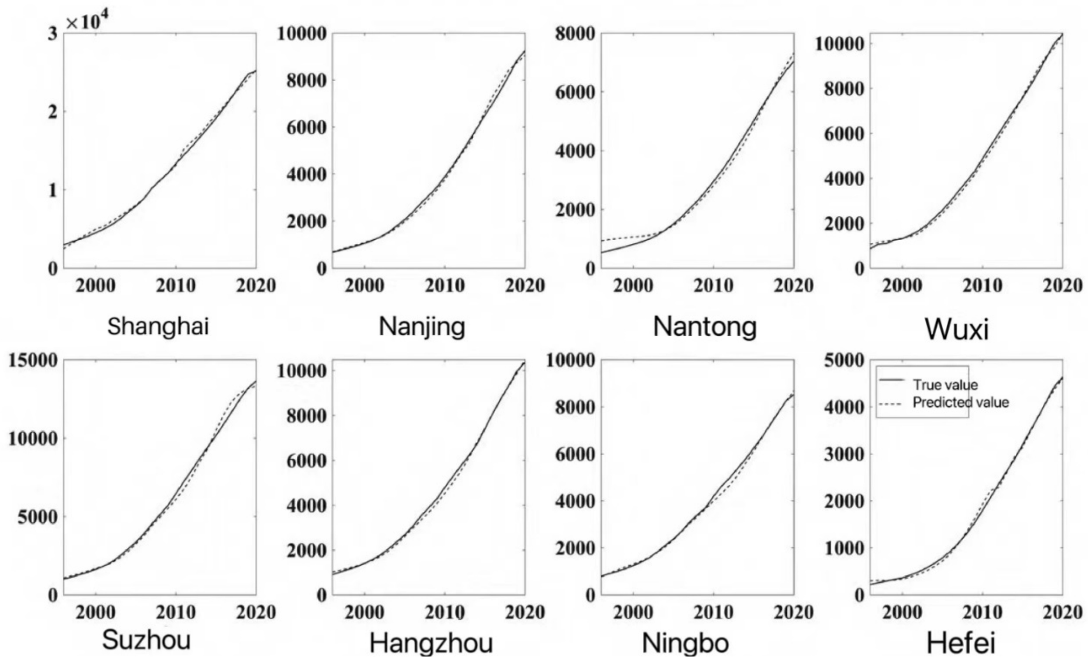

Figure 1 Comparison between the fitted and observed values of the real GDP model for each city (unit: billion yuan) .

3.2. Economic growth forecast

The estimated economic growth model for each city (see Table 1) is used to forecast the scale of future economic growth for each city, assuming that the future economy operates according to the current growth path under the assumption of the change path of production factors. Although production efficiency and the contribution of production factors to output are subject to change due to technological innovation, institutional change, etc., it is not possible to pre-determine the future evolution of these parameters. It is presupposed that the parameters of production efficiency and factor contribution will directly change the economic growth paradigm in the future, especially a small adjustment of factor contribution will likely cause drastic changes in output. Therefore, this paper only considers the growth trend and aggregate size of the economy of each municipality up to 2035 under the single condition of growth in the number of factors of production, assuming that the economy continues to operate under the current growth paradigm in the future, given the growth path of fixed capital stock and labor supply.

Assuming the growth path of capital stock and labor force, the potential size of the real economy is estimated, and based on this, the nominal size of the economy is projected by setting the overall inflation level. Based on the economic and administrative status and population attractiveness of each city10 and with reference to the average growth rate of labor supply in each city during the 13th Five-Year Plan period, it is assumed that the annual growth rates of labor supply in Shanghai, Nanjing, Nantong, Wuxi, Suzhou, Hangzhou, Ningbo, and Hefei are 2%, 1%, 0.3%, 1%, 1.5%, 2%, 2%, and 1%, respectively, by 2035. The growth rate of labor supply in 2035 is 2%, 1%, 0.3%, 1%, 1.5%, 2%, 2%, 1% for Shanghai, Nantong, Suzhou, Hangzhou, Ningbo and Hefei. With reference to the average rate of change of the GDP discount index of each city during the 13th Five-Year Plan period, the annual inflation rates of the above cities are set to 2%, 1%, 1.5%, 1%, 1.5%, 2%, 2%, and 2% for each city from 2021 to 2035, respectively. Under these assumptions, the growth trend and aggregate size of the economy in each place are examined under the five capitals stock accumulation growth rates.

