Forecasting Teacher Demand in China's Compulsory Education: A Time Series Analysis Approach

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Abstract

This study aims to forecast the demand for full-time teachers in China's primary education system for the year 2027, utilizing the ARIMA model. By incorporating variables such as student enrollments, the target student-teacher ratio, the current number of teachers, and projected retirements, the analysis provides a comprehensive estimate of future teacher needs. The results indicate a projected demand of 788,500 full-time teachers by 2027. This finding highlights the necessity for strategic planning and resource allocation to ensure the quality of education amidst increasing demand. The study underscores the importance of proactive recruitment and training initiatives to address the anticipated growth in teacher requirements. Overall, this research contributes valuable insights for policymakers and educational planners in developing effective strategies to meet future educational demands and maintain high standards of primary education in China.

Keywords: ARIMA Model; Teacher Demand Forecast; Primary Education

1. Introduction

In the context of globalization, education is not only the cornerstone of national development but also a key factor in enhancing national competitiveness. Numerous studies have shown that the quality of education directly impacts economic growth, social stability, and the enhancement of national innovation capabilities. Particularly in the primary education stage, it plays a crucial role in cultivating students' basic literacy, thinking skills, and social adaptability. China has the world's largest primary education system, making it essential to accelerate the high-quality progress of primary education (Liang, 2001). Efforts must be made to establish a high-quality and equitable basic public education service system, where teachers play an irreplaceable and vital role, serving as a critical component of this system.

The "China Education Modernization 2035" plan explicitly proposes the development of a high-quality education system with Chinese characteristics and world-class standards (Cheng & Chen, 2023). It aims to establish a standard system centered on teacher allocation, per-student funding, and teaching facilities and equipment, along with a dynamic adjustment mechanism for school conditions. Additionally, it emphasizes the need to "effectively address the structural, phased, and regional shortages of teachers" (Interpretation of China's Education Modernization 2035). Therefore, a more comprehensive and scientific understanding of the status of teacher resource allocation, population size, gross enrollment rate, and student-teacher ratio is particularly important.

Against this backdrop, this study aims to more accurately analyze and predict the demand and supply of full-time teachers in the primary education stage through time series analysis. Time series analysis is a statistical technique that examines data trends over time to forecast future values (Rumbley & Altbach, 2016). This method can reveal historical development patterns of particularly demand, capture potential trends and cyclical fluctuations, and provide scientific evidence for future teacher demand forecasts (Chang, Lee, & Tseng, 2022; Yu, 2023; Yang, 2020).

Specifically, this study will collect relevant data on the number of teachers, student enrollment, and

changes in educational policies in recent years at the primary education stage. By applying time series models, the study will forecast the future demand for teachers over a specified period. This will provide data support and scientific evidence for government departments and educational researchers in planning teacher workforce development and policy formulation, ensuring the rational allocation of teacher resources to meet the growing educational needs.

The findings of this study are expected to offer new perspectives and methods for building the teacher workforce in the primary education stage, further promoting the development of the education sector, improving education quality, and contributing to the achievement of the goals outlined in "China Education Modernization 2035." Based on above demonstration, the research question are as following:

- What are the trends in student enrollment in China's primary education system from the past decade, and how are these trends projected to evolve up?
- What are the historical trends in the number of full-time teachers employed in China's primary education system, and what factors have influenced these trends? How are these trends expected to continue leading up?
- Based on projected student enrollments, current student-teacher ratios, the aging teacher population, and expected retirements, what is the forecasted demand for full-time teachers in China's primary education system?

2. Method

The series of data on full-time teachers in China's primary education stage covers 69 periods from 1954 to 2022 and is retrieved from the National Bureau of Statistics of China (Educational Statistical Yearbook of China, 2019; National Data, 2022), the Ministry of Education of the People's Republic of China (Educational Statistics Yearbook of China, 2022; Education Statistic Data, 2022; National Statistic Gazette on the Educational Undertaking, 2022), and other relevant government reports and publications. The data includes the number of full-time teachers, student enrollment, educational policies, population size, gross enrollment rate, and student-teacher ratio. Given the length of the series, we apply trend analysis to explore the structures towards the goals outlined in "China Education Modernization 2035."

2.1. Data Collection

To forecast the demand for full-time teachers in the primary education stage in China using the ARIMA model, we will collect relevant time series data. The data sources and variables to be included are:

- Number of Full-Time Teachers: Annual data on the total number of full-time teachers in primary education.
- Student Enrollment: Annual data on the number of students enrolled in primary education.
- Student-Teacher Ratio: Annual student-teacher ratio in primary education.

