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Research article

Keywords: Total healthcare expenditures, Developmental stages, Correlation factors

Posted Date: October 11th, 2019

DOI: https://doi.org/10.21203/rs.2.15965/v1

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Evaluating Developmental Stages of Total Health Expenditures in China

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Abstract

Objective: This study evaluated developmental stages and trends of Total Healthcare Expenditure (THE) of 18 provinces in China. We explored characteristics of different development stages during healthcare expenditure, to provide scientific reference for Chinas health care policy making and regional healthcare planning.

Methods: Firstly, curve fitting and parameter estimation using SPSS21 software were carried out for the Logistic function model, and then the three-point or four-point method was applied to estimate the value of saturation K. Finally the Logistic function equation and fitting graph were obtained. According to the nature of Logistic curve, the study divided THE into three stages, gradual, rapid and slow growth, and predicted and analyzed THE developments in 18 provinces.

Results: 2015-2029 will be the key period for warning and controlling the total healthcare expense in China. By 2019, 15 provinces have entered a period of rapid THE growth. Chronologically, regions entering fast growth period are northeast (in 2005), east China (in 2008), northwest (in 2010), south China (in 2013), north China (in 2015) and southwest (in 2015). The earliest province to enter rapid growth period is Liaoning (in 2005), and Shandong will enter the period at latest (in 2045). In 2027, all 18 provinces will enter the rapid growth period, and end in 2045. During this period, rapid growth in total healthcare expense will last for about 23 years, with an average annual growth rate of 8.69%. Besides, THE will increase from 233.33 billion yuan to 842.926 billion yuan. The total healthcare expenditure will reach 547.249 billion yuan in rising fastest year. Through the rapid growth period, THE growth in the east show high starting expense (on average, 412.779 billion yuan per year initially), high final expense (1492.948 billion yuan per year), slow annual growth rate (7.80%), and long intervals (average duration of 17.88 years). In the central and western regions, the characteristics are low starting expense (on average, 89.772 billion yuan per year initially), low final expense (322.908 billion yuan per year at the end), fast annual growth rate (9.40%), and short intervals (average duration of 14.50 years). During rapid growth period of THE, expense characteristics in each province and region are consistent with regional economic levels.

Conclusions: THE growth pattern is in line with typical trend of "slow-fast-slow"

growth function. The expense developments vary between regions. Eastern region entered rapid and slow growth period later than the central and western regions. THE development stages and duration of the rapid growth period is correlated to regional economic level. The earlier it enters the fast growth period, the shorter it lasts, and vice versa. The government should take advantage of this period, from 2015 to 2029, to make policy preparations to respond THE rapid growth in China. Based on stage characteristics of THE development in different provinces, government should make regionally different healthcare policy considering local conditions. It should be able to control THE rapid growth in a reasonable scope, and fit with social economy.
Key words: Total healthcare expenditures, Developmental stages, Correlation factors

Introduction

Since the reform and opening-up policy, Chinese economy has made remarkable achievements: rapidly and steadily growing national and per capita income. Statistic reports showed that Chinas nominal GDP per capita increased from 381.00 yuan in 1978 to 53,700.00 yuan in 2016, with an average annual growth rate of 6.7%. This has directly promoted the development of Chinas medical environment, equipment and facilities. Medical scale and technology have achieved unprecedented achievements. China Statistical Yearbook showed that the number of hospital beds per thousand people (including community healthcare centers) increased from 1.93 in 1978 to 5.37 in 2016. The number of healthcare technicians per thousand people increased from 1.08 in 1978 to 6.12. Moreover, many new high-tech medical devices such as CT machines and MRI are also used in daily medical practices. This suggests that the development of medical and healthcare has improved residents life quality and physical health. In China, mortality rates of infants and maternal women have fallen, while the average life span has increased, and the level of social aging has increased. The infant mortality rate reduced from 50.20 per thousand in 1978 to 7.50 in 2016. The maternal mortality rate was 80.10 per 100,000 in 1991, 53.00 per 100,000 in 2009 and 19.90 per 100,000 in 2016. Life span increased from 67.9 years in 1981 to 74.83 years in 2010 and 76.40 years in 2016. At the same time, the proportion of elderly population is gradually increasing. The proportion of people aged 65 and over increased from 4.17% in 1978 to 16.70% in 2016. Our country has become an aging society. However, with significant achievements in healthcare, there has been a rapid increase in medical costs, higher than the growth rates of GDP and residents income, which ultimately leads to the increasing burden of resident's medical care. Nominal THE per capita increased from 11.45 yuan in 1978 to 3,351.74 yuan in 2016, with an average annual growth rate of 12.44%. That is nearly six percentage points above the average annual growth rate of nominal GDP per capita in the same period [1]. Medical services and healthcare costs are directly related to resident's health and economic burden. Under the premise of ensuring qualities of medical services and healthcare of residents, how to curb the rapid growth of medical expenses has become the priority of governments, healthcare practitioners, economists and residents [2-6]. In order to ensure that local residents have access to high-quality and affordable medical services and curb the rapid growth of medical costs at the same time, countries around the world are carrying out the reform of medical and healthcare system. China is also actively promoting comprehensive reforms including improving medical and healthcare system, medical security system, pharmaceutical circulation system, healthcare financing, and so on.

Healthcare financing is a common problem and great challenge to countries all over the world. THE is an important research object of health financing reform. Research on THE has been recognized as basic research related to healthcare policy decisions, so that international and national governments are paying more and more attention to this. The growth of THE should be in line with the socio-economic level [7]. Through reasonable scientific methods, we can predict the growth trend of THE in advance, which can help us understand the gap between social healthcare demands and government capability, make appropriate response in time, and control the growth of THE in a moderate range.

Total Healthcare Expenditure (THE) is the national healthcare accounts. It is a comprehensive measure that reflects the total expenditure of the whole society medical and healthcare in a certain period, usually per year. [8, 9]. Abroad studies on THE have been carried out earlier, with more mature theories and methods. In 1959, International Labor Organization conducted a study on the medical costs of social insurance and voluntary insurance in the United States, which was the first study on healthcare costs in the world [10]. Besides, the International Social Security Association (ISSA) carried out relevant research and laid the foundation for the later systematic and scientific study on THE [11]. Since the 1970s, society healthcare demand is constantly increasing, and many countries have paid more attention on the national health levels. With the increased investment by governments on healthcare, the prediction research in THE starts to get more attention. In 1977, American health economist Newhouse initiated the first empirical research on the factors affecting medical expenditure by comparing THE data of Organization for Economic Cooperation and Development（OECD）from different countries and years. The results showed that more than 90% of the differences in healthcare expenditure per capita can be explained by the differences in GDP per capita, revealing the significant effects of GDP per capita on healthcare expenditure [12]. In 1986, Leu used medical expenditure data in 19 OECD countries to investigate the effects form policy and made a prediction. It found that income was still the most important factor on determine medical expenditure and proposed that every 10% increase in government investment on medical would lead to a 2%-3% increase in medical expenditure [13]. Since 1990s, international healthcare cost researchers have paid more and more attention on THE prediction. In 1990, Getzen combined national income and inflation and used as a lagging variable to evaluate the prediction of OECD health expenditure. The results showed that the predicted value of total health expenditure was very close to the actual value (R=0.62) [14]. In medical insurance and assistance service center, Stephen Heffler, Sheila Smith and other scholars predicted the long-term development trend of THE in the United States based on a retrospective analysis of health costs since 1970. The result showed that THE would account for 17.7% of GDP by 2012 while its growth rate will be slow down a bit [15-18].

As a developing country, China started the research on the total healthcare cost later. In the early 1980s, led by the World Bank, China launched the healthcare development project and carried out THE research with government support [19]. Since 1990s, with THE study carried out in depth, many domestic and abroad researchers started to pay attention to predictions of THE future trends. According to report *China: Long-term Problems and Solutions in the Change of Health Model*, total health expenditure in China will rapidly increase in the next 40 years [20]. In 1996, Haichao Lei predicted the trend of THE to GDP ratio from 1996 to 2000. The results show that ratio of THE to GDP in China will not dramatically increase, but will continuously increase to 4.3% in 2000 [10]. In 2000, Chinas THE accounting group concluded that THE growth will steadily proportion to GDP, which is consistent with Yaqing Lis conclusion [21]. The regression prediction results showed that the regression coefficient between healthcare expenditure and GDP per capita was 1.2094. In 2006, Ying Chen established THE prediction model by BP neural network combination. The research shows that THE in China will keep increasing, which will not exceed the capacity of national economy in the near future, but will cause certain pressure on the national economy in long term scenario [22]. In 2015, Ruibo He predicted THE in China based on the time series model and found that there was a stable positive correlation in GDP, urbanization rate and THE. He proposed that the government should broaden the financing channels, increase investments in healthcare service, and curb the unreasonable growth of healthcare expenditure [23]. In 2017, Qiaoyan Liu predicted future trends of healthcare expenditure by applying system dynamics simulation method, which found that THE would increase steadily, reaching 7.45712 billion yuan in 2025. In order to control the unreasonable increase of healthcare cost, it is suggested to increase prevention inputs [24].

