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Factors Influencing Birth Rate and Forecasting in the Yangtze River Delta Based on Pearson Correlation Coefficients

Yongchang Wang[1]. XiaoPing Yang[2] and Yongchang Wang[1]*
[1]Master's degree, Faculty of Science, Zhejiang University of Science and Technology, Hangzhou, China
[2]Dean, School of International Business, Zhejiang Yuexiu University of Foreign Languages, Shaoxing, China
Email: wyc2001791211@163.com

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Abstract

This study investigates declining birth rates in the Yangtze River Delta region and forecasts Shanghai's birth rate from 2023 to 2032. Using data from 2001 to 2022, Grey Relational Analysis and Pearson correlation analysis identify key factors influencing birth rates and validate relevant hypotheses. A generalized linear regression model further examines complex relationships between multi-ple factors and birth rates.Results indicate that the number of secondary schools promotes birth rates, while graduate admissions suppress them, suggesting higher education might reduce fertility intentions. Long-term labor migration significantly impacts birth rate changes, while the relationship between urban built-up area and birth rates is complex.

Keywords

Birth Rate; Grey Relational Analysis; Pearson Correlation; Generalized Linear Regression Model; Time-Series Analysis; Grey Forecasting Model; Economic and Social Factors

1. Introduction

The birth rate, reflecting natural population growth, holds significant implications for sustainable socio - economic development. China's birth rate fluctuations are closely tied to economic growth, labor supply, social security, and public resource allocation. Economic, policy, and cultural factors all influence birth rates. Prior studies indicate a negative correlation between birth rates and per capita GDP, urban disposable income, and urbanization rates(Anand & Ravallion, 1993; Cai & Feng, 2021). This study delves into these factors, particularly in the Yangtze River Delta, where social, economic, and educational elements interplay to shape fertility trends. Economically, the Delta's rapid development has raised household incomes but also living costs, especially for housing and child-rearing. These factors have made fami-

lies more cautious in their fertility decisions (Cleland et al., 2006; LIU & GONG, 2020; Sobotka et al., 2011). Economic pressures can reduce the willingness to have children and lead to delayed childbearing, significantly impacting overall birth rates(Canning & Schultz, 2012; Hofferth, 1984). In large cities with acute economic pressures, the economic burden of childbearing is especially critical in fertility decisions (Simkhada et al., 2010). To account for these influences, this study incorporates the Consumer Price Index (CPI) as a variable, examining its impact on birth rates in the Delta while considering urban - rural differences.

Socially, family structure changes, such as the rise of single-person and dual-income households, have led the youth to delay childbearing or opt for fewer children (Barber, 2001). Shifting social values, especially in urban areas, have contributed to declining fertility intentions (Davis-Kean, 2005; Gyan & Kpoor, 2024). Parents' willingness to invest in their children's education is closely linked to socio-economic status (Finer & Sonfield, 2013; Hoff & Laursen, 2019). Furthermore, empirical studies using county-level data have revealed a significant negative correlation between unemployment rates and fertility rates, while employment rates positively impact fertility (Kamata & Iwasawa, n.d.). China's urbanization and delayed childbearing age may reduce future birth rates and slow population growth (Yi & Vaupel, 1989). This study employs a multi-regional population forecasting model to explore these relationships, focusing on three key social factors: long-term migrant labor from other provinces, employment scale, and urban built-up area.

Educationally, rising female educational levels have led to more deliberate choices between childbearing and career development (Shoven, 2010). The widespread availability of higher education has altered women's fertility decisions and raised family expectations regarding education quality, which impacts birth rates. Women with higher education tend to delay childbearing and prefer fewer children (Ng & Wang, 2020). This study examines the impact of graduate enrollment numbers on birth rates, a factor less explored in existing literature. Education also enhances individuals' knowledge about fertility choices and healthy pregnancy behaviors, increasing their ability to process information effectively (Grossman, 2017). Given the region's leading educational resources and standards, this study introduces the number of secondary schools as a variable to explore its potential impact on birth rates.

This study focuses on the significant effects of urban-rural income disparities, CPI differences, education, and social factors on birth rates in the Yangtze River Delta. Using Grey Relational Analysis to identify primary factors, Pearson correlation analysis to test hypotheses, and a Grey Forecasting Model to predict Shanghai's birth rates over the next decade, this research aims to provide a comprehensive analysis of these influences.