The data will be collected from authoritative sources such as the National Bureau of Statistics of China, the Ministry of Education of the People's Republic of China, and other relevant government reports and publications. The time frame for the data collection will cover the past 69 years to ensure a robust dataset for the analysis.

2.2. Time series analysis

Time series analysis has been applied in various domains, including environmental studies, medical research, and social issues. Numerous studies have explored innovative approaches to transform time series data. This study employs time series analysis to predict the demand for full-time teachers in China's primary education stage.

We conducted time series analysis to identify trends in teacher demand and build fitted models for forecasting. Before model construction, we will verify whether the dataset exhibits seasonal or non-seasonal patterns. If the dataset follows a non-seasonal pattern, we will apply the ARIMA (AutoRegressive Integrated Moving Average) model, following the criteria of ARIMA (p, d, q). The model selection process will consider the meaning of the parameters (Davies, Coole, & Osipyw, 2014; Junior, Salomon, & Pamplona, 2014):

- p represents the order of the autoregressive part, indicating the number of autoregressive terms (AR).
- d represents the degree of differencing required to make the series stationary.
- q represents the order of the moving average, indicating the number of lagged forecast errors in the prediction equation (MA).

To ensure the model's adequacy, we will perform a white noise examination using the Box-Pierce Chi-square statistic test. This test will determine whether the residuals of the model are independent. According to Box-Pierce's suggestion, the Chi-square values should be non-significant at lags of 12, 24, 36, and 48.

The steps involved in this time series analysis are as follows:

- Data Verification: Determine whether the dataset exhibits seasonal or non-seasonal patterns.
- Model Selection: If non-seasonal, apply ARIMA (p, d, q) and select the appropriate parameters (p, d, q) based on the dataset characteristics.
- Model Fitting: Estimate the model parameters using maximum likelihood estimation or other suitable methods.
- Model Diagnostics: Perform diagnostic checks, including the Box-Pierce Chi-square test, to ensure the model's residuals resemble white noise and meet the assumption of independence.
- Forecasting: Use the fitted ARIMA model to forecast the demand for full-time teachers over a specified period, providing forecast intervals to quantify uncertainty.
- Scenario Analysis: Conduct scenario analysis to explore the impact of different assumptions about future educational policies and demographic changes on the forecasted teacher demand.

By applying these steps, the study aims to provide accurate and reliable forecasts for teacher demand, supporting the planning and policy formulation efforts of government departments and educational researchers.

3. Results

3.1. The trends of primary student enrollments in China

The Figure 1 illustrates the trend in student enrollment in primary schools across China from 1954 to 2022. The x-axis represents the years, while the y-axis shows the number of students enrolled in primary schools. From 1954 to 1975, there is a noticeable upward trend, indicating a steady increase in student enrollment, likely due to policies promoting universal primary education and population growth. Between 1975 and 1991, a slight decline in enrollment is observed, reflecting demographic changes such as lower birth rates and shifts in population policies, including the introduction of family planning measures. From 1992 to 1997, there is another increase, likely driven by economic reforms and increased investment in education. However, from 1998 to 2013, a long-term decline is evident, which can be attributed to the effects of the one-child policy implemented in the late 1970s. Finally, from 2014 to 2022, there is a slight increase in enrollment, possibly due to the relaxation of the one-child policy in 2013 and the subsequent introduction of the two-child policy in 2016, as well as improved access to and quality of education.

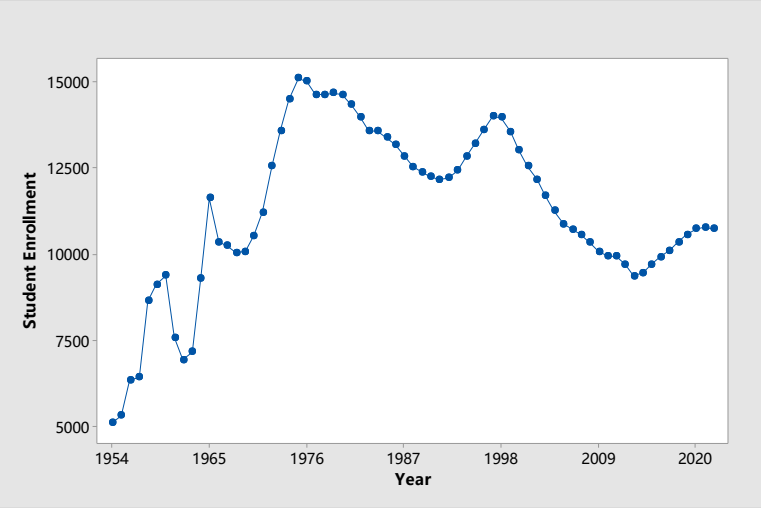

Figure 1. The primary student enrollments trend in China

3.2. The trends of primary education full-time teacher number.

The figure illustrates the trend in the number of full-time teachers in primary education across China from 1954 to 2022. The x-axis represents the years, while the y-axis shows the number of full-time teachers employed in primary schools. From 1954 to 1961, there is a steady increase in the number of teachers,