From the domestic research on THE prediction, it is found that total healthcare cost continues to rise rapidly, which may have a certain impact on the national economy. Therefore, efficient prediction is necessary. At present, most scholars have made a relatively accurate prediction of THE in China, which provides a good reference of healthcare service. The scientific prediction of THE in the future can grasp the development tendency of THE macroscopically and provide reference for healthcare decisions.

Currently used THE prediction models mainly include: time series model [25], state space model [26], co-integration regression method [27], neural network combination model [28], grey system GM (1,1) model [29], indirect DGM (1,1) model [30], self-organizing data mining prediction model [31], system dynamics model [32], ARIMA model [33-36], and logistic function model [37]. Among them, domestic and abroad scholars have conducted extensive studies on the Logistic function model, which has excellent and accurate prediction capability. But there are limited articles using the logistic function model to predict THE.

Logistic function curve, which is a symmetrical "S" curve, was first discovered by Belgian mathematician P. F. Verhulst. The logistic function model is a mathematical model to describe "S" type development. In nature, many things' development trajectories are in line with S-shaped curve. It is widely used in the fields of natural science and social science, to describe the development process of a certain object.

Logistic curve has three key time points (the unique inflection point t^*, the two time points t_1 and t_2). Furthermore, the two time points divide curve into three sections, corresponding to three different development stages: gradual growth stage, rapid growth stage, and steady growth stage respectively. Eventually it reaches saturation state. Logistic curve can be used to describe and predict the growth and development of healthcare protection [38]. According to existing prediction results, THE in China is in the growth stage overall. But it cannot increase indefinitely. Its growth follows the slow-fast-slow rule and consistent with the growth curve of Logistic function.

China has a vast territory, a large population, and extremely unbalanced economy in different regions. At the present stage, unbalanced and inadequate develop and increasing live requirements have become the main contradiction in our society. At present, THE in China has been increasing too fast and the distribution of healthcare resources is unbalanced, which has brought a series of problems to the economic society and residents health. Therefore, it is very necessary to effectively predict THE and its development stages, especially at the provincial level. This study used inflection points and stages of Logistic function to predict and analyze THE developments of 18 provinces in China. It aims to identify the current THE development stage in each province (gradual growth stage, rapid growth stage, or slow growth stage), in order to made a more objective analysis and predict Chinas THE development trend, and to provide scientific theoretical reference for Chinas economic development and healthcare system reform.

Methods

Data sources

This study used THE data from 2003 to 2016 in China. Limited by the availability of THE data, there are only 23 administrative regions' data in China THE Research Report 2017. Among them, Jiangsu, Hunan, Shanxi, Ningxia Hui Autonomous Region and Inner Mongolia Autonomous Region had THE data from 2007. These five regions were not included because they had less than 14 years THE data. Finally, we selected THE in 18 provinces for the purpose of this study. In the study, 18 provinces included cities, municipalities and autonomous regions. According to the administrative division, the provinces and municipalities are located in five regions. Three provinces are in the northeast of China: Heilongjiang, Jilin and Liaoning provinces; North China includes two municipalities: Beijing and Tianjin; Eastern China includs provinces of Shandong, Zhejiang, Fujian, Anhui, Jiangxi and the municipality of Shanghai; South China has Guangdong province and Guangxi Zhuang autonomous region; two provinces are in the Southwest of China: Sichuan and Yunnan; Northwest China includes Shanxi, Gansu and Xinjiang Uygur autonomous region.

As a main indicator for the evaluation of healthcare financing status in a country, National Health Accounts is divided into three levels: the source of healthcare funding, the institutional flow of healthcare funding, and the functional usage of healthcare funding. According to the three levels of healthcare financing, financing method, institutional method and functional method are formed to reflect health funds' composition, flow direction and use characteristics from different levels and angles [9].At present, Chinese national health accounts mainly provide two kinds of THE data: the source method and the institution method.

The data in source method are used in this study. Source method of health account is the first level in Chinese national healthcare accounts. It collects, sorts out, and measures THE in healthcare funding's financing channels and forms. It classifies healthcare funds by sources, and measures the total amount and internal composition of public healthcare resources. In a certain period, it macroscopically reflects the healthcare financing level and main financing channels in one region.

Data by source, which covered THE in China from 2003 to 2016, were derived from the source method in the China National Health Accounts Report 2017. The panel data of THE in 18 provinces were selected, which spanned 14 years. For convenient description, data referred to below are from the source method. The accounting caliber of THE data has been adjusted, and they are reliable.

The GDP deflator was derived from State Statistics Bureau, China Statistical Yearbook in 2017 and China economic net database. In order to eliminate impacts of population, economy and price factors on the growth of provincial GDP and THE, we transformed (per capita) GDP, (per capita) THE, and other expense data during 2004-2017 in 18 provinces, into actual values by the GDP deflator. As is shown in table 1, data referred to below are actual costs, unless otherwise stated.

Statistical measures

GDP Deflator

GDP deflator is an important price changes indicator in national economic accounting. It reflects trend and range of GDP changes in different periods. GDP deflator refers to the ratio of current-price GDP to the real measure of GDP over a particular period of time [39]. This study used GDP deflator in world health statistics report to calculate the actual national healthcare expenditures.

Actual national healthcare expenditures equals to Notional total healthcare expenditures divided by GDP deflator.

As shown in table 1, we took the price of 2016 as standard in this study, and GDP deflator in 2016 is set as 1 in China.

Average annual growth rate

Average annual growth rate is the average change of the growth per year over a certain period of time [37]. And the formula expressed as:

Average annual growth rate in n year = $\left(\sqrt[n-1]{\frac{\text{current year}}{\text{n years before}}} - 1\right) * 100\%$

Growth curve identification method

Growth curve identification methods includes Visual method, Least squares method and Growth feature method [14-15]. Growth feature method compared the characters of growth change of dynamic sequence with corresponding characters of cumulative curve to identify the growth curve. The basic principle is to choose the one that fits well both to the theoretical change rules and to the measured sequence as the optimal curve.

The curve is identified by comparing variable's growth change feature with curve's growth feature.

Equation to calculate the moving average of time series variables is as follow:

$$\bar{y}_t = \frac{\sum_{k=t-p}^{t+p} y_k}{2p+1}$$

2p+1 is the move duration, which value is increased, the sensitivity to random interference would be decreased. It also requires data of a longer duration, and mitigates the influence of y_t.

Equation to calculate the average increment of time series variables is as follow:

$$\bar{u}_t = \frac{\sum_{k=-p}^{p} k\bar{y}_{t+k}}{\sum_{k=-p}^{p} k^2}$$

For time sequence, identifying growth curve types is based on curve characteristics in the following. When the linear correlation is obvious, fitting curve type can be determined by the largest absolute value of correlation coefficient, which is calculated between the eigenvalue and the time value. Table 2 shows the identification of growth curve.

Table 2 Growth curve identification

Category	Growth characters on time variation	Curve types identification
$\bar{u}_t$	Nearly equal	Straight line
$\bar{u}_t$	Linear correlation	Quadratic parabola
$\bar{u}_t/\bar{y}_t$	Roughly consistent	Simple exponential curve
$\lg\bar{u}_t$	Linear correlation	Modified exponential curve
$\lg(\lg\bar{y}_t - \lg\bar{y}_{t-1})$	Linear correlation	Compertz curve
$\lg(\bar{u}_t/\bar{y}_t\bar{y}_{t-1})$	Linear correlation	Logistic curve

Logistic function model

Logistic function model is used to typically describe sigmoid curve's growth [40-42]. It has high credibility in describing and predicting the development process of a certain research object.

The equation of Logistic curve model is as follow:

$$\frac{dN}{dt}\frac{1}{N} = -\frac{r}{k}N + r\frac{dN}{dt}\frac{1}{N} = -\frac{r}{k}N + r$$

Where N represents the number of population, r represents the constant (growth rate), and k is the maximum capacity.