The growth rate of fixed asset investment in Shanghai in 2021 is 8%, and considering the impact of the epidemic, the real fixed capital stock growth rate may only be about 5%. Based on the current production technology and labor force growth rate of 2%, the total nominal GDP in Shanghai in 2021 will reach 4,287,596 billion yuan, which is slightly lower compared with the statistical publication value. Statistics show that the total number of actual employees in Shanghai in 2021 is 13.65 million, which is less than 14.01 million measured at 2% growth rate. Meanwhile, the overall inflation rate in Shanghai in 2021 is 3.3%, so if the actual number of employees and inflation rate are estimated, the forecasted value of nominal GDP in 2021 increases to 4,329.547 billion yuan, which is close to the actual statistical value.

Table 2 Shanghai Nominal Economic Aggregate Forecast, 2021-2035 (unit: hundred million yuan)

Year	3%	5%	7%	9%	10%
2021	41726.86	42875.96	44034.13	45201.26	45788.16
2022	44473.02	46956.20	49527.22	52187.47	53551.49
2023	47399.92	51424.73	55705.56	60253.46	62631.08
2024	50519.44	56318.50	62654.62	69566.11	73250.11
2025	53844.26	61677.97	70470.56	80318.10	85669.58
2026	57387.90	67547.48	79261.50	92731.90	100194.75
2027	61164.75	73975.55	89149.08	107064.35	117182.66
2028	65190.17	81015.34	100270.10	123611.99	137050.84
2029	69480.52	88725.06	112778.42	142717.20	162087.65
2030	74053.22	97168.47	126847.11	164775.28	187464.23
2031	78926.87	106415.39	142670.82	190242.60	219248.57
2032	84121.27	116542.27	160468.48	219646.10	256421.91
2033	89657.52	127632.87	180486.33	253594.14	299897.94
2034	95558.13	139778.89	203001.33	292789.12	350745.28
2035	101847.07	153080.77	228324.99	338041.99	410213.73

According to Table 2, with an average annual growth rate of labor supply of 2%, an annual inflation rate of 2%, and existing technical conditions, if the growth rate of fixed capital stock can be maintained at an average annual rate of 5%, Shanghai's total nominal GDP is expected to exceed 5 trillion yuan in 2023 and achieve a nominal economic output of 15 trillion yuan by 2035. Most conservatively, if the growth rate of fixed capital stock is only 3%, Shanghai's total nominal economic volume will break through 5 trillion yuan in 2024 at the latest, and will achieve trillions of incremental growth in 2027, 2030, 2032 and 2034, respectively, to break through 10 trillion yuan in 2035.

As shown in Table 3,the growth rate of fixed asset investment in Nanjing in 2021 is 6.2%, and if the growth rate of fixed capital stock reaches 5%-7%, the nominal GDP in 2021 will be between 1,529.298 billion yuan and 1,555.193 billion yuan under the forecast framework of this paper (see Table 3), which is slightly smaller than the actual statistical value, probably because the labor force employment to be higher than the 4.89 million estimated at a 1% growth rate, as well as a higher real inflation rate than 1%. By 2035, if the growth rate of fixed capital stock can be maintained at an average annual rate of 5%, the average annual labor force growth rate reaches 1%, and the inflation rate is 1%, Nanjing's nominal economic output may exceed RMB 2 trillion by 2027 and RMB 3 trillion by 2035. If the growth of fixed capital stock can be maintained at only 3%, Nanjing may achieve the target of RMB 2 trillion in economic output around 2029.

