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Spatiotemporal Evolution and Influencing Factors of Population Growth Transition in China during the COVID-19 Pandemic

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Abstract: At present, China has lost its demographic dividend. Meanwhile, in the face of the twin challenges of rising living costs and the uneven distribution of educational resources, the fertility intentions of ordinary people are rapidly declining. In the background, China's latest birth incentive policy has not had the desired effect. Especially with the COVID-19 pandemic, these issues have become more complicated, making it more difficult to achieve policy goals. Analysis of changing characteristics and influencing mechanisms in China's current stage of population growth is therefore significant. Such analysis can help improve China's population structure and preserve the advantage of human resource endowment. In this paper, we use data from 2008, 2012, 2016, and 2020 as made available from the resources of China's National Bureau of Statistics and National Health Commission. These included annual macro statistics, seventh census data, and COVID-19 pandemic data, allowing us to analyze the influencing mechanism of China's population growth by using the Geographic Detector Model. The research revealed the dependency ratio as the primary factor influencing spatial differentiation of population growth in China, indicating that the dependency burden plays a role in inhibiting population growth. The secondary factor showed different changes in stages. At the same time, any two factors showed more substantial explanatory power after the interaction, meaning the spatial distribution of China's population growth results from the joint influence of many factors. The strong interaction was mainly concentrated around the dependency ratio and were with women's political participation and internet coverage. However, under the impact of the COVID-19 pandemic, the explanatory power of traditional factors was diluted, leading to a decline in the strength of interaction.

Keywords: population growth transition; aging population; influencing mechanism; spatiotemporal evolution

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1. Introduction

In recent years, the rising cost of living in China has reduced ordinary people's willingness to have children, thus affecting long-term stability in the country's population development [1]. This problem has become more complex with the COVID-19 pandemic, which accelerated the aging of China's population. Rapid aging has distorted the age structure of China's population and hindered the high-quality development of the Chinese economy [2]. Against this background, on 20 July 2021 the Chinese government issued a document on optimizing the birth policy to promote a long-term balanced development of the population. The decision put forward fertility incentive policies from three aspects:

(1) The government should align its fertility policy with its economic and social development policy by strengthening tax, employment, housing, and other support measures.
(2) The government should improve the birth guarantee to address young people's worries.
(3) The government should strive to promote equality in education.

In addition, the document requires governments to formulate medium- and long-term population development plans and to implement new birth policies. Therefore, scholarship should focus on how to bring about this policy's desired effect of improving China's population structure and maintaining the advantage of human resource endowment.

Ecological economists accept that the global population cannot grow forever. They do not recommend the involuntary control of population growth because it would discourage the discussion of issues such as inequality, unemployment, debt, social cohesion, and conflict [3]. This view is supported by modern Malthusians, who advocate natural control of population growth by promoting coordination between population and economic development [4]. Developed economies naturally have low or even negative population growth, but developing economies are often accompanied by high fertility rates [5]. This phenomenon verifies the Malthusians' judgment.

Population growth and economic growth have obvious non-monotonic correlations. That is, their correlation may be positive or negative, depending on the impact of population growth on the dilution effect of per capita human capital investment [6]. At the same time, population growth and economic growth also have interrelated characteristics. According to demographic transition theory, population development changes in stages with the progression of productivity. High productivity leads to the balance of a low death rate and low birth rate, causing a significant decline in the natural growth rate of the population [7]. For example, population aging has hampered economic growth in recent years, especially in the more aged countries that are mainly developed countries [8]. This is the point of demographic transition theory.

However, the impact of population aging on economic growth is reflected not only in macroeconomic outcomes but also in inflation and labor force participation. For example, a larger elderly share of the population leads to lower growth in real GDP, mostly in countries with low population growth rates. Aging has put substantial downward pressure on inflation due to subdued aggregate demand. In addition, the results show that the aging of the labor force has reduced the labor supply. To mitigate the adverse effects of population aging, a combination of labor market policies, pension reforms, investment in human capital, and technological innovation should be prioritized in policymaking [9].

For developing countries, "getting old before getting rich" is a huge challenge [10]. Although countries with low rates of natural population growth are the more susceptible to population aging, reduced population sizes do not lead to apparent economic recession in developed countries [10]. With a solid foundation in science and technology, developed countries can sustain technological innovation and drive economic growth despite negative population growth. However, due to developing countries' lack of scientific and technical innovation, their loss of demographic dividend leads to economic recession and a decline in national income [11]. Coupled with the heavy burden of support brought by an aging society, multiple pressures affect the fertility willingness of ordinary people and cause the economies of these countries to fall into long-term recession or stagnation [12]. Especially when compounded with the impact of an economic crisis, population aging in developing countries has more serious adverse effects on long-term economic stability [13]. Population aging may also bring opportunities for economic transformation in developing countries, but these countries need to adopt efforts to improve their scientific and technological achievements so they may stimulate technological innovation to compensate for the loss of labor supply [14]. For developing countries, too, the path is fraught with obstacles.