Belgian mathematician P.F.Verhulst summarized it into the following mathematical model:

$$y(t) = \frac{k}{1+e^{a-rt}}\ ,\ k > 0, a \in R, r > 0$$

Where t is the time variable, k is the saturation level, a is the parameter variable, and r is growth rate factor.

Using the existing data, the three unknown parameters k, a and r in the model can be estimated.

(1) Use three-point method (or four-point method) to estimate the value of k [38].

If there are odd numbers of points on {yt}, the value of k can be estimated by the three-point method:

$$k = \frac{2y_1 y_{\frac{n+1}{2}} y_n - (y_1 + y_n)y_{\frac{n+1}{2}}^2}{y_1 y_n - y_{\frac{n+1}{2}}^2}$$

If there are even numbers of points on {yt}, the four-point method is used to estimate the value of k:

$$k = \frac{y_1 y_n \left(y_{\frac{n}{2}} + y_{\frac{n+1}{2}}\right) - (y_1 + y_n) y_{\frac{n}{2}} y_{\frac{n+1}{2}}}{y_1 y_n - y_{\frac{n}{2}} y_{\frac{n+1}{2}}}$$

If the three-point method (or four-point method) is not good enough to estimate the appropriate value of k, the maximum difference method is used instead. In this method, k-value is 4-6 times of the maximum cost difference of THE [40].

(2) Curve fitting: SPSS21.0 statistical software was used for curve fitting in Logistic function model, and k-value was taken as the upper limit value. Model hypothesis testing was verified by Anova. According to R value of correlation coefficient, R^2 value of fitting degree and the result of Anova, comprehensive judgment is made to determine whether Logistic function model could be used for statistical analysis.

(3) Characters of Logistic curve [43]: there are three key points on the Logistic curve, which are the only inflection point t^* and two time points t_1 and t_2. The calculation formula is as follows:

$$t^* = \frac{a}{r}\ ,\quad t_1 = \frac{a-1.317}{r},\ t_2 = \frac{a+1.317}{r}$$

Firstly, the three unknown parameters k, a and r of the Logistic function model were estimated, and then the three key time points (the unique inflection point t*, the two time points t_1 and t_2) of the Logistic function model were calculated. Lastly, the growth of curve can be divided into three stages: gradual growth stage, rapid growth stage, and slow growth stage, based on the inflection point and time point of Logistic function. Its a progressive growth phase from the beginning to t_1, a rapid growth phase from t_1 to t_2, and a slow growth phase beyond t_2. The Logistic curve presented a concave increasing trend before t* and a convex increasing trend after t*, and the curve grew fastest around t* point as shown in Figure 1.

In prediction study, Guifeng Ma [37] and other researchers found that the development of THE is a process by getting slow to fast, and slow down again. The development trend of the THE is in accordance with Logistic curve. Logistic function model can be applied to predict and analyze growth trend and stage of THE objectively [41- 43].

Statistical Analysis

Firstly, the study sorts out and analyzes the original panel data of THE of 18 provinces from 2003 to 2016 by Excel 2010, and selects an appropriate growth curve model. And then, nominal value of THE is converted into actual value with GDP deflator. This research adopts the growth characteristic method to find growth characteristics of panel data through correlation coefficient and identification table of growth curve model. In the curve fitting of logistic function model, we set 2003 to 1 and 2016 to 14 as the time variable. The time series (from 2013 to 2016) was independent variable, THE was dependent variable, and K value was taken as the upper limit value, $P<0.01$ was defined as the parameter test level, and Anova was used to perform hypothesis testing on the model. According to the curve fitting index R^2 and Anova results, the curve fitting effect of Logistic function model was judged. Finally, we select Logistic curve as prediction model [44]. The development trend of THE in China was analyzed in stages, based on the inflection point theory of Logistic function model proposed by Guobing Fan [43].

Hypothesis tests of model and each coefficient had statistically significant ($P<0.001$). The model hypothesis was tested with ANOVA. The results showed that all P values were less than 0.001, indicating that the function model is statistically reliable. T test on each coefficient showed that the coefficient values in the model were not 0, and they are all statistically reliable ($P<0.001$). After fitting, the parameters were estimated. a and r values calculated, and the logistic function model of THE in each province was obtained.

Results

On March 17, 2009, the Central Committee of the Communist Party of China and the State Council released opinions to the public on deepening the reform of the medical and healthcare system. Documents presented that a sound basic medical and healthcare system covering both urban and rural residents should be established to effectively mitigate difficulties and costs of medical services, and finally provide safe, effective, convenient and affordable medical and healthcare services. Therefore, a new medical reform officially kicked off in 2009. So this study takes 2009 as the time node to discuss THE development status of 18 provinces, which is of more theoretical and practical significance.

Table 6 and figure 2 show that from 2003 to 2016, the average annual growth rate of THE in 18 provinces was 12.72%. Except Anhui (14.61%) and Liaoning (10.46%), other provinces in northeast china, north china and east China hovered around 12%.

With the exception of Sichuan (15.24%) and Guangdong (12.04%), the average annual growth rate of THE was around 14% in other provinces of south china, southwest china and northwest China. The annual average growth rate of THE in 18 provinces from 2003 to 2009 was 13.26%, faster than that from 2009 to 2016 (12.27%). Besides, annual average growth rate fluctuated greatly among provinces. From 2003 to 2016, THE in Sichuan province increased the fastest, 15.24%. Shanxi and Anhui provinces followed with 14.96% and 14.61% respectively. From 2003 to 2016, THE average annual growth rates of Liaoning, Beijing and Zhejiang, were 10.46%, 11.12% and 11.34% respectively, slower than others. From 2003 to 2009, , THE annual growth rates of Jilin, Heilongjiang, Anhui and Shanxi provinces fluctuated greatly compared to that from 2009 to 2016, with absolute percentage value changes of 9.42%, 8.82%, 6.10% and 5.94%, respectively. Zhejiang, Tianjin and Shandong showed the smallest fluctuation, with absolute percentage value changes of 0.15%, 0.91% and 0.92%, respectively.

GDP per capita, THE per capita and healthcare consumption elasticity per capita (in average) of 18 provinces from 2003 to 2016 are not much different from national values (in average). This indicates that the selected 18 provinces is a good sample representation. From 2003 to 2009 and 2009 to 2016, THE average annual growth rates per capita in 18 provinces were 12.94% and 11.00% respectively, while GDP average annual growth rates per capita in the same period were 10.31% and 7.11% respectively. From 2003 to 2016, the THE average annual growth rate per capita was 11.87%. The THE growth rates per capita in north china, northeast china and east china were slower than the average, among which, Beijing had the slowest growth rate of 7.75%, followed by Tianjin (8.09%), Shanghai (8.64%), Guangdong (9.28%) and Zhejiang (9.83%). However, THE per capita in Sichuan, Shanxi and Anhui increased faster, with 15.52%, 14.56% and 14.56% respectively. According to normality test, THE and its growth rate, GDP and its growth rate, THE per capita and GDP per capita in 18 provinces from 2003 to 2016 all follow normal distribution. Simple correlation analysis results show that, from 2003 to 2016, Pearson correlation coefficients in THE and GDP, THE per capita and GDP per capita, THE growth rate and GDP growth rate, and THE per capita growth rate and GDP per capita growth rate were 0.984, 0.982, 0.798 and 0.986 ($P=0.000<0.001$) respectively. It shows that THE (per capita) in 18 provinces changes with GDP (per capita). Economic level determines investment intensities of healthcare funding in provinces. From 2003 to 2016, the elastic coefficient of healthcare consumption per capita in 18 provinces was 0.72, which was lower than national average of 0.80. Among them, from 2003 to 2009, this coefficient of Beijing, Tianjin and Guangdong was greater than 1. This shows that healthcare investment in 18 provinces is insufficient, and the growth rate of healthcare investment per capita is generally slower than economic growth.

