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Research on Population Projection of High School Students and their Demand for Educational Resources in the Context of Dual Circulation

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Abstract: High school is a link between compulsory education and higher education in China. The precise projection of high-school population is also a key premise of the rational high-school educational-resource allocation which is of importance to educational quality. Improving the education quality can promote the population quality and increase the accumulation of human capital to create a new geographic dividend and contribute to the new development model of dual circulation. Encouraging governments at all levels to increase financial investment in education is a demand-side dimension to study the demand for high-school educational resources. When promoting human capital accumulation, China should transform the reliance of its economic growth from "demographic dividend" to "talent dividend" to build a new development model of dual circulation. This paper built a Leslie model by matrix laboratory (MATLAB) to predict the high-school population and study the demand for high-school educational resources.

Keywords: Dual circulation; High schools; Demand for education resources; Leslie model

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1. Introduction

Since May 2020, General Secretary Xi Jinping lay emphasis on "gradually form a new development model in which domestic and foreign markets boost each other with the domestic market as the mainstay." In March 2021, the 14th Five-Year Plan for Economic and Social Development and Long-Range Objectives through the Year 2035 in the People's Republic of China was officially passed by the National People's Congress. As an important content, the new development model of dual circulation was also included in the 14th Five-Year Plan, showing that it has become a new direction of the country's economy. In the context of dual circulation, improving education quality can promote population quality and human capital accumulation to form a new demographic dividend and to boost the economy. A rational allocation of educational resources is of importance to the improvement of education quality and it requires a premise of a precise projection of school-age population. Based on the background of dual circulation, this paper studied the high-school population project and the demand for educational resources.

As it is a link between compulsory education and higher education, the high school boasting the functions of providing talents for higher education and cultivating high-quality labor force for manufacturing industry plays a decisive role in improving labor's education attainment and human capital quality. The growth of these two aspects has provided talents for the economic development. In China, high

schools include two types, namely Regular High Schools and Secondary Technical Vocational Schools (Medium level). The second type is divided into Specialized Secondary Schools, Vocational High Schools and Skilled Workers Schools. This paper selected the overall population of high-school population as the research objective.

As for high schools, the demand prediction in the next several years can help allocate the demand for educational resources and make a plan for the in-school educational resources, which is conducive to improving teaching skills and qualities and providing better education. As for high school students and their family, a rational education arrangement and sufficient education resources can satisfy individual demand for education, increase years of education and promote human capital accumulation, thus improving students' risk resistance capabilities to face the changes of labor demand. Moreover, individual and family capital accumulation can be raised in the long term. The structure and scale of school-age population and their changes are related to the adjustment of the demand for educational resources. The increase of school-age population can lead to a shortage of educational resources, indicating that the individual demand for education cannot be met. On the other hand, the decrease of school-age population can result in a waste of educational resources or their remaining idle. The misplaced demand and supply of these resources can cause a decrease of the overall teaching efficiency, failing to reach the original teaching goals. This paper will predict the high-school population, analyzed the demand for educational resources in high schools and proposed feasible suggestions, aiming to adjust the education arrangement and quality of high schools, to increase the human capital accumulation of China, and to promote the new development model of dual circulation.

This research may include three following contributions. First, the combination of demography and human capital theory enriches the research perspectives. Second, the high-school population project and the demand for educational resources in high schools acting as the link between basic education and higher education are of importance to improving human capital accumulation. Third, the study on the allocation of high-school educational resources in provinces can clearly show the current differences of the high-school education among regions; and the prediction of the changes of the future population can provide suggestions for each region to optimize educational resources and narrow the gap of the educational resources.