China has enjoyed the beneficial influence of a demographic dividend for a long time, but it is now facing the loss of this dividend [15]. Rapid population aging is the general trend and the irreversible condition of China's population development, both at present and in the future. This trend decides the long-term challenges and the difficulty of coping with them. To actively deal with aging, the Chinese government should consolidate its economic foundation, improve its governance capacity, encourage cultural values, enrich the conditions for social livelihood, promote ecological civilization, and so forth [16]. The data of the Seventh National Census of China confirmed the trends and underscored the challenges, showing that the 14th five-year plan will mark a significant transition period for China's population growth. During this period, in its efforts to optimize the population's age structure and to cope with aging, the Chinese government should strive to realize multi-level, high-quality development. Such development may feature a harmony of population with resources and the environment; it may create an economic model and social environment conducive to the population's high-quality development [17]. It has become China's national strategy to deal with the aging of the population. It is expected that China's population size can reach a peak level after the middle of the 21st century; it will then turn to negative growth. The years 2035 and 2050 will both be critical nodes of China's population development, which may show signs of significant change and deserve special attention [18].

Although the academic achievements around population growth and population aging have been abundant, there are still some shortcomings. The content of the existing research show a focus on analyzing current population aging and its impact on economic development; explorations of spatial layout, and of its principles of population growth, are inadequate. In particular, research has not yet begun to investigate recent changes in population growth under the COVID-19 pandemic. The methods used in existing research have explored the causal relationship between population growth and economic growth using traditional measurement methods, thus providing policy references for macroeconomic decisions. However, there is still a lack of research using spatial statistical methods on the principle of spatiotemporal variation in China's population growth. Acknowleding these shortcomings, we decided to summarize the spatial differentiation of China's population growth, analyzing the factors that influence its spatial differentiation and thus observing the mechanisms that influence the spatial distribution of China's population growth at different stages. Finally, we added the external factor of the COVID-19 pandemic to track current changes in China's population growth. This paper aims to inform improvements to China's population structure, first identifying the core influencing factors of Chinese population growth and their interaction effects and then combining the existing policies to find the content defects and details. Finally, we present recommendations concerning policy in areas such as economy, epidemic prevention, and birth incentive; these recommendations are expected to help reduce the living pressure and care burden of young people. These aspects provide a reference program by which the government may optimize the birth incentive policy; they will eventually help to improve China's population structure.

2. Theoretical Analysis and Variables

2.1. Theoretical Analysis

Malthusian demographic theory highlights the importance of controlling population growth. Malthus considered that rapid population growth would easily cause global food crises, resulting in consequences such as the overexploitation of natural resources, lagging economic development, decline of human welfare, and so forth. These problems are serious in some developing countries where population growth is out of control [19]. However, Malthus's dialectical relationship between population and food could not explain the actual influencing mechanism of population growth in developing countries. Population development theory later began to demonstrate the opportunities and challenges brought to human society by population growth from human biological nature [20]. Theorizing a hierarchy of needs indicates that people experiencing differences in culture and wealth cannot simply rely on birth control and other measures to curb population growth. On the contrary, the number of people should be indirectly controlled by improving the population's quality and stimulating individuals' high-level needs [21,22]. Therefore, theory points out that a decline in developed countries' birth rates is due to the progress of social civilization and individuals' pursuit of higher needs. To meet individuals' highest needs, it is necessary to control fertility and reduce the burden of raising children [23]. The social school of population development theory was born in the mid-19th century and advocated civilization theory, which points to the progress of social civilization as the leading cause of slowed population growth. The manners promoting social civilization include economic development, education popularization, political integrity, and social progress; these can also lead to lower birth rates [24].

Population growth is not a static process but a dynamic phase in population transition theory, which organically connects productivity and population development, showing that population development changes in stages as productivity progresses. Specifically, low productivity leads to high birth rates and high death rates; high productivity leads to low birth rates and low death rates [25]. This population transformation theory divides population development into a preliminary stage, a transitional stage, and a modern stage (Figure 1).