Table 3 show that in the correlation coefficient table of growth curves of 18 provinces, the absolute value of Logistic function correlation coefficient in 14 provinces is the highest, and correlation coefficient in only four provinces is higher than that of other functions. They are 0.986 (Beijing), 0.997 (Shandong), 0.992 (Fujian) and 0.967 (Sichuan), which is close enough to their highest value. In 18 provinces, the absolute value of Logistic function correlation coefficient is above 0.9, and only that of Heilongjiang province is less than 0.9, which is 0.892. It indicates that the Logistic function model is the best choice for cost prediction analysis. The fitting results in table 4 show that the R^2 is the degree index of curve fitting, and the values of R^2 in 33 countries are all greater than 0.9. Among them, correlation coefficients of Logistic function in Beijing (0.986), Shandong (0.997), Fujian (0.992) and Sichuan (0.967) are the highest. This indicates that the model has high fitting accuracy and it can be used to analyze and predict THE.

Above results show that Logistic function model can accurately predict THE in 18 provinces. Equations and fitting graphs of Logistic function model about THE in 18 provinces are shown in table 5.

The estimation of time points (t1 and t2) and inflection point t* can be calculated by logistic function after fitting, as shown in table 7. Its a gradual growth stage from the beginning to t1, a rapid growth stage from t1 to t2, and a slow growth stage beyond t2. Ignoring influences of policy and social factors, predicted data in table7 shows that THE development in 18 provinces has generally entered rapid growth period, and time enters this period is different. THE in the east is later than that in the central and western regions to enter rapid and slow growth periods. By 2019, 15 provinces have entered rapid growth period, and only Tianjin, Shandong and Guangdong are still in gradual growth stage. Except east china, north china and south china, other regions have entered rapid growth period. THE development in whole northeast China has entered slow growth period, while Heilongjiang, Jilin and Liaoning entered this period from 2018 to 2019. According to relevant data, THE growth rates in Heilongjiang (from 2006 to 2017), Jilin (from 2006 to 2017) and Liaoning ((from 2005 to 2017)) were 11.74%, 11.23% and 8.77% respectively, which are basically consistent with predicted results. The predicted results show that growth rates in Heilongjiang (from 2006 to 2018), Jilin (from 2006 to 2018) and Liaoning (from 2005 to 2018) are 11.85%, 11.84% and 10.45% respectively. The region entered fast growth period in chronological order is northeast (2005), east China (2008), northwest (2010), south China (2013), north China (2015) and southwest (2015). The earliest province to enter rapid growth period is Liaoning (2005), followed by Heilongjiang (2006) and Jilin (2006). From 2010 to 2013, six provinces entered THE rapid growth stage: Xinjiang Uygur Autonomous Region (2010), Shanxi province (2010), Gansu province (2013), Jiangxi province (2012), Fujian province (2010) and Guangxi Zhuang Autonomous Region (2013). From 2015 to 2018, Beijing, Zhejiang, Shanghai and Sichuan provinces entered the fast growth period in 2015, 2016, 2017 and 2015 respectively. After 2019, Yunnan province (2019), Guangdong (2021), Tianjin (in 2026) and Shandong (2027) enter this period, which makes Shandong is the last province to enter THE rapid growth stage

Durations of THE rapid growth period in 18 provinces are quite different. The earlier TEH enters fast growth period, the shorter the duration is, and vice versa. The region entering the fast growth period in chronological order is northeast (2005), east China (2008), northwest (2010), south China (2013), north China (2015) and southwest (in 2015). However, duration in this period is reverse. Average duration is north china (20 years), southwest (18 years), east china (17 years), south china (17 years), northwest (14 years), and northeast (13 years). THE development stages and duration length in rapid growth period in 18 provinces are consistent with regional economic levels. The duration gradually decreases from east to west. The longest durations were in Beijing and Zhejiang province, with 20 years, followed by Guangdong, Tianjin and Yunnan, with 19 years, after which are Shanghai and Shandong province, with 18 years. Heilongjiang, Jilin and Anhui province have the shortest THE rapid growth duration, 12 years. At the same time, the study found that, except a few cases, developments and changes of THE were very regional. For provinces in the same region or cities in the same province, the time entering THE fast growth period and its duration were relatively similar to each other. This phenomenon is most typical in northeast and northwest china. Affected by economic levels, this two regions enter THE rapid growth period earlier, and has short duration and earlier peak time.

Table 8 shows that THE average annual growth rate in 18 provinces during rapid growth period was 8.69%, which was lower than that of 12.72% from 2003 to 2016.

The THE annual growth rate during rapid growth period is regionally different, northeast china (11.38%), east china (8.56%), northwest china (8.40%), southwest china (8.02%), south China (7.96%) and north China (6.87%). In several regions, THE average growth rate during rapid period is inconsistent with economic level, greatly affected by healthcare policy orientation, urbanization rate, disappearance of demographic dividend and aging. It exceeded 10.00% in Heilongjiang, Jilin, Anhui and Shanxi provinces. On the contrary, due to spillover effect and siphonic effect of regional resources, THE annual growth rate in Gansu (5.36%), Guangdong (7.02%) and Beijing (6.69%) was generally slow. Meanwhile, it is estimated that annual average healthcare expenditure in the 18 provinces will increase from 233.330 billion yuan to 842.926 billion yuan. THE will reach 547.249 billion yuan in rising fastest year. At the end of rapid growth period, THE annual average in northeast china, north china, east china, south china, southwest china and northwest china will reach 126.403 billion yuan, 903.517 billion yuan, 1408.319 billion yuan, 1161.095 billion yuan, 788.512 billion yuan and 212.432 billion yuan respectively, with increase of 94.018 billion yuan, 655.984 billion yuan, 1017.888 billion yuan, 840.77 billion yuan, 582.436 billion yuan and 141.651 billion yuan respectively. THE in east, south and north china will have biggest increases. Provinces with highest THE were Shandong (5722.981 billion yuan), Guangdong (2018.293 billion yuan), Zhejiang (114.614 billion yuan) and Tianjin (1029.288 billion yuan), while Heilongjiang, Jilin and Liaoning provinces had relatively low expenditure of 127.190 billion yuan, 104.753 billion yuan and 147.266 billion yuan respectively at the end of this period. It shows that THE growth has nothing to do with the time early or late enter the rapid growth period. In Guangdong, Shandong and Zhejiang provinces, expenses in rapid growth period increased significantly, reaching 1,462.323 billion yuan, 4,093.144 billion yuan and 859.141 billion yuan respectively. However, Heilongjiang and Jilin show similar increase, with 94.023 billion yuan and 77.41 billion yuan respectively. According to healthcare statistic yearbook, THE growth value in Heilongjiang and Jilin from 2006 to 2017 was 90.927 billion yuan and 66.773 billion yuan respectively, which was consistent with results in this study.

Discussion

As an important indicator to reflect total healthcare inputs of a country or region [45], THE reflects changes of national, social and individual expenditure on the whole. It is necessary to analyze THE systematically and deeply to find its trend and rule. In the early stage, our research group conducted a trend fitting analysis of THE (source method) in China from 1978 to 2014. We found that our country would enter into rapid growth period around 2022, with ending around 2045. THE development in rapid growth period will last about 23 years. From 1978 to 2018, it was still in a gradual growth stage in our country. The prediction result is basically consistent with that in this article from 2003 to 2016. As is shown in this paper, in 2027, all 18 provinces will enter the rapid growth period, and end in 2045, lasting 23 years. The results suggest that we can make full use of this period to adjust to THE rapid growth in China.

We found that THE (per capita) in 18 provinces changed with GDP (per capita), and the growth rate of health investment per capita is generally slower than economic growth. By 2019, 15 provinces have entered rapid growth period with different time. THE in the east is later than that in the central and western regions to enter rapid and slow growth periods. Durations of THE rapid growth period in 18 provinces are quite different. The earlier TEH enters fast growth period, the shorter the duration is, and vice versa. THE development stages of duration length in rapid growth period are consistent with regional economic levels. The duration gradually decreases from east to west. At the same time, the study found that, except a few cases, THE developments and changes were very regional. For provinces in the same region or cities in the same province, the time to enter THE fast growth period, development stages and duration were relatively close to each other. THE growth rate and range have nothing to do with the time entering the rapid growth period.