The disparity in birth rates between urban and rural populations has garnered significant attention. Existing literature suggests this difference is influenced by multi-

ple factors, including economic development, educational levels, social culture, and family planning. As disposable income increases in urban areas, families tend to prioritize optimizing the quality of life and educational investment for their children, often through fertility control (Repo, 2018). Research indicates that improved economic conditions lead families to weigh additional factors in their fertility decisions, particularly those concerning education investment and quality of life. For instance, Becker posited that under resource constraints, families opt for fertility control to better invest in their children's education and development(Barro & Becker, 1989). Furthermore, the urbanization process increases living costs, which in turn affects family fertility decisions. Paul Demeny explored the suppressive effect of high urban living costs and limited housing resources on fertility rates. He found that urbanization leads to rising living costs—especially in housing, education, and healthcare—prompting families to make more cautious fertility decisions (Demeny, 2003). This economic pressure reduces fertility intentions and alters fertility perceptions. In contrast, rural areas, where economic pressure is lower, tend to be more influenced by traditional values, leading to higher birth rates. This highlights the pivotal role that the economic environment plays in fertility decisions across urban and rural contexts. Therefore, we propose Hypothesis 4: The urban built-up area is significantly negatively correlated with birth rates.

As research advanced, scholars recognized the complexity and diversity of birth rate influencing factors. Becker's fertility economics theory emphasizes that families must weigh the trade-off between the quality and quantity of children in fertility decisions. Economic factors such as household income and education costs play a crucial role in shaping fertility choices (Becker, 1970). Leibenstein's cost-utility theory focuses on the costs (both direct and indirect) of raising children and the utility they provide. His research indicates that as per capita income increases, the costs of raising children rise while the marginal utility of children decreases for families. This suggests that economic development often leads to a reduction in the desired number of children, thereby decreasing fertility intentions and expected birth rates (Leibenstein, 1981). The Yangtze River Delta region, the focus of this study, is one of the most economically developed areas in China, with relatively high household incomes. However, the cost of living, particularly in housing and education, is significantly above the national average. This aligns with the international perspective that economic pressures contribute to a decline in birth rates.

Economic conditions are widely regarded as key determinants of birth rates. Relatively low living costs and ample employment opportunities can encourage family formation, whereas excessive economic pressures may lead individuals to delay marriage and childbirth, thereby influencing fertility rates. Ronald Lee's research on demographic transitions highlights that the shift from high birth and death rates to low birth and death rates in countries is primarily driven by economic development. Economic progress is typically accompanied by improved sanitation and healthcare

services, which reduce mortality rates and alter fertility behaviors. Lee's study found that in the early stages of economic development, a decline in mortality precedes a reduction in birth rates, leading to rapid population growth in the short term. However, as economic development continues, birth rates gradually decline, ultimately stabilizing population growth(Lee, 2003).

John Bongaarts' 2006 study delves into past trends in the juvenile, background, and senescent components of life expectancy across 16 high-income countries.Bongaarts discovered that before 1950, life expectancy increased significantly, mainly due to lower juvenile and background mortality. However, after 1950, improvements in life expectancy slowed as juvenile and background mortality reductions became less pronounced. In contrast, senescent mortality declined more rapidly, becoming the primary factor behind the rise in life expectancy at birth (Bongaarts, 2006).Furthermore, Boucekkine and colleagues' research suggests that the relationship between economic growth and birth rates follows an inverted U-shaped curve. Birth rates initially rise in the early stages of economic growth but decline as the economy continues to expand (Boucekkine et al., 2002). Consequently, this study will focus on analyzing the influence of economic factors on birth rates.

In the Yangtze River Delta region, rapid urbanization, a large employment scale, and abundant educational and job opportunities have led to social modernization influencing fertility. Higher employment rates typically correlate with stronger economic performance, which can lead to increased household income and greater economic stability. Many studies have shown that rising household income can improve economic security, making childbirth a more viable option. Becker's family economics theory suggests that higher family income promotes a greater willingness to have children (Becker, 1992). Given these factors, this study proposes Hypothesis 2: There is a significant positive correlation between the size of the employed population and the birth rate.

Additionally, immigration has a multidimensional impact on urban fertility patterns. Immigrant groups typically exhibit higher fertility rates, which can drive short-term population growth. Immigrants often bring a younger labor force, which can enhance urban fertility rates (Prskawetz et al., 2008). However, as they integrate into society and adapt to local culture, their fertility behavior may change. Over time, native residents of immigrant-receiving cities typically have lower fertility rates, and the fertility rates of immigrant populations may gradually converge with those of the locals, a phenomenon known as the "assimilation effect." Relevant studies indicate that the birth rate in immigrant cities is not only directly influenced by the fertility rates of immigrant groups but is also closely tied to the broader socio-economic environment of the city.

In light of these dynamics, this study introduces the variable of "long-term out-of-province migrant labor" to investigate its impact on birth rates and proposes Hypothesis 5: There is a significant negative correlation between long-term

out-of-province migrant labor and the birth rate.