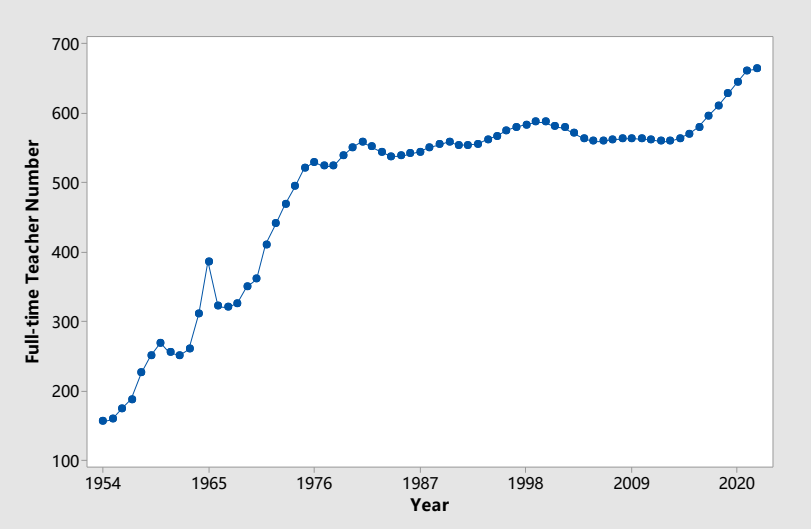

Figure 2. The trends of primary education full-time teacher number

reflecting the expansion of the education system. Between 1962 and 1967, a fluctuation occurs. Despite these movements, the overall trend from 1968 onwards is a continuous increase in the number of full-time primary education teachers, driven by efforts to improve educational access, quality, and various educational reforms. This long-term growth underscores China's commitment to enhancing its educational workforce to support the increasing number of students and improve the quality of primary education.

3.3. Forecasting the primary student enrollments in China.

As for the forecast data for student enrollment, this study applies the ARIMA model to build the forecasting framework. This study selects one fitted model, specifically ARIMA (0,1,1), to address the trend of student enrollment in China's primary education. Table 1 shows that the parameters of the ARIMA model are significant with alpha < 0.05 and one regular difference.

Table 1. The parameters of suggested ARIMA models

ARIMA(0,1,1)	Coef	SE Coef	t-Value	p-Value
AR(0)	/	/	/	/
Difference	1			
MA(1)	-.317	.117	-2.713	.009
Constant	80.778	99.472	.812	.420

*Number of observations: Original series 69 (1954-2022), after differencing 68

The suggested models for predicting student enrollment in primary education over the next decade are displayed in Table 2. Considering the actual value of ACF and PACF (In Figure 3), the result of the ARIMA (0,1,1) model has shown the trend more smoothly (see Figure 4). The model indicates that student enrollment in China's primary education will continue to follow a certain trend over the next decade. This finding suggests that strategic planning and resource allocation are essential to accommodate the expected changes in student numbers and to ensure the continued provision of quality education.