The study found that, except for special THE development in northeastern provinces, THE in other provinces entered rapid growth period around 2009, consistent with time node of new medical reform in China. Increased financial inputs, the full coverage of social medical insurance and rigid release of medical demands, jointly have contributed in promoting the rapid increase of THE. We analyzed changes in time nodes of gradual growth stage, rapid growth stage, and slow growth stage, and found THE growth is in line with typical trend of "slow-fast-slow" growth function [44, 46]. As shown in table 8, 2015-2029 will be the key period for warning and controlling THE in China. Besides, expense developments are obviously regional. THE growth in the east show high starting expense (on average, 412.779 billion yuan per year initially), high final expense (1492.948 billion yuan per year), slow annual growth rate

(7.80%), and long intervals (average duration of 17.88 years). In the central and western regions, the characteristics are low starting expense (on average, 89.772 billion yuan per year initially), low final expense (322.908 billion yuan per year at the end), fast annual growth rate (9.40%), and short intervals (average duration of 14.50 years). During THE rapid growth period, expense characters in each province and region are consistent with regional economic levels. Among them, by 2019, the whole western region has entered the rapid THE growth period in advance, affected by development strategy of western economic, disappearance of demographic dividend, and backflow of floating population. On the contrary, THE generally enter the rapid growth period around 2015 and is expected to end at 2045 in the eastern region. This period began at 2015 with full implementation of serious disease insurance for urban and rural residents, policy implementation of drug price reform, and rigid release of massive suppressed demands for medical care. With policy implementations, eastern medical institutions achieved rapid revenue growth and scale expansion, resulting in serious siphon phenomenon of patients, medical expenses and medical staff [47]. At the same time, fiscal budget and the spillover effect of medical resources in urban agglomerations play significant roles in prolonging the rapid THE growth period in the eastern region.

Researchers studied THE development trend and stage division of each provinces based on individual conditions. Around 2005 or 2006, the three provinces in northeast china entered the rapid growth period, and end at 2018 or 2019, lasting for about 12 years. During this period, three northeastern provinces have encountered a bottleneck in economic development. Neither nation nor province should take northeast economic revitalization as policy focus to enhance economic vitality and development momentum. The central government provides financial support for peoples health care in the northeastern region. Shandong province in eastern china, which THE rapid growth period will start around 2027 and end in 2045, is almost the same as Tianjin in THE development stages. This fully indicates that sufficient government inputs can push THE into the rapid growth period. Xinjiang province is located in the westernmost part of China, and shows shorter duration and lower expense in THE growth. However, in the western region, Xinjiang was the first region to see the inflection point change of THE. In 2010, it reached the inflection point, and expenditure growth changed from gradual growth to rapid growth. In whole rapid growth period, the average annual growth rate will remain at 9.55%. According to relevant information, the predicted results agree with the actual results in Xinjiang province, which was 40,613.1 billion yuan in 2009 [48]. From 2009 to 2016, THE of Xinjiang increased at an average annual rate of 12.92%. Change of THE growth is related to west development policies, designated support, healthcare transfer payment and so on.

Through literature review, we found that the population aging [49-52], excessive reliance on out-of-pocket healthcare expenditure [53-54] and unreasonable allocation and usage of healthcare resources [55-59] are the three key issues affecting THE growth in China. According to data of United Nations, chinas elderly population will reach 17% in 2020, 24% in 2030 and 33% in 2050, far exceeding the standard (10%). China will have severe aging phenomenon in the next 30 years. Due to declining health status, disease spectrum change and increased prevalence of chronic non-communicable diseases, the elderly has increasing rigid demands for medical resources, which directly contributes to THE growth. In 1992, Murthy and Ukpolo used THE data from 1960 to 1987 in the United States to analyze and predict THE growth trend using co-integration test and error correction model. Results showed that the proportion of aged population and the number of physicians per 100,000 population had a significant impact on medical expenditure, and there was a positive correlation between population aging and medical expenditure, while a negative correlation between number of physicians and medical expenditure [60]. In 2006, foundation for applied economics research studied THE developments of some European countries in the OECD by the middle of the century, under the condition of demographic uncertainty. The study found that the population aging had become the main factors influencing THE growth in these countries. By 2025, the ratio of THE to GDP in these countries will increase by two to five percent on average [61]. R.Waldeyer and R.Bririks measured the direct medical expenses with type II diabetes in Germany, and used markov model to predict the results. They found that from 2010 to 2040, the prevalence rate of type II diabetes among people aged 40 will increase from 10.5% to 16.3%, and disease burden will increase from 11.8 billion euros in 2010 to 21.1 billion euros [62]. At the same time, low level of basic medical and healthcare services, improvement of healthcare awareness,two-child policy, high cost of hospital delivery and frequent pregnancy complications indirectly affect THE rapid growth. The proportion of out-of-pocket healthcare expenditure reflects guarantee level of healthcare service in local residents, which directly determines the severity of expensive medical treatment. Relevant studies show that the proportion of families bearing catastrophic medical expenses is positively correlated with that of out-of-pocket healthcare expenditure. For every 1% increase in out-of-pocket healthcare expenditure, the radio of families bearing catastrophic medical expenses rose by 2.2%. However, the proportion of out-of-pocket healthcare expenditure in china is far away from "15% of self-sufficiency ratio in medical expenses" [63].

Development stages of THE vary greatly among provinces in China, so the government adjust strategies to local conditions, making regionally differentiated healthcare policy strategies. As the main body of medical and healthcare service inputs, government should focus on fair investments and effective managements, in view of the coming rapid growth stage of THE. Through regional economic development, improving disposable personal income, healthcase input legislation, less hierarchical management, balanced fiscal responsibility, tax financing mode adjustment, equilibrium transfer payments, and other means, address the structural problems of THE, it makes effort to solve structural problems of THE. The above strategies should reach the following achievements: (1) The target location of healthcare inputs is clear, and the low-income groups and poor people are as main subsidy subjects, with public healthcare as the key inputs; (2) The priority of local financial budgets should be given to basic healthcare services; (3) Governments improve public access to primary healthcare services and provide free medical services to low-inccome groups; (4) Strengthen publicity efforts in healthcare education to improve residents health care awareness and healthcare quality; (5) Efforts should be made to improve basic public healthcare services, especially in preventing and controlling chronic non-communicable diseases.

The study has several strengths. Trend extrapolation is the main method of prediction models [64]. The study used it and found that Logistic function model is currently suitable for THE prediction in China, with a good prediction output. We carried out comparative analysis of interprovincial expense, explicitly described development trends and three stage characteristics of THE in each region and province, and found the key period for early warning to prevent rapid cost growth. Results provide the important theoretical basis for comprehensive and complete understanding of THE developments in China.

The present study has some limitations that should also be clarified. First, any model is based on historical data, however a complex economic system will change with time and environment. Therefore, from the perspective of prediction models, dynamic changes of some confounding factors, such as economic and social policies, cannot be accurately evaluated in the prediction. Second, limited by data accessibility, as the sample was collected only from 18 provinces, the findings in the current study may not be generalized to other13 provinces in China. In the future, the study will be gradually expanded to conduct comprehensive analysis in 31 provinces.

Conclusions

The study used Logistic function model to analyze and predict THE development trend of 18 provinces, after stripping price factors. We found that THE growth is in line with typical trend of "slow-fast-slow" growth function. 2015-2029 will be the key period for early warning and controlling THE in China. In 2027, all 18 provinces will enter the rapid growth period, and end at 2045. In this period, rapid growth in total healthcare expense will last for about 23 years, with an average annual growth rate of

8.69%. Besides, expense developments are obviously regional. TEH development stage and duration of rapid growth period is consistent with the regional economic level. The government should make full use of this period from 2015 to 2029, making policy preparations to respond THE rapid growth in our country. Based on stage characteristics of provincial THE development, government adjust strategies to local conditions, making regionally differentiated healthcare policies. It should control THE rapid growth in a reasonable scope, and consistent with social economy. The study provides scientific reference for formulating specific and different macro healthcare policies and strategies in the future.

Abbreviations

GDP: gross domestic product; THE: total health expenditure.

Declarations

Acknowledgments

The authors would like to thank Dr. Xiuyun Wu for the language revision to the manuscript, and professor Wengui Zheng for his insightful comments. We would like to thank the participating institutions and the managers for their supports in the data collection.

Funding

The present study was supported by the National Natural Science Foundation of China (71273191; 71673202), and by the Natural Science Foundation of Shandong Province (ZR2014GL012; ZR2011GM005).

The content is the responsibility of the authors and does not necessarily represent the views of the funding agencies. These funding bodies had no role in the design of the study, data collection, data analysis, interpretation of data, writing of the manuscript, or the decision to submit the article for publication.

Availability of data and materials

DE-identified interview transcripts are available on request from the corresponding author.

Authors contributions

GFM, ANM designed the study. XL analyzed the data and interpreted the results. LJQ wrote and revised the draft of the manuscript. YW and QL coordinated the data collection. All authors read and approved the final manuscript.