Table 3 Nanjing's nominal economic aggregates forecast for 2021-2035 (unit: hundred million yuan)

Year	3%	5%	7%	9%	10%
2021	15033.48	15292.98	15551.93	15810.35	15939.37
2022	15590.09	16132.94	16683.92	17242.99	17525.54
2023	16167.29	17019.03	17898.30	18805.43	19269.56
2024	16765.87	17953.79	19201.07	20509.46	21187.13
2025	17386.62	18939.90	20598.66	22367.89	23295.33
2026	18030.34	19980.16	22097.98	24394.72	25613.74
2027	18697.90	21077.56	23706.44	26605.22	28162.64
2028	19390.17	22235.24	25431.96	29016.01	30965.19
2029	20108.08	23456.50	27283.09	31645.25	34046.63
2030	20852.56	24744.83	29268.95	34512.73	37434.71
2031	21624.61	26103.93	31399.36	37640.05	41159.95
2032	22425.24	27537.68	33684.84	41050.75	45255.90
2033	23255.52	29050.17	36136.67	44770.50	49759.45
2034	24116.53	30645.73	38766.96	48827.31	54711.16
2035	25009.43	32328.94	41588.71	53251.72	60155.63

As shown in Figure 2, the total economic volume of the eight trillion GDP cities in the Yangtze River Delta region will be about 15 trillion RMB in 2021. Under the above assumptions of labor supply changes and inflation rate, if the average fixed capital stock growth rate reaches 3%, the total economic volume of the eight cities will reach 27 trillion RMB by 2035; if the average fixed capital stock growth rate reaches 5%, the total economic volume of the eight cities will likely double by 2035 and exceed 35 trillion RMB by 2035; when the average fixed capital stock growth rate When the average growth rate of fixed capital stock is maintained at 7%, the total economic volume of the eight cities will likely double by 2030 ahead of schedule and jump to a new level of 48 trillion yuan by 2035.

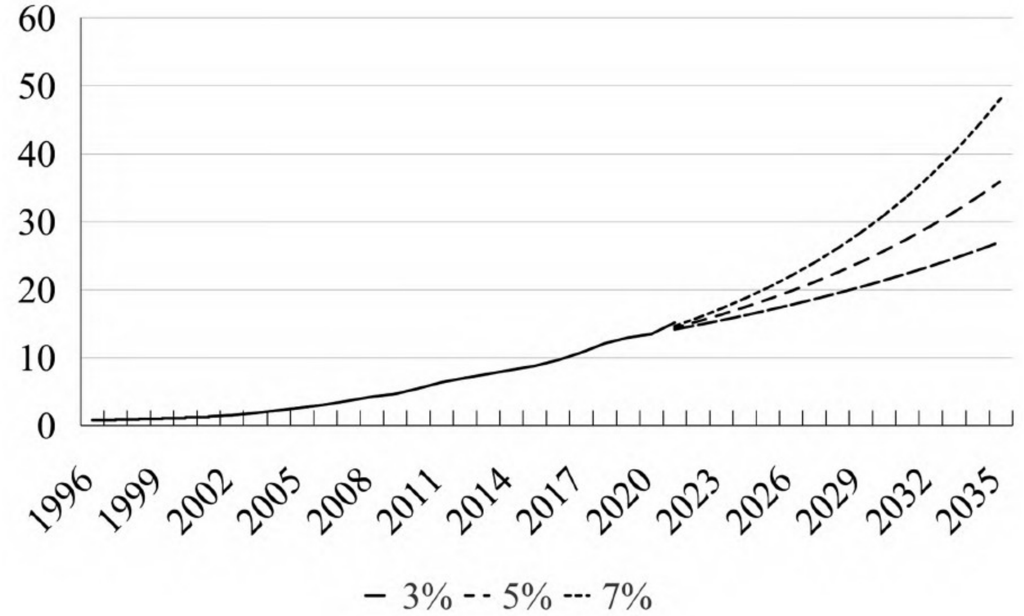

Figure 2 Total economic volume and forecast of trillion GDP cities in Yangtze River Delta from 1996 to 2021 (unit: trillion RMB)