2. Literature review

In terms of population projection, scholars at home and abroad have obtained rich experience and achievements such as creating many models for it. In 1798, Malthus proposed Malthusian growth model, which presumed the relative growth rate of the population is a constant; as the population grows exponentially, it is also called the population exponential growth model; and this model can roughly predict the population in a short term but the result deviates from the actual condition [1]. In 1838, Verhulst revised Malthus's model by considering the changes and limitations of natural environment and changing the original constant into a variable which decreased with time and finally stabilized at a fixed value; the revised one is called Logistic model; and as it can better fit the real conditions, the model has become a typical one for studying the growth of biological populations in a limited space [2]. Leslie, an Australian statistician built the Leslie matrix (also called the Leslie model) by discretizing the time, grouping the age, and predicting the population with matrix; and this model has evolved into a discrete mathematical random model used to predict population size and age structure [3]. The common models at present evolved from the Malthusian growth model, the Logistic model, and the Leslie model by upgrading the algorithms. There are many factors influencing education. Population size and structure can exert significant effects on education. Schultz, a representative of human capital theory, believed that the change of school-age population could directly influence the supply of educational resources [4].

Although domestic research on population project started late, many scholars and experts studied and explored the classification methods for population project according to the population characteristics of Chinese cities, making them better applied into this field. Li, used CPPS software to project the number of students receiving basic and compulsory education from 2016 to 2035 and estimated the scale of faculty, teaching fund and dormitories based on the population census data in 2010 from the perspective of making a strategic plan for compulsory education. Her research shows that the school-age population in the period of compulsory education will increase in around 2022, rapidly expand in a short term, peak at 2030 and them drop [5]. Zhao, applied the Leslie model and a composite fertility rate model based on random distribution to predict the school-age population in different provinces of China under the policy of universal two-child policy according to data of different ages from The Sixth National Census. It is found in the research that the policy has a great effect on the population before school and in the period of compulsory education, but the effect will not last long; besides, there are large differences in the trending and changing amplitude of school-age population among different provinces; and this factor needs to be considered fully in the education planning [6].

There is a little domestic literature on how to allocate educational resources by the school-age population project. Liang, concluded from the sixth national population census in 2010 that the population size of primary and middle schools would boom in 2021 and 2017 [7]. Liu, believed that the investment in education has a significantly positive influence on the economic growth as for the whole country [8].

It can be seen from the previous literature that there are several models for population project at present and they become increasingly mature. Besides, the methods based on different theories have their own advantages and ranges of application. Additionally, although there exist unavoidable errors in predicting the future population size and structure based on current data, the prediction can reflect the development trend of population in a certain period. But the researches focus more on the school-age population of preschool education and compulsory education and less on the population projection of high-school population and its demand for educational resources. This paper aims to propose feasible suggestions for adjusting the education arrangement and quality of high schools in the context of dual circulation by predicting the high-school population and analyzing the demand for educational resources in the future. Besides, it also sets the goal of promoting the human capital accumulation of China and the new development model of dual circulation.

3. The model of high-school population projection

As the new development model of dual circulation was adopted from 2020 to the future, an important period when the time frames of the two centuries converge, and 2021 and 2050 are the key points in this period, this paper chose the high-school population in the period of 2021-2050 to make a prediction.

This paper build a Leslie model based on MATLAB software to predict the number of high-school students in the next 30 years according to the sixth population census. Building a Leslie model needs to discretize the population, divide it into n groups of ages at the same interval. Meanwhile, the interval should be verified whether it satisfies the transferring process. It is presumed in this model that the population will not change with the limitations of natural resources and the survival and fertility rates within age groups are only related to age groups. As mathematical software, MATLAB featuring a high efficiency of value circulation and a complete image function adopts matrix manipulation. It is very appropriate for the construction of Leslie models to predict the high-school population and analyze the demand for educational resources. The process of building the model is as follows.

3.1. Model presumption

Reform and opening up is the fundamental policy of China. In the context of dual circulation, China will open its door wider. But only in terms of population, here, it is presumed as a close population system regardless of immigrants and emigrants, that is, the change of nationality is not considered.

It is presumed that in the period of 2021-2050, there will not incidents that affect the population and its change such as wars and serious disasters. Besides, the population change is not constrained by natural resources. The time unit is year and the group interval is one year. Population from 1 to 100 years old and above is divided into 100 age groups while o year old refers to new-born babies. The change of birth rate, death rate and gender proportion brought by population mobility within domestic regions is not taken into account. The school-age population repeating a grade is excepted.