Competing interests

The authors declare they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Ethical approval for conducting the study was obtained from the ethics committee of Weifang Medical University. All the participating institutions provided consents before any data for the study were collected.

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Schedule

Table 1 GDP deflator for 2003-2016 in China

Year	GDP deflator
2003	0.604
2004	0.646
2005	0.671
2006	0.697
2007	0.752
2008	0.810
2009	0.809
2010	0.865
2011	0.936
2012	0.958
2013	0.980
2014	0.988
2015	0.989
2016	1.000

Table 2 Growth curve identification

Category	Growth characters on time variation	Curve types identification
$\bar{u}_t$	Nearly equal	Straight line
$\bar{u}_t$	Linear change	Quadratic parabola
$\bar{u}_t/\bar{y}_t$	Roughly consistent	Simple exponential curve
$\lg\bar{u}_t$	Linear change	Modified exponential curve
$\lg(\lg\bar{y}_t - \lg\bar{y}_{t-1})$	Linear change	Compertz curve
$\lg(\bar{u}_t/\bar{y}_t\bar{y}_{t-1})$	Linear change	Logistic curve

Table 3 Correlation number of growth curves in 18 provinces (correlation coefficient r and value of time series t)

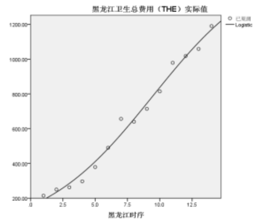
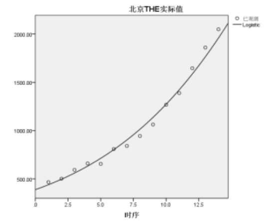
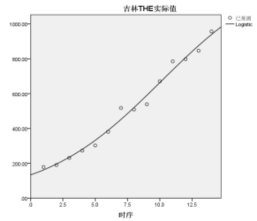
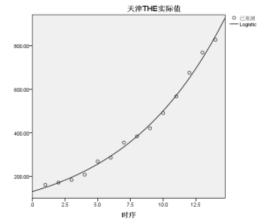
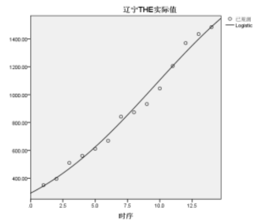
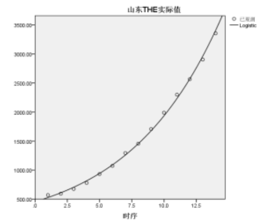
Provinces	u_t	$\bar{u}_t/\bar{y}_t$	lg$\bar{u}_t$	lg(lg$\bar{y}_t$-log$\bar{y}_{t-1}$)	lg($\frac{\bar{u}_t}{\bar{y}_t\bar{y}_{t-1}}$)
Heilongjiang	0.460	-0.684	0.523	-0.472	0.892 *
Jilin	0.579	-0.757	0.603	-0.628	0.900 *
Liaoning	0.842	-0.680	0.865	-0.424	0.934 *
Beijing	0.973	0.879	0.990 *	0.639	0.986
Tianjin	0.942	-0.135	0.962	0.263	0.985 *
Shandong	0.998 *	-0.420	0.981	0.007	0.997
Shanghai	0.945	-0.080	0.945	0.138	0.986 *
Zhejiang	0.934	-0.393	0.927	-0.131	0.990 *
Fujian	0.987	0.793	0.994 *	0.910	0.992
Anhui	0.860	-0.962	0.858	-0.793	0.966 *
Jiangxi	0.959	-0.397	0.911	0.023	0.972 *
Guangdong	0.952	0.944	0.985	0.858	0.991 *
Guangxi	0.777	-0.582	0.787	-0.310	0.963 *
Sichuan	0.974 *	-0.243	0.949	0.944	0.967
Yunnan	0.904	-0.029	0.898	0.005	0.965 *
Shanxi	0.924	-0.770	0.880	-0.187	0.978 *
Gansu	0.958	-0.589	0.904	-0.173	0.977 *
Xinjiang	0.963	-0.894	0.976	-0.618	0.978 *
18 provinces	0.989 *	-0.303	0.986	-0.38	-0.987
the whole nation	0.968 *	0.158	0.951	0.306	-0.911

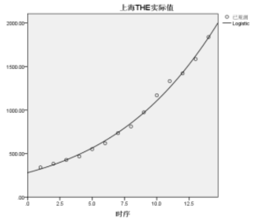
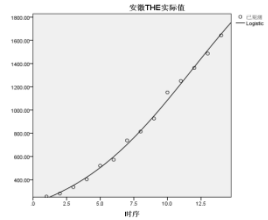
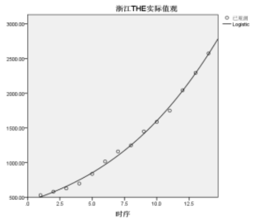
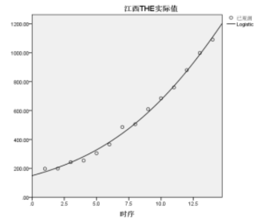
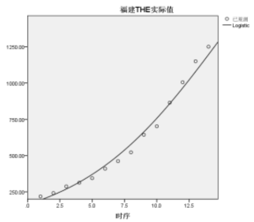
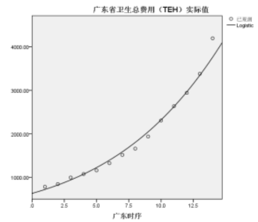
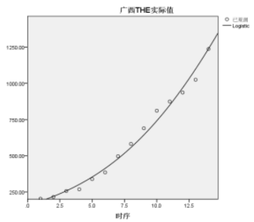
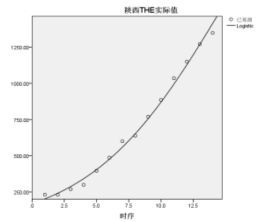
Note: the * in the table indicates the highest correlation coefficient.

Table 4 Fitting and parameter estimation of THE in logistic function model

Regions	Provinces	test of goodness of fit		analysis of variance		t test for each coefficient		estimate of parameter	
		R	R2	F	P	t	P	Con	b1
Northeast	Heilongjiang	0.993	0.986	825.926	0.000	122.794	0.000	0.006	0.791
	Jilin	0.994	0.987	934.399	0.000	140.021	0.000	0.007	0.804
	Liaoning	0.995	0.990	1149.794	0.000	177.358	0.000	0.003	0.826
North China	Beijing	0.994	0.988	975.427	0.000	243.077	0.000	0.002	0.879
	Tianjin	0.997	0.993	1825.282	0.000	310.228	0.000	0.008	0.871
East China	Shandong	0.999	0.997	4002.082	0.000	431.061	0.000	0.002	0.864
	Shanghai	0.998	0.996	2766.229	0.000	362.368	0.000	0.003	0.865
	Zhejiang	0.998	0.996	2754.973	0.000	381.625	0.000	0.002	0.872
	Fujian	0.993	0.987	911.092	0.000	167.806	0.000	0.006	0.835
	Anhui	0.998	0.977	3530.575	0.000	276.722	0.000	0.005	0.807
	Jiangxi	0.996	0.992	1449.247	0.000	226.491	0.000	0.006	0.845
South China	Guangdong	0.994	0.989	1070.496	0.000	238.648	0.000	0.002	0.872
	Guangxi	0.995	0.990	1156.568	0.000	198.494	0.000	0.006	0.843
Southwest	Sichuan	0.997	0.994	2035.824	0.000	266.028	0.000	0.003	0.844
	Yunnan	0.996	0.992	1610.002	0.000	285.918	0.000	0.005	0.870
Northwest	Shanxi	0.996	0.991	1385.844	0.000	194.250	0.000	0.006	0.826
	Gansu	0.996	0.993	1634.661	0.000	235.684	0.000	0.010	0.842
	Xinjiang	0.998	0.996	2682.991	0.000	284.354	0.000	0.007	0.833
18 provinces	-	0.999	0.998	6781.809	0.000	676.404	0.000	0.000	0.885
the whole nation	-	0.998	0.996	3010.774	0.000	479.86	0.000	0.000	0.892

Table 5 Equation and fitting graphs of THE in logistic function model

Number	Provinces	Logistic function model equation	Logistic function fitting graph	Number	Provinces	Logistic function model equation	Logistic function fitting graph
1	Heilongjiang	Y（t）=1573.25/(1+e2.24-0.23t)		4	Beijing	Y（t）=9875.97/(1+e2.98-0.13t)	
2	Jilin	Y（t）=1338.78/(1+e2.24-0.22t)		5	Tianjing	Y（t）=12856.58/(1+e4.63-0.14t)	
3	Liaoning	Y（t）=2127.79/(1+e2.08-0.17t)		6	Shandong	Y（t）=69872.45/(1+e4.94-0.15t)	