Education is a key factor influencing birth rates and has long been an important subject in both demographic and socio-economic research. Numerous studies have demonstrated that higher educational attainment significantly affects fertility decisions, as individuals with higher levels of education are more likely to pursue careers and personal goals (Gibson-Davis & Percheski, 2018). For example, T. Paul Schultz emphasized the significant impact of education, particularly female education, on fertility rates. Research has shown that increased educational attainment leads women to delay marriage and childbirth, while simultaneously reducing their total fertility. Educated women are more inclined to enter the labor force, which raises their opportunity costs and motivates them to have fewer children (Schultz, 1969).

In the Yangtze River Delta region, where educational resources are abundant and the overall education level is high, these theoretical insights are particularly relevant. This study incorporates two variables—graduate enrollment numbers and the number of general secondary schools—to examine their relationship with birth rates. Based on these considerations, this study proposes Hypothesis 1 and Hypothesis 3: There is a significant negative correlation between graduate enrollment numbers, the number of general secondary schools, and the birth rate.

The main contributions of this study are as follows:

- **Introduction of Graduate Enrollment as an Innovative Variable:** This study introduces graduate enrollment numbers as a new variable to explore the potential suppressive effect of higher education on fertility intentions.
- **Incorporation of Urban-Rural Disparities:** This research refines key economic indicators, such as disposable income and the consumer price index, into urban and rural categories, offering insights into the heterogeneous effects of economic factors on demographic outcomes.
- **Inclusion of Migrant Labor as a Novel Indicator:** This study introduces the migration of labor from outside the region as a new indicator to examine how external labor migration influences regional birth rates.

2. Data and methods

2.1. Detailed Explanation of Variable Selection

The variables selected for this study are primarily sourced from the China Statistical Yearbook, with supplementary data from the Shanghai Statistical Yearbook, Jiangsu Statistical Yearbook, Zhejiang Statistical Yearbook, and Anhui Statistical Yearbook. Additionally, data on migrant labor from outside the region is obtained from the National Rural Economic Situation Statistical Materials, China Rural Management Annual Report, and China Rural Policies and Reform Statistical Yearbook. The dataset covers the period from 2001 to 2022 for the Yangtze River Delta region. To address the missing migrant labor data for the years 2001-2005, linear interpolation

was applied to ensure data completeness and continuity.

GDP: Gross Domestic Product (GDP) serves as a key indicator of the overall economic output of a region. A higher GDP typically indicates a higher standard of living and more employment opportunities, but it may also result in higher living costs, which could influence family fertility decisions(Doepke et al., 2023).

Urban Disposable Income and Rural Disposable Income: Income levels directly affect family economic burdens and fertility intentions. Urban residents typically enjoy higher income levels but also face higher living costs, which may reduce fertility intentions(Glaeser, 1998). In contrast, rural residents have lower income levels, but the relative cost of raising children is also lower, potentially leading to higher fertility intentions(Birdsall & Griffin, 1988).

Employment Numbers: The availability of more employment opportunities can improve family economic stability, thereby encouraging fertility. However, in modern society, an increased female labor force participation rate may lead to lower fertility intentions, as women often face the challenge of balancing career development with childbearing(Gerson, 2019).

Urban Built-up Area: The expansion of urban built-up areas often coincides with improved infrastructure and enhanced living standards, which may influence fertility decisions. However, increased urbanization also brings higher living costs, potentially affecting fertility intentions(Kulu & Washbrook, 2014).

Graduate Enrollment and Number of Secondary Schools: Graduate enrollment reflects the level of higher education in a region. Higher education levels often delay marriage and childbearing, especially for women, as they increase the opportunity cost of childbearing by encouraging career development(Kreyenfeld, 2010). Moreover, the accessibility of basic education plays a crucial role in shaping fertility rates, as improved education tends to change traditional family norms and encourages the preference for fewer children with better quality.

Urban and Rural Consumer Price Indices: The Consumer Price Index (CPI) reflects the cost of living. A higher CPI generally indicates increased living costs, which could suppress fertility intentions(Glaeser et al., 2005).

Migrant Labor from Outside the Region: The mobility of labor reflects the availability of economic opportunities and employment choices for households. While the increase in migrant labor can raise household income, it may also lead to family separation, which could influence fertility decisions(Mincer, 1978).

In summary, this study selects 11 key indicators, including one main behavioral indicator and ten factor indicators. The main behavioral indicator is the birth rate, denoted as X_i in the calculations. The ten factor indicators include GDP, employment numbers, urban and rural disposable incomes, urban and rural consumer price indices, graduate enrollment, number of secondary schools, urban built-up area, and migrant labor from outside the region. These factors are represented as $X_2 - X_{11}$ in the analysis.