3.2. Model construction

Variables in the Leslie model include age-specific fertility rate, age-specific death rate and sex ratio at birth. Age-specific fertility rate (ASFR) is the ratio of the number of babies in each age group to the total number of women in that age group. Age-specific death rate (ASDR) refers to the proportion of female deaths in each age group to the total number of females in that age group. Age-specific survival rate (ASSR) can be calculated by ASDR. The sex ratio at birth (SRB) means the ratio of the number of male newborn babies to the number of female newborn babies in the birth population.

The description of symbols are as follows:

xi(t) is the number of the females in Group i in Year t in the country, and i = 1, 2, …, 100.

bi(t) represents the birth rate of the females in Group i in the country, the reproductive age $i \in [i_1, i_2]$. When $i \notin [i_1, i_2]$, bi=0. According to the national population census, the range of young females' reproductive ages is [18,49].

di(t) refers to the death rate of the females in Group i in Year t.

si(t) symbolizes the survival rate of the females in Group i in Year t, namely si(t)=1-di(t).

w(t) means the proportion of the female babies

The population relationship of different age groups in the country can be obtained during the forecast period.

In Year t+1, the first group of females, that is, the newborn female babies in the previous year:

$$x(t+1)=\sum_{i=1}^{n} b_i w(t) x_i(t) \qquad (1)$$

In Year t+1, the females in Group i+1 is the number of survivors in Group i in Year t:

$$x_{i+1}(t+1)=s_i x_i(t),\ i=1,2,\ldots n-1; t=1,2\ldots \qquad (2)$$

Then the total female population is $X(t)=\left[x_1(t), x_2(t), x_3(t), \cdots x_n(t)\right]^T$.

Build a Leslie matrix, and satisfy $x(t+1)=Lx(t)$. Where:

$$L=\begin{vmatrix} wb_1 & wb_2 & \cdots & wb_{n-1} & wb_n \\ s_1 & 0 & \cdots & 0 & 0 \\ 0 & s_2 & \ddots & \vdots & \vdots \\ \vdots & \vdots & \ddots & 0 & 0 \\ 0 & 0 & \cdots & s_{n-1} & 0 \end{vmatrix} \qquad (3)$$

When L and are known, for any t= 1, 2, …, n, the prediction formula can be obtained according to the recursion formula:

$$X(t)=L^t X(0) \qquad (4)$$

According to the sixth national population census in 2010, the proportion is 0.4588.

Then the complete prediction data of the total population can be obtained according to the sex ratio. The Compulsory Education Law stipulates that parent, or the statutory guardian should send the children who are above 6 years ole to schools to receive and finish compulsory education; and that children from the region which lacks educational resources can go to schools at seven years old. In combination of schools' autumn admissions in China, the admission age of primary schools is universally six years old, the students who are receiving compulsory education are aged from 6 to 14 years old, and the students who are receiving high-school education are aged from 15 to 17 years old. To make analysis convenient, the situation of school-age population repeating a grade is excepted. Restricting the age according to the prediction data of the total population can get the prediction data of the high-school population.

4. Project results

4.1. The prediction result of the total population

According to the latest news from the National Bureau of Statistics on 29th April, 2021, the Chinese population in 2020 keeps growing, which is consistent with the prediction. Thus, this prediction method can be considered credible basically. Next, the prediction result and real data need to be compared to further test whether the prediction method is credible or not. The comparison result is shown in **Table 1**.

Table 1. Comparison results

Year	2011	2012	2013
The actual population (ten thousand people)	134735	135404	136072
The predicted population (ten thousand people)	131988	132560	133108
Error	2.03%	2.10%	2.17%

Comparing the China Statistical Yearbook from 2011 to 2013, the error rate is around 2%. China has successively carried out the selective two-child policy and the universal two-child policy after the six national population census in 2010, which has exerted great impact on the population size and structure. Besides, data sources are different. Based on the two reasons above, the two-percent error rate can be accepted so this prediction method can be considered credible.