Number	Provinces	Logistic function model equation	Logistic function fitting graph	Number	Provinces	Logistic function model equation	Logistic function fitting graph
7	Shanghai	Y（t）=11028.00/(1+e3.50-0.15t)		10	Anhui	Y（t）=2696.83/(1+e2.60-0.21t)	
8	Zhejiang	Y（t）=14215.76/(1+e3.35-0.14t)		11	Jiangxi	Y（t）=3391.89/(1+e3.01-0.17t)	
9	Fujian	Y（t）=2660.35/(1+e2.77-0.18t)		12	Guangdong	Y（t）=25159.98/(1+e3.92-0.14t)	
13	Guangxi	Y（t）=3892.41/(1+e3.15-0.17t)		16	Shanxi	Y（t）=3081.48/(1+e2.92-0.19t)	

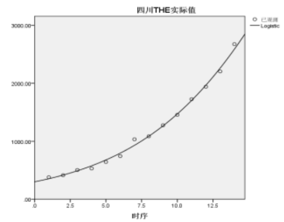
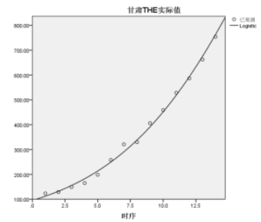
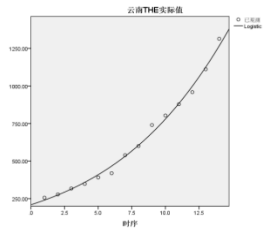
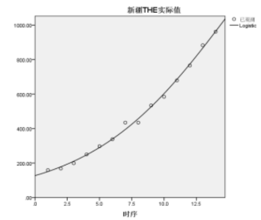
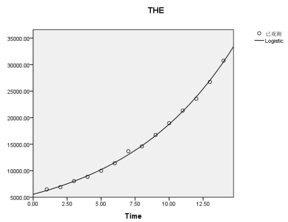
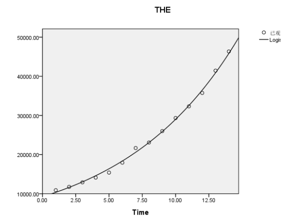
Number	Provinces	Logistic function model equation	Logistic function fitting graph	Number	Provinces	Logistic function model equation	Logistic function fitting graph
14	Sichuan	Y（t）=11943.15/(1+e3.58-0.17t)		17	Gansu	Y（t）=2534.67/(1+e3.23-0.17t)	
15	Yunnan	Y（t）=7883.10/(1+e3.67-0.14t)		18	Xinjiang	Y（t）=2187.67/(1+e2.73-0.18t)	
19	18 provinces	Y（t）=6173517.32 /(1+e7.01-0.12t)		20	the whole nation	Y（t）=1198346.57/(1+e4.86-0.11t)	

Table 6 Average growth rates of THE in 18 provinces

Regions	Provinces	Average growth rates		
		2003-2016	2003-2009	2009-2016
Northeast	Heilongjiang	11.50	16.33	7.51
	Jilin	12.60	17.77	8.35
	Liaoning	10.46	13.41	8.00
North Chin	Beijing	11.12	8.57	13.35
	Tianjin	11.76	12.25	11.34
East China	Shandong	13.29	13.79	12.87
	Shanghai	11.61	10.70	12.39
	Zhejiang	11.34	11.42	11.27
	Fujian	12.69	10.76	14.37
	Anhui	14.61	17.93	11.83
	Jiangxi	13.86	15.77	12.25
South China	Guangdong	12.04	9.44	14.33
	Guangxi	14.47	15.35	13.72
Southwest	Sichuan	15.24	17.07	13.70
	Yunnan	12.96	12.36	13.47
Northwest	Shanxi	14.96	18.20	12.26
	Gansu	14.34	16.27	12.72
	Xinjiang	14.59	16.57	12.92
18 provinces	-	12.72	13.26	12.27
the whole nation	-	11.77	12.13	11.47

Table 7 THE development inflection points and time points in 18 provinces

Regions	Provinces	Data start years	Inflection point The number of years			Year of inflection point		
			t_1	t_*	t_2	t_1	t_*	t_2
Northeast	Heilongjiang	2003-2016	4.01	9.74	15.47	2006	2012	2018
	Jilin	2003-2016	4.20	10.18	16.17	2006	2012	2018
	Liaoning	2003-2016	4.49	12.24	19.98	2005	2012	2019
North Chin	Beijing	2003-2016	12.79	22.92	33.05	2015	2025	2035
	Tianjin	2003-2016	23.66	33.07	42.48	2026	2036	2045
East China	Shandong	2003-2016	24.15	32.93	41.71	2027	2036	2045
	Shanghai	2003-2016	14.55	23.33	32.11	2017	2026	2035
	Zhejiang	2003-2016	14.52	23.93	33.34	2016	2026	2036
	Fujian	2003-2016	8.07	15.39	22.71	2010	2017	2025
	Anhui	2003-2016	6.11	12.38	18.65	2008	2014	2020
	Jiangxi	2003-2016	9.96	17.71	25.45	2012	2020	2028
South China	Guangdong	2003-2016	18.59	28.00	37.41	2021	2031	2040
	Guangxi	2003-2016	10.78	18.53	26.28	2013	2020	2028
Southwest	Sichuan	2003-2016	13.31	21.06	28.81	2015	2023	2031
	Yunnan	2003-2016	16.81	26.21	35.62	2019	2028	2038
Northwest	Shanxi	2003-2016	8.44	15.37	22.30	2010	2017	2024
	Gansu	2003-2016	11.25	19.00	26.75	2013	2021	2028
	Xinjiang	2003-2016	7.85	15.17	22.48	2010	2017	2024
18 provinces	-	2003-2016	46.63	57.41	68.19	2048	2059	2070
the whole nation	-	2003-2016	31.04	42.56	54.09	2033	2044	2056

Table 8 Estimates of THE in China

Regions	Provinces	Year span	Gradual growth stage	Rapid growth stage	Slow growth stage	THE (hundred million yuan/year)			Average annual growth rate（%）
						t1	t*	t2	
Northeast	Heilongjiang	2003-2016	-2006	2006-2018	2018-	331.67	810.22	1271.90	11.85
	Jilin	2003-2016	-2006	2006-2018	2018-	273.43	656.00	1047.53	11.84
	Liaoning	2003-2016	-2005	2005-2019	2019-	366.44	696.62	1472.66	10.45
North Chin	Beijing	2003-2016	-2015	2015-2035	2035-	2131.76	4962.67	7777.46	6.69
	Tianjin	2003-2016	-2026	2026-2045	2045-	2818.90	6845.54	10292.88	7.05
East China	Shandong	2003-2016	-2027	2027-2045	2045-	16298.37	37725.18	57229.81	7.23
	Shanghai	2003-2016	-2017	2017-2035	2035-	2455.94	5789.47	8932.66	7.44
	Zhejiang	2003-2016	-2016	2016-2036	2036-	2834.73	7143.42	11426.14	7.22
	Fujian	2003-2016	-2010	2010-2025	2025-	556.44	1283.64	2121.31	9.33
	Anhui	2003-2016	-2008	2008-2020	2020-	559.62	1294.51	2062.93	11.48
	Jiangxi	2003-2016	-2012	2012-2028	2028-	720.73	1738.33	2726.29	8.67
South China	Guangdong	2003-2016	-2021	2021-2040	2040-	5559.70	13459.15	20182.93	7.02
	Guangxi	2003-2016	-2013	2013-2028	2028-	846.79	1858.68	3038.97	8.89
Southwest	Sichuan	2003-2016	-2015	2015-2031	2031-	2419.92	5941.72	9484.41	8.91
	Yunnan	2003-2016	-2019	2019-2038	2038-	1701.59	3882.43	6285.83	7.12
Northwest	Shanxi	2003-2016	-2010	2010-2024	2024-	609.57	1486.84	2400.55	10.29
	Gansu	2003-2016	-2013	2013-2028	2028-	1041.65	1852.99	2279.55	5.36
	Xinjiang	2003-2016	-2010	2010-2024	2024-	472.21	1077.43	1692.86	9.55
18 provinces	-	2003-2016	-2048	2048-2070	2070-	1135443.97	2825014.24	4688853.80	6.66
the whole nation	-	2003-2016	-2033	2033-2056	2056-	227687.72	527615.64	894558.50	6.13