2.2. Grey Relational Analysis

Following the selection of the aforementioned influential factors, grey relational analysis is conducted. The grey relational analysis method evaluates the degree of association between factors based on the similarity of their developmental trends, enabling the identification of the relative importance of these factors(Zhang et al., 2020). The implementation process is outlined as follows:

2.2.1. Calculation of Grey Relational Coefficients

To eliminate the influence of dimensionality, the original data is standardized using the following formula:

$$x_t^{'} = \frac{x_i(t) - \mu_i}{\sigma_i} \quad i = 1,2,...,11; \quad t = 1,2,...,22 \qquad (1)$$

Where i represents the 11 selected indicators, and t corresponds to the years from 2001 to 2022. $x_i(t)$ denotes the raw data value of the $i-th$ indicator in the $t-th$ year; μ_i is the mean of the $i-th$ indicator; μ_i is the standard deviation of the $i-th$ indicator; and $x_t^{'}$ is the standardized value of the data. This method involves an initial transformation of the raw data, eliminating the impact of dimensional discrepancies between indicators and resulting in a dimensionless matrix.

2.2.2. Calculation of the Difference Sequence Matrix

The birth rate serves as the primary sequence, while the influencing factor indicators constitute the factor sequence. The difference sequence matrix is computed using the following formula:

$$\Delta_i(t) = | x_i(t) - x_1(t) | \quad i = 2,\ldots,11; t = 1,2,\ldots,22 \quad (2)$$

Where i and t take the same values as previously defined. In the absolute difference sequence, the maximum value $\Delta_{max} = 5.00839571$ and the minimum value $\Delta_{min} = 0.00206143$ are selected.

2.2.3. Calculation of the Grey Relational Matrix

The grey relational matrix is computed based on the following relational coefficient formula:

$$R_i(t) = \frac{\Delta_{min} + \rho\Delta_{max}}{\Delta_i(t) + \rho\Delta_{max}} \qquad (3)$$

where i and t take the same values as previously defined. Let the distinguishing coefficient be denoted as $\rho = 0.5$, and using the maximum value $\Delta_{max} = 5.00839571$ and minimum value $\Delta_{min} = 0.00206143$, the grey relational coefficient matrix is computed.

2.2.4. Calculation of the Grey Relational Degree

The grey relational degree is determined using the following formula:

$$\beta_i = \frac{1}{N}\sum R_i(t), \quad N = 10 \tag{4}$$

The grey relational degrees calculated reveal the strength of the relationship between the ten factor sequence indicators and the birth rate. The figure below illustrates the distribution of grey relational degrees for each indicator, providing further analysis of the extent to which each factor influences fluctuations in the birth rate.

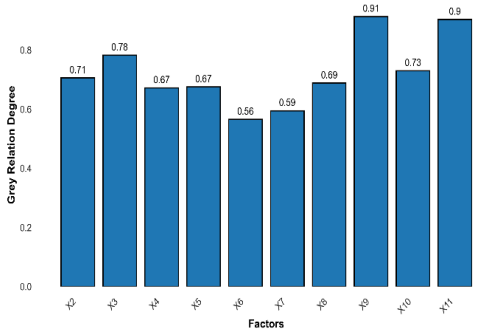

Figure 1. Grey Relational Degree between the Birth Rate and the Indicators

Figure 1 shows that the number of graduate admissions and the number of long-term migrant workers outside the province exhibit the highest grey relational degrees, at 0.91 and 0.90, respectively, indicating that these two factors have the most significant impact on the birth rate. Following these, the grey relational degrees for employment and urban built-up area are also relatively high, at 0.78 and 0.73, respectively, highlighting their importance in influencing the birth rate. In contrast, the grey relational degrees for the urban consumer price index and rural consumer price index are comparatively lower, at 0.56 and 0.59, suggesting that these factors have a smaller effect on the birth rate. According to the relational degree values presented in Figure 1, the indicators are ranked in descending order as follows: number of ordinary middle schools (0.91) > long-term migrant workers outside the province (0.90) > employment (0.78) > urban built-up area (0.73) > GDP (0.71) > number of graduate admissions (0.69) > urban disposable income (0.67) = rural disposable income (0.67) > rural consumer price index (0.59) > urban consumer price index (0.56). The top six ranked indicators are: number of ordinary middle schools, long-term migrant workers outside the province, employment, urban built-up area, GDP, and number of graduate admissions.