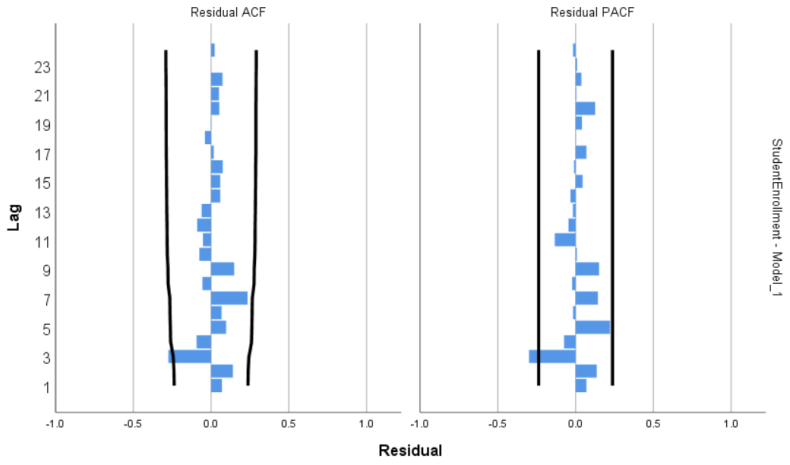

Figure 3. ACF & PACF figure

Table 2. Forecasts of student enrollment for 5 years

Forecast

Model		2023	2024	2025	2026	2027
Student Enrollment-Model_1	Forecast	10776.3388	10857.1169	10937.8950	11018.6730	11099.4511
	UCL	12023.9116	12920.4967	13575.8174	14126.6841	14615.2485
	LCL	9528.7661	8793.7371	8299.9726	7910.6620	7583.6537

3.4 Forecasting the full-time teacher number in China.

As for the forecast data for the number of full-time teachers, this study applies the ARIMA model to build the forecasting framework. This study selects one fitted model, specifically ARIMA (0,1,0), to address the trend of full-time teacher numbers in China's primary education. Table 3 shows that the parameters of the ARIMA model are significant with alpha < 0.05 and one regular difference.

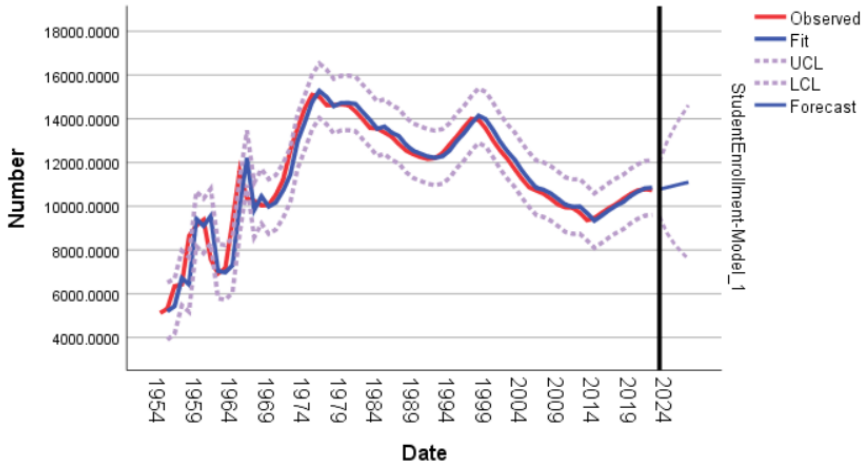

Figure 4. Forcasting trend of student enrollment

Table 3. The parameters of suggested ARIMA models

ARIMA(0,1,1)	Coef	SE Coef	t-Value	p-Value
AR(0)	/	/	/	/
Difference	1			
MA(0)	/	/	/	/
Constant	7.456	2.119	3.5	.001

*Number of observations: Original series 69 (1954-2022), after differencing 68

The suggested models for predicting the number of full-time teachers in primary education over the next 5 years are displayed in Table 4. Considering the actual value of ACF and PACF (In Figure 5), the result of the ARIMA (0,1,0) model has shown the trend more smoothly (see Figure 6). The model indicates that the number of full-time teachers in China's primary education will exhibit a growing trend over the next decade. This finding underscores the need for strategic planning and resource allocation to effectively manage the anticipated increase in teacher numbers and to maintain the quality of education.

Table 4. Forecasts of full-time teacher number for 5 years

		Forecast				
Model		2023	2024	2025	2026	2027
Full-time Teacher Number-Model_1	Forecast	670	678	685	693	700
	UCL	705	727	746	763	778
	LCL	636	629	625	623	622

3.5 Forecasting the demand of teacher for next 5 years.

To calculate the demand for full-time teachers, considering retirements, the following formula can be

used. The formula is:

$$T_{new}=Et/Rt-(T_{curren\ t}-T_{retired})$$

Where:

- T_{new} = Number of new teachers needed
- Et = Number of student enrollments number
- Rt= Target student-teacher ratio
- $T_{current}$ = Current number of full-time teachers
- $T_{retired}$ = Number of teachers retiring in the given year