The above forecast results show that under the conditions of a given labor force growth rate and inflation, the faster the rate of capital accumulation and the stronger the economic growth momentum, the shorter the time to achieve the economic aggregation target according to the current economic growth pattern. The above analysis points out that the economic growth effect of small changes in labor supply may be relatively weak. To test this judgment, in the above projection framework, assuming that labor supply in each municipality can maintain only 0.01% growth, and using the same inflation and capital accumulation settings for each municipality as in the above projection framework, the economic aggregates for 2021-2035 under the current growth pattern of each municipality The forecast results for the size and trend are shown in Figure 3.

From Figure 3, it can be found that the timing of achieving the next trillion dollars target for economic aggregates in each city does not change while labor supply remains at essentially the same level. However, if there is a larger decrease in labor supply, it will have a significant inhibiting effect on the economic growth of each city. Figure 4 shows the predicted economic growth results of each city under a 5% annual reduction in labor supply and different rates of capital accumulation. As shown in Table 1, the cities of Shanghai, Nanjing, Suzhou, Hangzhou and Hefei have relatively low reliance on labor for economic growth, and a 5% annual reduction in labor supply will not have a significant impact on the timing of achieving the next trillion dollars target in these cities. As the output contribution of labor force is still relatively high, Nantong and Wuxi will probably face the possibility of weak economic growth in the face of a negative 5% annual growth of labor force supply, and the achievement of the next trillion target will depend on a higher rate of capital accumulation. Although for Shanghai, Nanjing, Suzhou, Hangzhou and Hefei, the significant reduction of labor supply seems to have less impact on future economic growth, attention needs to be paid to the social problems caused by the large labor outflow and high unemployment, and the instability of the labor market may cause unstable factors that are detrimental to economic development. Therefore, to promote economic growth, cities should still focus on stabilizing labor supply while accelerating the rate of capital accumulation.

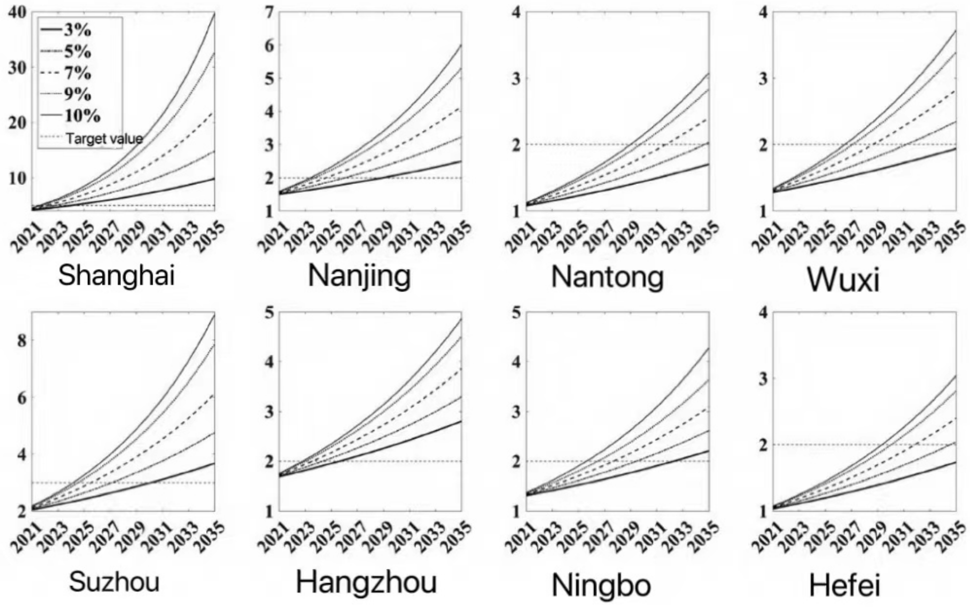

Figure 3 Economic growth forecast by city under 0.01% growth rate of labor supply and different rates of capital accumulation (unit: trillion yuan)