2.3. Pearson Correlation Analysis

2.3.1 Calculation of the Correlation Coefficient

The Pearson correlation coefficient method is a statistical approach used to accurately measure the degree of linear relationship between two variables(Ahlgren et al., 2003; Bollen & Barb, 1981; de Winter et al., 2016). The formula for the Pearson correlation coefficient is:

$$r_{X_i X_1} = \frac{\sum_{t=1}^{N}(x_{i,t} - \bar{X}_i)(x_{1,t} - \bar{X}_1)}{\sqrt{\sum_{t=1}^{N}(x_{i,t} - \bar{X}_i)^2} \cdot \sqrt{\sum_{t=1}^{N}(x_{1,t} - \bar{X}_1)^2}} \tag{5}$$

where i and t take the same values as previously defined. $r_{X_iX_1}$ denotes the Pearson correlation coefficient between the $i-th$ variable and the birth rate; N represents the sample size; Based on the strength of the correlation between each factor and the birth rate, a heatmap was generated, as shown in Figure 2.

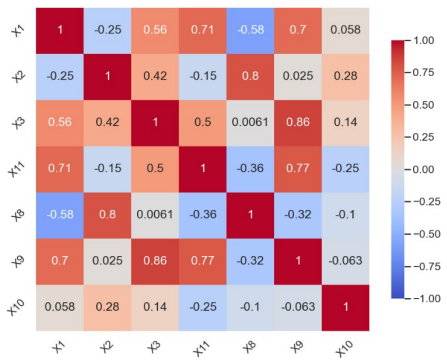

Figure 2. Pearson Correlation Coefficient Heatmap

According to the results in Figure 2, the correlation coefficient between the birth rate and GDP is -0.246, indicating a weak negative correlation. This result suggests that there is a certain inverse relationship between GDP and the birth rate, although the impact is relatively weak. Specifically, as GDP increases, the birth rate shows a slight declining trend. Despite the weak correlation, this negative relationship still suggests that GDP may exert some inhibitory effect on the birth rate. It is possible that the relationship between GDP and birth rate is non-linear or involves more complex interactions.

The correlation coefficient between the birth rate and employment is 0.564, showing a moderate positive correlation. This indicates a certain synchronicity between employment and the birth rate. As employment increases, the birth rate also exhibits an upward trend. The correlation coefficient between the birth rate and long-term migrant workers outside the province is 0.711, reflecting a strong positive correlation. This result indicates a significant relationship between changes in long-term migrant workers and the birth rate. As the number of long-term migrant workers increases, the birth rate also rises.

The correlation coefficient between the birth rate and the number of graduate admissions is -0.585, showing a moderate negative correlation. This suggests an inverse relationship between the number of graduate admissions and the birth rate. An increase in the number of graduate admissions may lead to a decrease in the birth rate. The correlation coefficient between the birth rate and the number of ordinary middle schools is 0.705, indicating a strong positive correlation. This shows a highly consistent trend between the number of middle schools and the birth rate. As the number of middle schools increases, the birth rate also rises, suggesting that the number of middle schools may have a direct positive effect on the birth rate.

The correlation coefficient between the birth rate and urban built-up area is 0.058, nearly zero, indicating that there is virtually no significant linear correlation between urban built-up area and the birth rate.

2.3.2 Significance Test of the Correlation Coefficient

The correlation coefficient is computed from sample data and is influenced by factors such as sample randomness and sample size. Therefore, it is necessary to assess

the reliability of the sample correlation coefficient through a significance test. The null hypothesis for testing the absence of correlation is H_0. The test statistic is then calculated, and typically, a t-distribution test is used, with the following formula:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \quad (6)$$

where r is the Pearson correlation coefficient $r_{X_i X_1}$, n is the sample size, and $df = n-2$ represents the degrees of freedom. Based on the computed test statistic, the corresponding p-value is obtained from the t-distribution table. If the p-value is less than the significance level (0.05), the null hypothesis H_0 is rejected, indicating that a significant linear relationship exists between the two variables in the population. The detailed results are presented in Table 4.