According to the prediction of the national total population from 2021 to 2050, a prediction graph of the national total population can be drawn. The data from 2010 to 2020 are compared with the actual data and the comparison result is also shown in Table 1. The data from 2021 to 2050 are the prediction of the national total population in the next 30 years. The prediction of the national total population is shown in **Figure 1**.

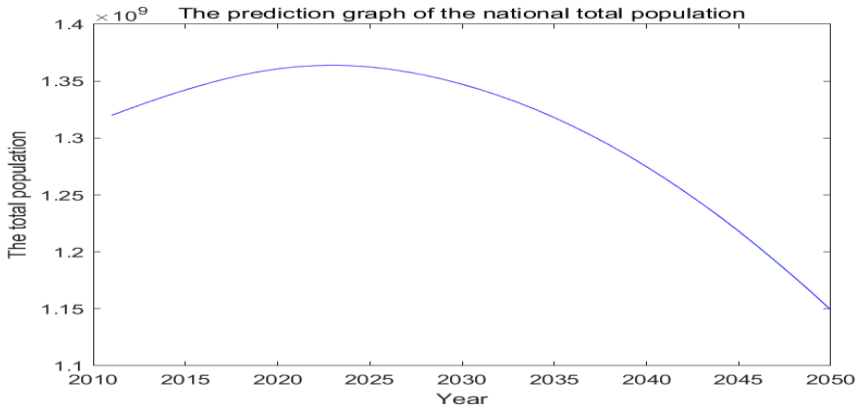

Figure 1. The prediction graph of the national total population

It can be seen from the graph above that the total population shows an upward trend before 2023 and then it drops year on year.

4.2. The prediction result of high-school population

School-age population refers to the number of people who reach the prescriptive school age in the permanent resident population of a certain region. The high-school education system of most regions in China features a three-year schooling. The Compulsory Education Law stipulates that parents or the statutory guardian should send the children who are above 6 years ole to schools to receive and finish compulsory education; and that children from the region which lacks educational resources can go to schools at seven years old. In combination of schools' autumn admissions in China, the admission age of primary schools is universally six years old, the students who are receiving compulsory education are aged from 6 to 14 years old, and the students who are receiving high-school education are aged from 15 to 17 years old. According to the presumption that the situation of school-age population repeating a grade is excepted, the calculated population from 15 to 17 years old is the high-school population based on the prediction of the national total population and the age limitations. The prediction result is shown in **Table 2**.

Table 2. The predicted high-school population from 2021 to 2050

Year	Number (ten thousand people)	Year	Number (ten thousand people)
2021	3914.64	2036	3323.43
2022	4016.05	2037	3220.02
2023	4185.77	2038	3112.81
2024	4226.61	2039	3005.28
2025	4299.19	2040	2901.79
2026	4319.47	2041	2799.50
2027	4099.05	2042	2703.65
2028	3855.44	2043	2623.86
2029	3616.66	2044	2556.93
2030	3617.25	2045	2504.02
2031	3609.88	2046	2457.63
2032	3597.73	2047	2410.01
2033	3563.90	2048	2366.36
2034	3503.10	2049	2323.40
2035	3420.42	2050	2289.23

It can be seen from the prediction results and the prediction graph of high-school population above that the population is increasing year on year from 2021 and reaches 43.19 million in 2026. However, it starts to dramatically drop from 2026 and decreases stably from 2029.The prediction of high-school population is shown in **Figure 2**.