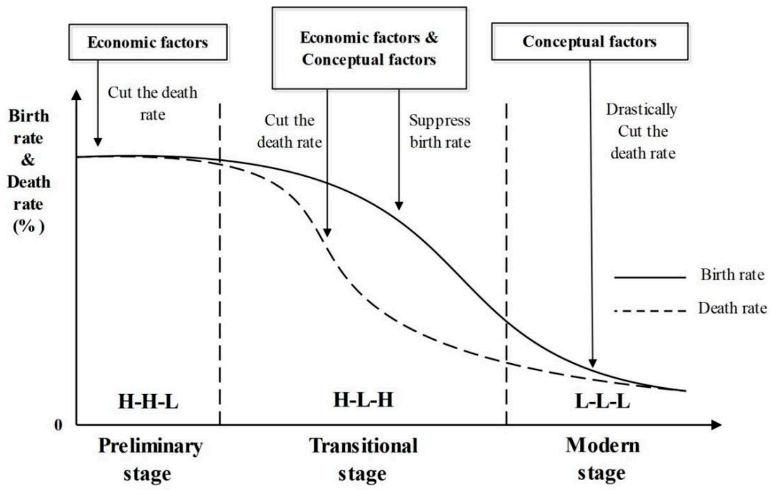

Figure 1. Stage transition of population growth and its characteristics.

Productivity is low during the preliminary stage and living resources can only meet common needs. At this stage, the population growth limit is determined by the limitation of living resources. Therefore, mortality is reduced without suppressing fertility. Most developing countries are at this stage [23]. The transitional stage is a period in which productivity increases to improve people's quality of life. However, at this stage, most people only live in relatively affluent material conditions, and tiny economic fluctuations can break the balance. Thus, to maintain their existing quality of life and reduce the cost of raising children, people choose late marriage and late childbearing; some people even decide not to have children. This condition leads to a decline in fertility across a society. When productivity reaches a high level, the high quality of living standards may lead to a change in human psychological views. People begin to pursue high-level needs dominated by individual values that reshape the human conception of fertility. The new view consciously controls the size of the family and pays attention to cultivating offspring. The birth rate declines and remains low, even reaching negative growth throughout society. This is known as the modern stage, common in developed countries [26].

China's economy has made remarkable achievements and is now in a transitional period of high-quality development. Productivity has risen rapidly, but regional differences are stark. Therefore, China's population development is in a transitional stage and population growth is gradually slowing due to the combined influence of numerous factors. However, the impact of the COVID-19 pandemic, considered one of the most horrific disease outbreaks in all of human history [27], has broken the balance and accelerated the aging of China's population.

2.2. Variables

2.2.1. Dependent Variable

Population growth is a fundamental concept that reflects the general trend of population change in a country or region within a certain period. It is generally measured by the natural population growth rate. However, as a country's economy develops and its quality of life (and health care) improves, the death rate stabilizes at a lower level. For example, since 2000, the average annual death rate in China has been stable at less than 7‰. On the other hand, the birth rate is relatively sensitive and shows significant interannual fluctuations due to national economic conditions, policy guidance, and even public opinion. Therefore, we selected the birth rate as the dependent variable in this study (Table 1).

Table 1. Variables and their units.

Factors	Variables	Units	Sign
Dependent variable	Birth rate	%	y
Independent variable	Proportion of spending on education, culture, and entertainment	%	x_1
	Dependency ratio	%	x_2
	Bearing capacity of fertility support facilities	Ten thousand people/bed	x_3
	Women's political participation	%	x_4
	Women's educational achievement	%	x_5
	Internet coverage	%	x_6
Independent variable-external factor	Number of confirmed cases of COVID-19	One person	x_7

Note: The proportion of female members in grassroots autonomous organizations was used to represent women's political participation.

2.2.2. Independent Variable

(1) Economic factors

The transitional stage is where economic factors dominate and most families maintain a precarious financial balance. Whether income can cover the cost of parenting based on guaranteeing basic needs is the primary consideration in family fertility decisions [26]. Therefore, in this study we selected two economic factors: the proportion of spending on education, culture, and entertainment, and the dependency ratio (Table 1).

(2) Social factors

The development of society also has an essential impact on population growth. The progress of social civilization changes concepts of lifestyle and consumption, thus transforming population development. At the same time, modern life stimulates the subjective will to maintain a high quality of life and to help women and their families make scientific reproductive decisions [28,29]. Therefore, we selected one social factor: the bearing capacity of fertility support facilities (Table 1).

(3) Conception-related factors

The pursuit of self-worth affects the conception of fertility. Since men are not the primary bearers of fertility, the change in their attitudes is relatively delayed and not strong. When pursuing higher needs, women question traditional ideas emphasizing women's parenting responsibilities over their self-development, thus promoting changes in their fertility concepts. This questioning view encourages women to control the cost of parenting and to save time and money for self-development [30,31]. Therefore, we selected three factors that represent such a conception: women's political participation, their level of education, and internet coverage (Table 1).