Table 4. Significance Test Results of Pearson Correlation Coefficients

	Birth Rate (‰)	GDP (Billion Yuan)	Employment Population (Ten Thousand People)	Graduate Students Enrollment(People)	Secondary Schools Number (Schools)	Urban Developed Area (Square Kilometers)	Province - Out Labor Force (Ten Thousand People)
Birth Rate (‰)	1(0.000***)	-0.246(0.021**)	0.564(0.000***)	-0.585(0.000***)	0.705(0.000***)	0.058(0.593)	0.711(0.000***)
GDP (Billion Yuan)	-0.246(0.021**)	1(0.000***)	0.42(0.000***)	0.8(0.000***)	0.025(0.819)	0.284(0.007***)	-0.149(0.167)
Employment Population (Ten Thousand People)	0.564(0.000***)	0.42(0.000***)	1(0.000***)	0.006(0.955)	0.857(0.000***)	0.14(0.192)	0.499(0.000***)
Graduate Students Enrollment (People)	-0.585(0.000***)	0.8(0.000***)	0.006(0.955)	1(0.000***)	-0.322(0.002***)	-0.102(0.345)	-0.361(0.001***)
Secondary Schools Number (Schools)	0.705(0.000***)	0.025(0.819)	0.857(0.000***)	-0.322(0.002***)	1(0.000***)	-0.063(0.558)	0.775(0.000***)
Urban Developed Area (Square Kilometers)	0.058(0.593)	0.284(0.007***)	0.14(0.192)	-0.102(0.345)	-0.063(0.558)	1(0.000***)	-0.249(0.019**)
Province - Out Labor Force (Ten Thousand People)	0.711(0.000***)	-0.149(0.167)	0.499(0.000***)	-0.361(0.001***)	0.775(0.000***)	-0.249(0.019**)	1(0.000***)

Note: ***、**、* indicate significance levels of 1%, 5%, and 10% respectively

The results show that the p-value for the correlation between GDP and the birth rate is 0.021, which is below the 0.05 significance level, indicating that the negative correlation is statistically significant. This result further corroborates previous studies that suggest an inverse relationship between economic development levels and birth rates. Although the absolute value of the correlation coefficient is relatively small, it implies that economic growth may exert a suppressive effect on birth rates through a series of complex mechanisms, particularly in high-income and high-consumption environments, where declining birth rates may be closely linked

to rising living costs and changing social structures.

The p -value for the correlation between employment and the birth rate is highly significant. The variable shows a moderate positive correlation with the birth rate, suggesting that an increase in employment may lead to a rise in the birth rate. This finding is statistically highly significant and supports Hypothesis 2 (H_2) proposed in this study, which suggests that an increase in employment opportunities may encourage fertility decisions within families. This finding reflects the idea that economic prosperity and improvements in the labor market may provide greater support for families, thereby contributing to higher birth rates.

The p -value for the correlation between long-term migrant workers outside the province and the birth rate is nearly zero, with a very high level of significance, showing a strong positive correlation. The increase in migrant workers outside the province is highly consistent with the rise in birth rates, suggesting that it may play a key role in driving changes in birth rates. This result contrasts with Hypothesis 5 (H_5) proposed in this study, suggesting that the mobility of migrant workers may, to some extent, stimulate a rise in birth rates. However, this finding may be moderated by other potential variables, indicating that the relationship may be the result of multiple interacting factors, warranting further investigation.

The p -value for the correlation between graduate admissions and the birth rate is highly significant and shows a moderate negative correlation. This suggests that an increase in graduate admissions may lead to a decline in the birth rate, reflecting that this variable may suppress the growth of birth rates to some extent. This result supports Hypothesis 1 (H_1) proposed in this study, which suggests that higher education levels, particularly the expansion of graduate education, may reduce fertility intentions. As higher education becomes more widespread, particularly in the field of graduate education, the phenomenon of fertility postponement among younger populations becomes increasingly evident, thereby exerting a suppressive effect on birth rates.

The p -value for the correlation between the number of ordinary middle schools and the birth rate is nearly zero, with a very high level of significance, showing a strong positive correlation. The increase in the number of ordinary middle schools is highly consistent with the rise in birth rates, suggesting that this variable may be one of the key drivers of changes in birth rates. This result contradicts Hypothesis 3 (H_3) proposed in this study. Typically, the increase in educational facilities is associated with socioeconomic development; however, in this study, this result may reflect that improvements in educational resources provide greater fertility support for young families. Particularly in regions with well-developed education systems, family fertility decisions may be more positively influenced.

The p -value for the correlation between urban built-up area and the birth rate is 0.593, and the significance test indicates that this correlation is not statistically significant. Given that the correlation coefficient is close to zero and the p -value is far greater than 0.05, it indicates that there is virtually no significant linear relationship between urban built-up area and the birth rate. This result suggests that the relationship between urbanization and birth rates may not be a simple linear one and could involve more complex nonlinear or indirect mechanisms. This finding does not support Hypothesis 4 (H_4) proposed in this study, and further research may need to consider other potential factors, such as housing policies and social welfare,

to better understand this complex relationship.