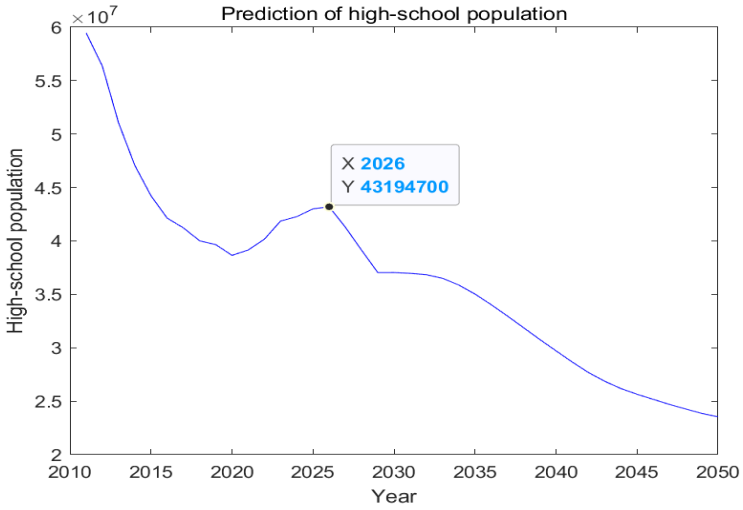

Figure 2. The prediction graph of high-school population

5. Analysis of demand for educational resources

As for schools, the allocation of educational resources means the sum of all the resources occupied, used and consumed in the education process. It includes the human resources represented by faculty, material resources like school buildings and teaching facilities, and financial resources like educational appropriations. The financial resource is the monetary representation of human and material resources. Educational appropriations include operating expenses and public expenditure of education. The former one is the main part of educational appropriations and its scale determines how much money is invested in education, and thus it is a guarantee of undertaking normal teaching and education in schools [9]. This paper took the teacher-student ratio as the index of measuring the human resources, the school building areas as the index of measuring the material resources and the educational appropriations as the index of measuring the financial resources. Due to the lack of corresponding measurement index, this paper analyzed the demand for faculty and school buildings.

5.1. Analysis of the demand for faculty

The teacher-student ratio is an important index to measure education quality and it reflects the allocation of educational resources. When it comes to the estimation of the demand for high-school faculty, the "Notice of the Central Organization, the Ministry of Education, and the Ministry of Finance on Unifying the Standards for the Establishment of Urban and Rural Primary and Secondary School Staff" (Central Editing Office issued [2014] No. 72) can be referenced to unify the standards for the establishment of elementary school staff in counties, towns, and rural middle schools" to the urban standards. The ratio of high-school staff to students is 1:12.5. In combination with the changes of the predicted population size, the demand for high-school faculty in the next 30 years can be estimated. The analysis of the demand for faculty is shown in **Figure 3**.

5.2. Analysis of the demand for school buildings

Teaching activities must be undertaken in the corresponding places. Safe, sufficient and comfortable school buildings are the necessity of ensuring the study, work and life of students and teachers. As the 2013 Educational Statistics Yearbook of China shows, the school buildings are composed of three parts, namely teaching and subsidiary buildings, office buildings and living buildings. In fact, the condition of school buildings represents the basic condition of running a school and the school's material strength. Thus, this paper chose the index of school buildings as the observation index of the demand prediction of educational facilities.