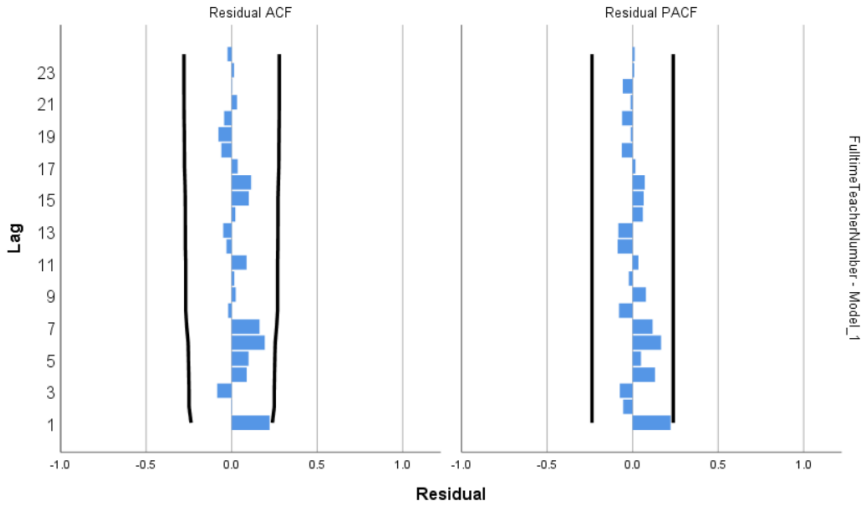

Figure 5. ACF & PACF figure

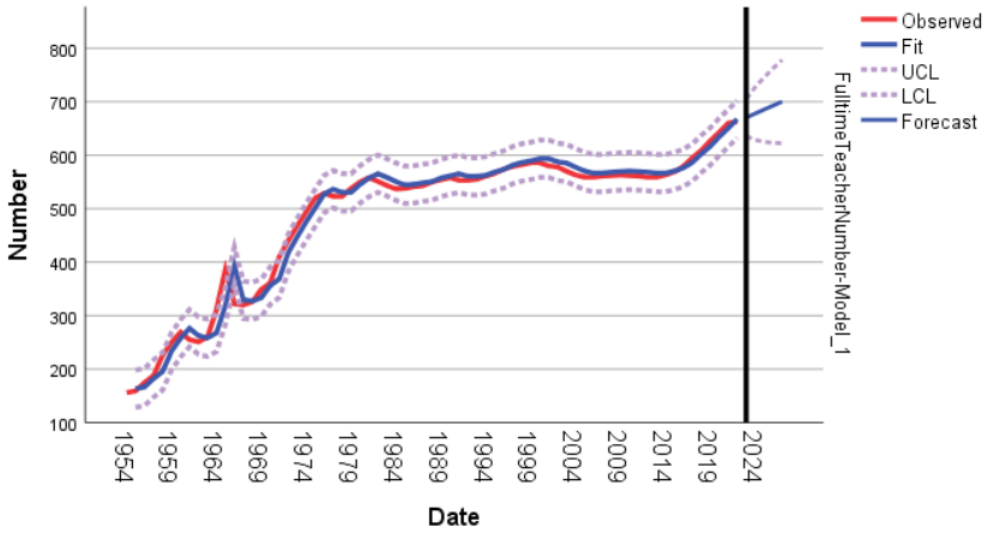

Figure 6. Forecasting trend of full-time teacher number

Based on this calculation formula, the projected demand for full-time teachers in 2027 will be like following:

Student enrollments (Et) = 11,099
Target student-teacher ratio (Rt) = 19
Current number of full-time teachers (TcurrentT_{current}Tcurrent) = 6,29
Number of retiring teachers (TretiredT_{retired}Tretired) = 34

T_{new}= 11099/19 -（629-34）= -78.85

Based on this calculation formula, the projected demand for full-time teachers in 2027 will be 788,500 people. This projection takes into account the anticipated number of student enrollments, the target student-teacher ratio, the current number of full-time teachers, and the estimated number of retirements. By incorporating these variables, the formula provides a comprehensive estimate that can guide strategic planning and resource allocation. Ensuring an adequate number of teachers is crucial for maintaining the quality of education and meeting the changing needs of the student population in China's primary education system. This finding underscores the importance of proactive measures to recruit and train new teachers to address the expected increase in demand.

4. Conclusion

In conclusion, this study provides a detailed forecast of the demand for full-time teachers in China's primary education system for the year 2027. Utilizing the ARIMA model, the analysis incorporates key factors such as student enrollments, the target student-teacher ratio, the current number of teachers, and retirement projections. The forecast indicates that 788,500 full-time teachers will be required to meet the educational needs of the growing student population. This projection underscores the critical importance of strategic planning and resource allocation in the education sector. By addressing the anticipated increase in teacher demand, policymakers can ensure the continued provision of high-quality education. Proactive measures, including recruitment and training programs, will be essential to bridge the gap between current and future teacher requirements.

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