2.4 Generalized Linear Regression Analysis

Following the in-depth exploration of correlations among variables, this study further employs a generalized linear regression model to dissect the impact mechanisms of various factors on the birth rate. The model designates the birth rate as the dependent variable and incorporates multiple independent variables, including GDP, employment population, urban residents' disposable income, rural residents' disposable income, urban residents' consumer price index, rural residents' consumer price index, graduate student enrollment, and the number of ordinary secondary schools. This comprehensive approach aims to construct a robust predictive framework that elucidates the independent effects of each variable on the birth rate.

Table 5. Omnibus Test Results

Likelihood Ratio Chi-Square	Degrees of Freedom	P-value
182.211	8	0.000***

Note: ***、**、* indicate significance levels of 1%, 5%, and 10% respectively

The omnibus test, presented in Table 5, shows a likelihood ratio chi-square value of 182.211 with 8 degrees of freedom, and the corresponding P-value is effectively 0 ($P<0.001$). This result unequivocally demonstrates the model's excellent fit to the data, indicating that the set of independent variables possesses significant explanatory power regarding the birth rate. This provides a solid foundation for subsequent estimation and inference of the parameters (see Table 6 for details).

Table 6. Parameter Estimates of Generalized Linear Regression Analysis

Parameter	Coefficient	Standard Error	Wald	P	95% Lower Confidence Limit	95% Upper Confidence Limit
Intercept	9.354	0.098	9187.901	0.000***	9.163	9.545
GDP (Billion Yuan)	0.997	0.437	5.212	0.022**	0.141	1.853
Employment Population (Ten Thousand People)	1.715	0.451	14.478	0.000***	0.832	2.599
Urban Residents' Disposable Income (Ten Thousand Yuan)	8.806	1.285	46.94	0.000***	6.287	11.325
Rural Residents' Disposable Income (Ten Thousand Yuan)	-7.659	1.222	39.246	0.000***	-10.055	-5.262
Urban Residents' Consumer Price Index (%)	-6.567	1.666	15.536	0.000***	-9.832	-3.301
Rural Residents' Consumer Price Index (%)	7.872	2.028	15.062	0.000***	3.896	11.848
Graduate Student Enrollment (People)	-3.844	0.561	46.883	0.000***	-4.945	-2.744
Number of Ordinary Secondary Schools (Schools)	1.175	0.592	3.943	0.047**	0.015	2.335

Note: ***、**、* indicate significance levels of 1%, 5%, and 10% respectively

The generalized linear model's parameter estimates show all predictors are statistically significant ($p<0.05$), indicating each explanatory variable significantly impacts the explained variable. The intercept is 9.354 (SE=0.098, $p<0.001$), the baseline value when all standardized explanatory variables are zero. GDP has a standardized coefficient of 0.997 ($p=0.022$), meaning a one-standard-deviation increase in GDP is linked to a 0.997 -unit rise in the explained variable. This suggests that economic development may enhance the birth rate through improved social welfare and healthcare. Employment population has a coefficient of 1.715 ($p<0.001$), showing the most significant positive impact. This aligns with the correlation analysis in Section 2.3, highlighting employment's crucial role in boosting birth rates by improving economic security and family stability.

Notably, urban and rural residents' disposable income have opposite effects. A one-standard-deviation rise in urban income corresponds to an 8.806 -unit increase in the explained variable ($p<0.001$), while rural income has a significant negative effect ($\beta=-7.659$, $p<0.001$). Price index effects also differ between urban and rural areas. The urban consumer price index has a significant negative effect ($\beta=-6.567$, $p<0.001$), whereas the rural index shows a significant positive effect ($\beta=7.872$, $p<0.001$). Among education - related variables, graduate student enrollment is negatively correlated ($\beta=-3.844$, $p<0.001$), this echoes the findings in Section 2.3, illustrating how the expansion of graduate education delays childbearing and reduces fertility intentions, while the number of ordinary secondary schools is positively correlated ($\beta=1.175$, $p=0.047$). This complements the correlation analysis in Section 2.3, indicating that secondary education expansion may enhance the birth rate by bolstering confidence in children's education and fostering a family-friendly environment. All variables' 95% confidence intervals exclude zero, confirming the parameter estimates' statistical reliability.

Comparing standardized coefficients reveals urban residents' disposable income has the largest effect size, followed by rural income and price index variables, highlighting income and price factors' dominant role in the model. The results indicate urban and rural economic indicators have significant and opposing impacts on the explained variable. This finding, suggesting a need to explore the underlying economic and sociological mechanisms, adds depth to our understanding of the variables' complex interplay in influencing the birth rate.