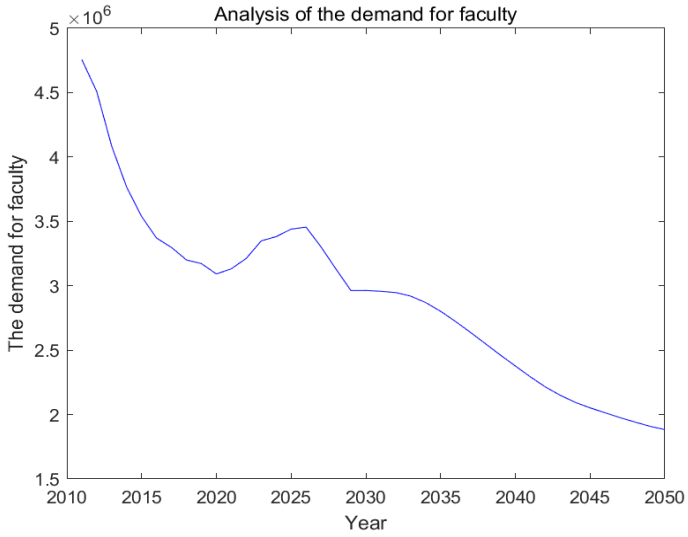

Figure 3. Analysis of the demand for faculty

There are no uniform standards of constructing school buildings in high schools, and instead, provincial municipal governments issue relevant regulations to construct the school building. As the common high schools are located at towns, which means there is no common high schools in rural areas, the construction standard of constructing high school buildings was stipulated in the Construction Standard of School Buildings in the Common Primary and Middle Schools in Urban Areas (Standard No. 102 [2002]), that is, the building area for every high-school student in cities is 6.4 to 7.4 square meters. However, it is shown in the Statistical Communiqué on National Education Development in 2019 that there were 39.949 million high-school students in China and the building area reached 567.8856 square meters. By calculation, the average area of per high-school student is 14.215 square meters at present, much larger than the maximum planning index of the average building area of per high-school student stipulated by the national government. Therefore, this paper presumed that the average building area of a high-school student was unchanged while taking it as the prediction standard of school buildings in common high schools. Besides, this paper also combined the predicted number of high-school students in the context of the universal two-child policy to further predict the demand for the school building areas in high schools in the next 30 years. The analysis graph of the demand for school buildings in high schools is shown in **Figure 4**.

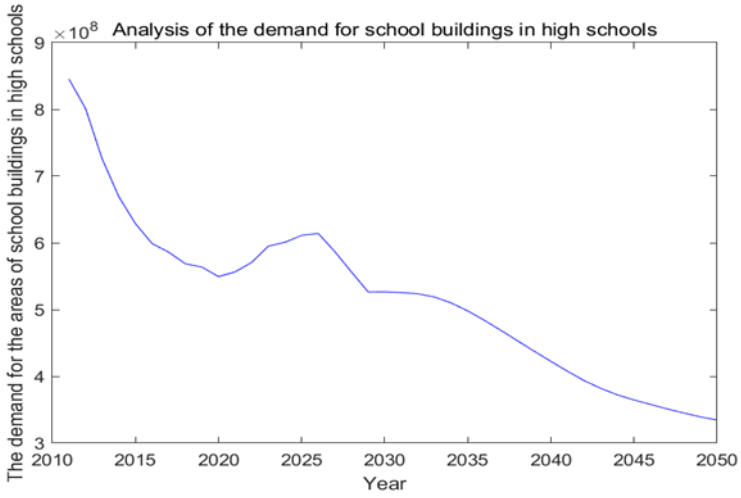

Figure 4. Analysis graph of the demand for school buildings in high schools

6. Conclusions and suggestions

This paper summarized the relationship between the high-school-age population changes and the number of teachers, and between the high-school-age population changes and educational investment. Besides, it also analyzed and explained the number of high-school students, the number of teachers required and the educational appropriations required from 2021 to 2050. In addition, it proposed targeted suggestions when combining the current development of high-school education in China.

6.1. Ensure the strategic development position of common high schools and allocate educational resources rationally

As a whole, the high-school population will grow rapidly before 2026 but after 2026, the population will start to decrease year on year. From the analysis above, the total number of teachers and the areas of school buildings cannot meet the future demand. If the supply of teachers and school building areas cannot be improved at the same time, the supply of high-school educational resources will be insufficient, leading to the lag of high-school education and the greater imbalance of the education development in different regions. Meanwhile, if the supply of teachers and school building areas cannot be reduced at the same time, it will cause a waste of educational resources or a problem of the resources' remaining idle, resulting in a loss of the overall efficiency. Thus, the rational allocation of educational resources can avoid the misplace of the supply and demand side and it can better promote the new development model of dual circulation.