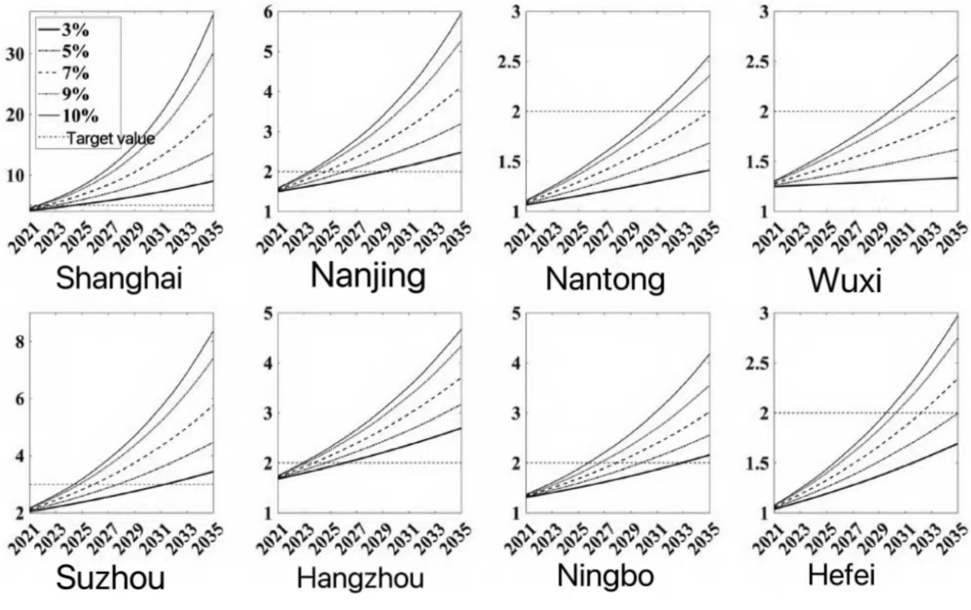

Figure 4 Labor supply – 5% growth rate, economic growth forecast by city under different rates of capital accumulation (unit: trillion yuan)

4. Conclusion

This paper draws on the long-term economic growth forecasting method of the World Bank, establishes an economic growth model based on the Cobb-Douglas type production function, uses economic data from 1996 to 2020, applies a combination of Monte Carlo simulation sampling and annealing algorithm to estimate the model, and uses it to forecast to 2035 under the assumptions of production factors and inflationary change paths The size and growth trend of economic aggregates in eight trillion GDP cities in the Yangtze River Delta region. The findings of the study are as follows.

The economic growth model constructed in this paper, which allows for structural mutations in the economic growth paradigm, has a high ability to fit the actual economic output of each city; the forecast results indicate that the future growth of economic aggregates in each city will still depend mainly on capital accumulation and stable labor supply, and sustained capital accumulation at a sufficient rate is the key to achieving the goal of economic aggregates in each city. If each city can maintain an average annual growth rate of 3%-5% in fixed capital accumulation, the sum of the economic aggregates of the eight cities will likely reach about 30 trillion yuan in 2035, among which, Shanghai's economic aggregates will likely exceed 5 trillion yuan around 2024, Suzhou's GDP will likely reach 3 trillion yuan by 2030, and Nanjing and Hangzhou are expected to reach 3 trillion yuan by 2030. "Nantong, Wuxi, Ningbo, and Hefei may achieve a total of RMB 2 trillion in 2030-2035. From the results of the study, it is clear that the key to promoting economic growth and achieving economic goals is to improve production factor inputs, especially to expand investment and accelerate capital accumulation. At the same time, it is also necessary to focus on scientific and technological innovation, improve the efficiency of social and economic resource allocation, and enhance social production efficiency.

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