3. Discussion

This study provides an in - depth examination of how economic, social, and educational factors influence birth rates within the Yangtze River Delta region, with a particular focus on forecasting future birth population trends in Shanghai. Through the application of grey relational analysis, we have successfully identified and ranked the key determinants of birth rates. These factors encompass economic indicators such as GDP and disposable income, alongside social and educational variables in-

cluding secondary school numbers, migrant worker populations, and graduate school enrollment rates. Further analysis using Pearson correlation has revealed that while the number of secondary schools has a positive impact on birth rates, graduate school enrollment may serve to suppress fertility intentions. Migrant worker populations have also emerged as a significant social factor in shaping regional fertility trends. Our forecasts indicate a concerning downward trend in Shanghai's birth population over the next decade, posing a substantial challenge to the city's demographic stability. While we have made efforts to integrate multi - source data to strengthen our findings, the discussion also highlights the complex interplay of various factors affecting birth rates. Economic factors, represented by GDP and disposable income, reflect the material foundation and living standards that influence family fertility decisions. On one hand, an improved economic environment can enhance family confidence in the future, thereby encouraging fertility intentions. On the other hand, the rise in living costs and the intensification of work - life conflicts in high - income settings may also exert a certain inhibitory effect on birth rates. Social factors, such as the number of migrant workers, influence birth rates through population mobility and the optimization of labor resource allocation. Migrant workers bring fresh vitality to urban development. Their integration into urban life and access to reproductive health services are closely linked to urban birth rates. The number of secondary schools, as an educational factor, reflects the level of regional educational resources. A well - developed education system can enhance residents' quality of life and expectations for the future, which may have a positive impact on birth rates. However, graduate school enrollment reflects the trend of higher education expansion. The delay in childbearing age caused by the pursuit of higher - degree education and the adjustment of career planning may lead to a decline in fertility intentions and a reduction in the birth rate. In terms of urban built - up area, although our analysis did not reveal a significant linear relationship with birth rates, this does not mean that urbanization has no impact on birth rates. On the contrary, the process of urbanization may influence birth rates through multiple pathways, such as changes in lifestyles, housing conditions, and social support systems. The rapid expansion of urban - built - up areas may lead to the dispersion of population distribution, increasing the cost of social interaction and reducing fertility intentions. At the same time, the transformation of urban functions and the upgrading of industrial structures may also alter the demand for labor, thereby indirectly affecting birth rates. Our research findings carry significant policy implications. For cities like Shanghai facing the challenge of a declining birth population, it is crucial to adopt a multi - dimensional policy framework to address this demographic issue. Economic policies should focus on providing targeted support to low - income and rural families. Measures such as subsidies, tax incentives, and the provision of affordable housing can help alleviate the economic pressures that negatively impact fertility decisions. In terms of urban planning, optimizing the urban built - up

area and housing environment is vital for improving urban livability. Creating more family - friendly residential areas, improving public service facilities, and enhancing community support systems can positively influence fertility intentions, particularly in densely populated cities like Shanghai. In the field of education, aligning higher education expansion with employment opportunities is essential. Strengthening the connection between graduate education and labor market demands, providing career guidance and employment support services for students, and reducing the mismatch between education and employment can help decrease the suppressive effect of graduate school enrollment on fertility intentions. Additionally, formulating effective policies to address labor migration and promote the integration of migrant workers into urban areas is crucial for minimizing regional disparities in fertility behavior. Enhancing the social security and welfare levels of migrant workers, improving their access to reproductive health services, and increasing their sense of belonging to the city can contribute to stabilizing and even increasing birth rates.

4. Conclusions

Our research provides insights into the demographic dynamics of Shanghai and the Yangtze River Delta region, exploring the complex interplay of economic, social, and educational factors on birth rates. We have integrated educational and social variables to enhance understanding of fertility drivers in the region.

However, limitations exist. The lack of micro - level data restricts detailed analysis of individual and household - level fertility decisions. Also, the linear assumption of Pearson correlation may not capture all complexities, especially nonlinear effects. Moreover, differences between predicted and actual birth data highlight the need for more nuanced predictive models.

It is important to note that our findings are based on correlation analysis, which does not imply causation.

Looking ahead, the declining trend in Shanghai's birth population calls for targeted policy actions. Economic policies should support low - income and rural families to alleviate economic pressures on fertility decisions. Optimizing the urban built - up area and housing environment is crucial for improving urban livability, which is closely linked to fertility intentions. Aligning higher education with employment opportunities can help reduce the suppressive effect of graduate school enrollment on fertility intentions. Additionally, strategies to address labor migration, especially the integration of migrant workers into urban areas, are essential to minimizing regional disparities in fertility behavior.

The demographic transformation of the 20th century and the public's trust in the government's commitment provide a foundation for optimism. The success of these policies will depend on the government's serious response to the population issue and significant social effort.

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