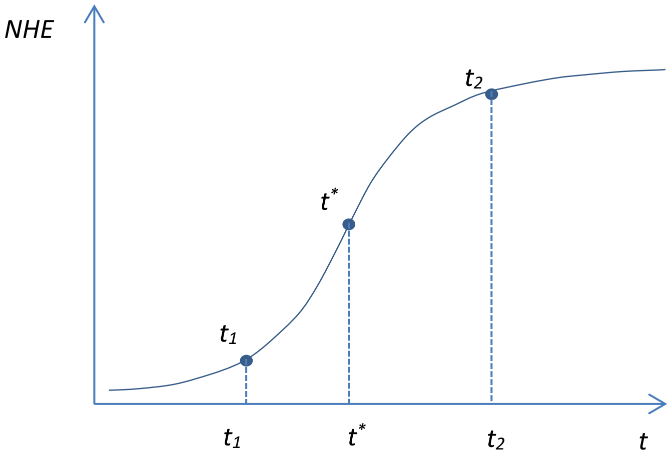


Figure 1 Characters of Logistic curve

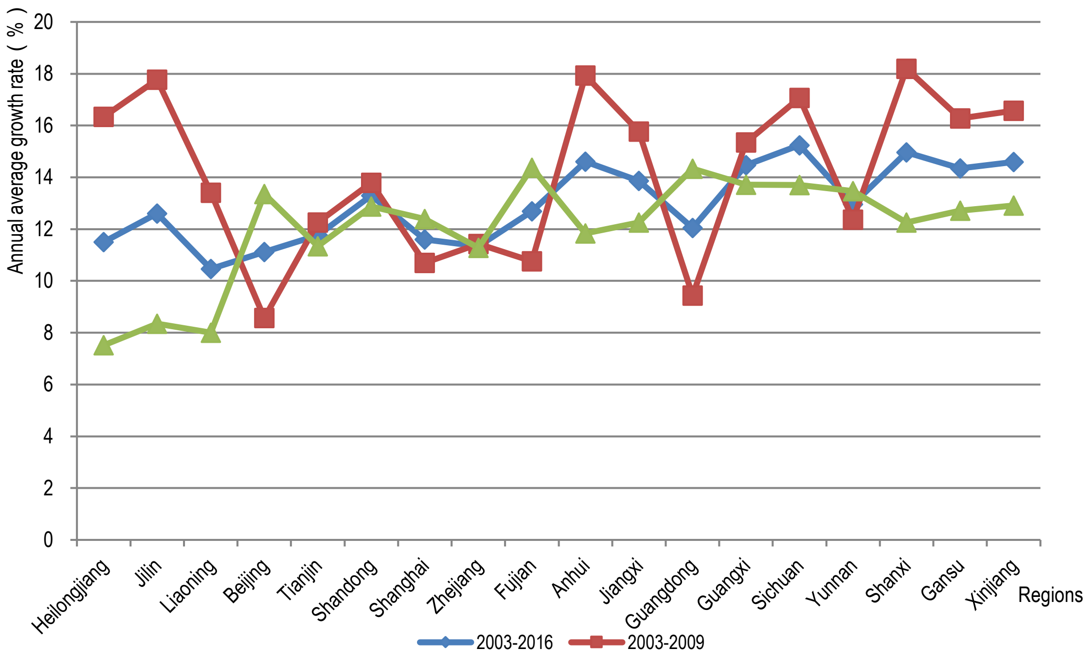


Figure 2 Average growth rates of THE in each stage

Figures

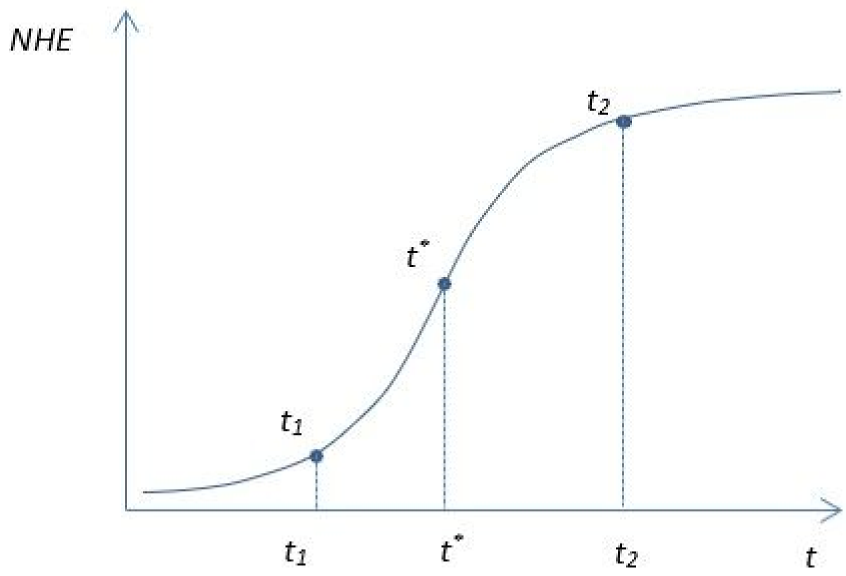


Figure 1 Characters of Logistic curve

Figure 1

Characters of Logistic curve

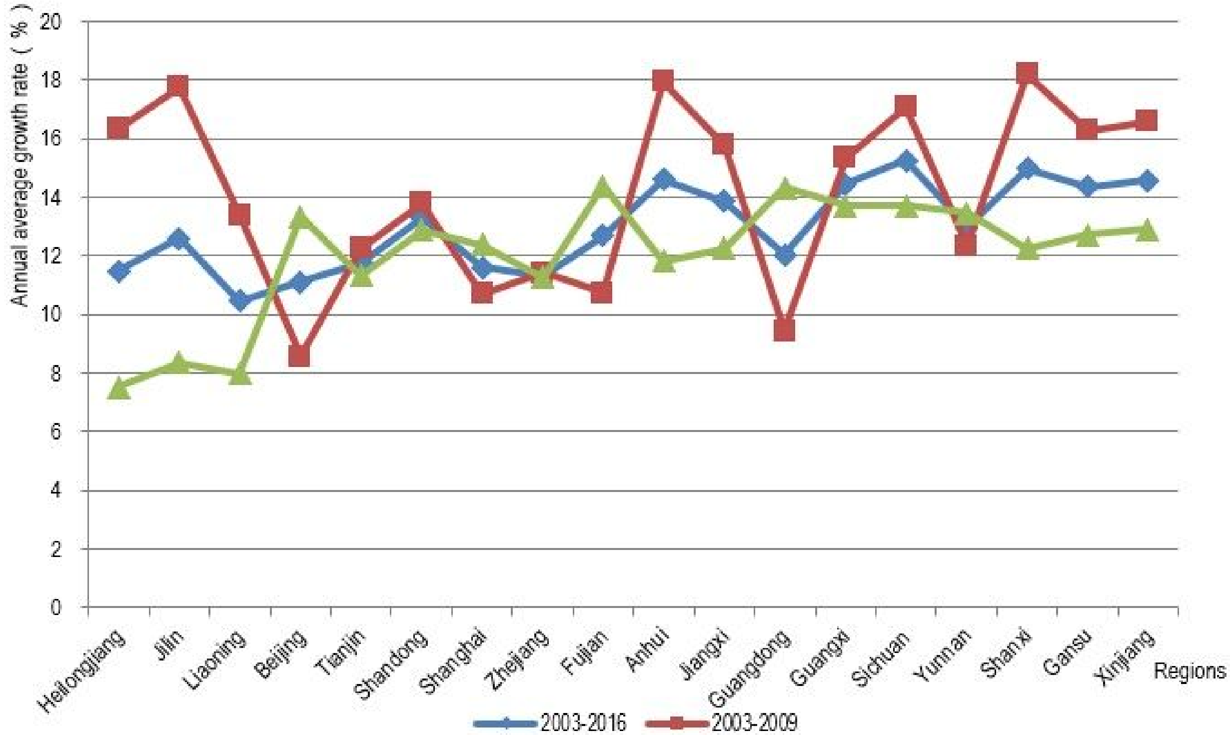


Figure 2 Average growth rates of THE in each stage

Figure 2

Average growth rates of THE in each stage