High-school education is different from compulsory educational resources. It is not compulsory and obligatory so it is adjusted and controlled by the market. At present, the management system of basic education is controlled by the local governments, featuring level-to-level administration. The county-level governments are the main bodies of the investment in higher education. However, they give priority to compulsory education due to the limited financial resources, leading to the insufficient investment in high-school education. Even worse, some impoverished counties cannot appropriate any fund for high-school education, which causes that the high schools in rural areas bear heavy debt burden. As the investment in high-school education is stipulated and managed by the local governments and the economic development of different regions is imbalanced, these regions' investment in high-school education is not balanced. Meanwhile, as the poor regions have no sufficient financial support for high-school education, their high-school education has to rely on the market.

6.2. Cultivate faculty resources and improve the allocation efficiency of educational resources

It can be known from the analysis above that there will be a large gap in the faculty resources in high schools. As the distribution of educational resources is dramatically imbalanced between regions and between rural and urban areas. There is a waste of teachers' resources in some regions while a serious shortage of teachers' resources in some regions. As is known to us, cultivating teachers needs a long time and the improper planning will produce serious errors in the allocation of high-school educational resources in the future.

It is necessary to strengthen human resources and build modernized personnel management that considers all the personnel in the school as the most valuable resources, focuses on individual development and sets its goal of giving full play into everyone's ability. Firstly, it is important to recognize the practical value of human resources. The educational management of common high schools should not be satisfied with the establishment of teachers' posts, the deterioration of job placement, the assessment and appointment. Otherwise, it will ignore the development, utilization and cultivation of the internal potential of the school personnel. Schooling management should avoid entering the erroneous zone of the thinking modes of the traditional human management, and be aware of the value of human resources and the management of human resources. Secondly, it is imperative to build up the modernized system of managing

human resources to rationally allocate human resources in schools with high efficiency. To stabilize the number of teachers, some common high schools still use administrative means to restrict the flow of the teachers at present. To reach this goal, common high schools should build a system that is conducive to the flow of talents and inner competition to select the superior and eliminate the inferior. This method can identify the unqualified teachers, introduce talents who are willing to devote themselves to education cause, stabilize the system of human resources and improve the effective management of human resources.

It is of importance to rationally allocating the faculty and improving the utilization efficiency of human resources. The healthy and rapid development of common high schools rely on their faculty. A rational faculty structure can promote the interaction among teachers to complement each other and give full play into their capabilities. Besides, it can also form the group consciousness and enable them to help each other, creating a good atmosphere for the healthy growth of talents. The optimal allocation of faculty teams should be paid attention to, which means mixing the new and the old teachers together in the age structure, combining the easy and difficult knowledge in the knowledge structure and matching the high- and low-level of projects. With these efforts, an ideal teamwork structure can be formed. In addition, facing the large gap in the faculty of different common high schools, departments at all level should incline to the schools with weak strength in faculty so that these schools can create a good development.

6.3. Promote the reform of educational appropriate system

It is vital to rationally and scientifically arrange common high-school education and to optimize the educational resources. There are two modes of high-school education in China at present, namely common high-school education and secondary technical vocational school education (Medium level). Both of them can send talents to colleges and universities and play an important role in cultivating talents for the society. They are the important ways to cultivate talents. Firstly, due to the demand of economic development, the two modes should make a big progress, and the key of development is to adapt to the needs of economic and social development and meet the educational needs of the masses. As the vocational education has got more attention and support from the country at present, the common high-school education should be focused on and developed to maximize the demand of the economic development for junior and middle talents and to satisfy parents' demand for encouraging their children to receive high-school education. Secondly, a rational arrangement of schools should be set and adjusted. Schools should be prevented from being scattered and too concentrated. In the adjustment of the arrangement, we should overcome the one-size-fits-all approach, should not take the wide range of school distribution, small scale, etc., as the reasons for the low efficiency of educational resources. Simply abolishing schools or merging them blindly cannot be adopted. Instead, it is helpful to start from the local population, natural conditions and the affordability of the local economy and environment to utilize educational resources with high efficiency and to arrange the schools in a scientific and rational manner.

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