In addition, to further track the current changes in China's population growth, we added the external factor of the COVID-19 pandemic from the 2020 results. The variables were automatically graded using the natural break point method, according to the specific value of each year.

3. Spatial and Temporal Evolution Analysis

3.1. Spatial and Temporal Evolution of Population Growth

The level intervals of the factors are determined using the isometric breakpoint method. As can be seen from Figure 2, the overall birth rate of China's population has remained stable for a long time. The birth rate is higher in northwest and central China, but low in northeast China. Since the onset of the COVID-19 pandemic in 2020, the birth rate has fallen sharply, especially in northwest and eastern China.

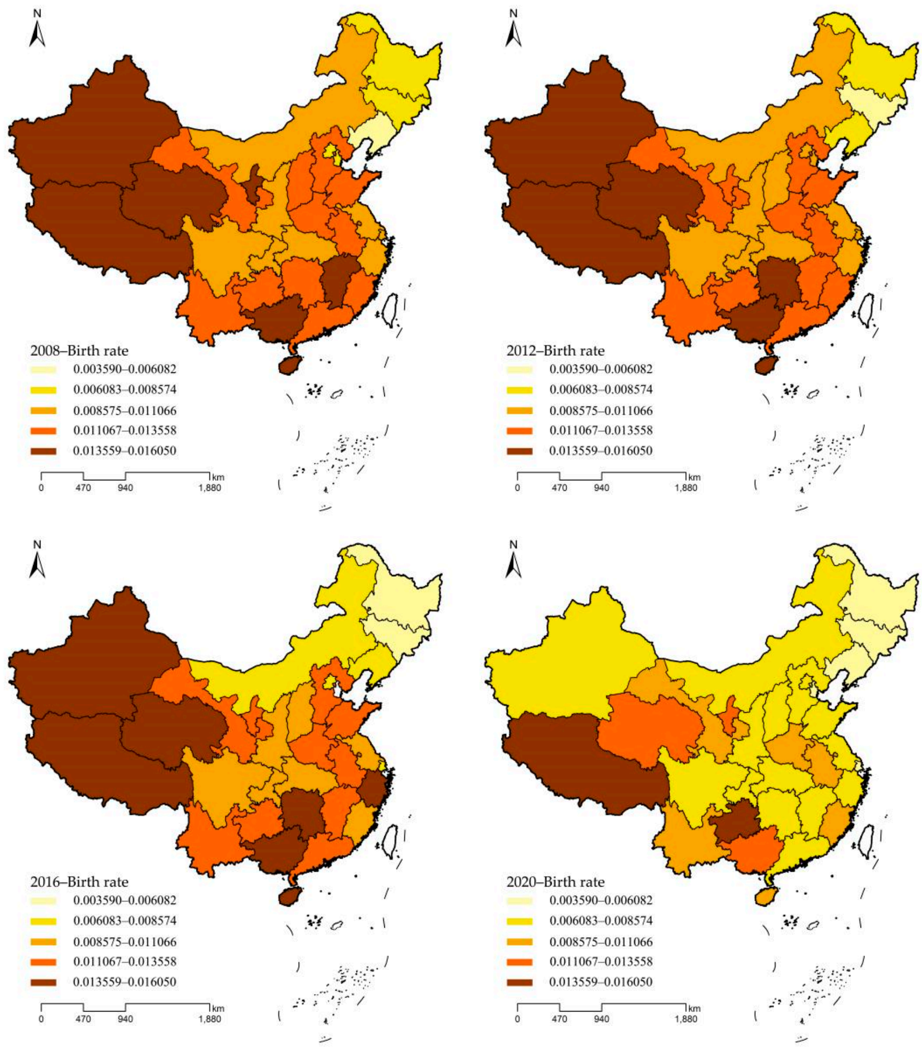

Figure 2. Spatial and temporal evolution of population growth (these maps reference the standard maps (No.: GS(2020)4632) provided by the Map Technology Review Center of the Ministry of Natural Resources of China).

3.2. Spatial and Temporal Evolution of Economic Factors

As can be seen from Figure 3, the proportion of spending on education, culture, and entertainment did not change significantly but dropped, apparently due to the impact of the COVID-19 pandemic, in 2020. The areas with high dependency ratios gradually extended from the central and western regions toward the east. Besides, the dependency ratio was much increased after the onset of the COVID-19 pandemic.

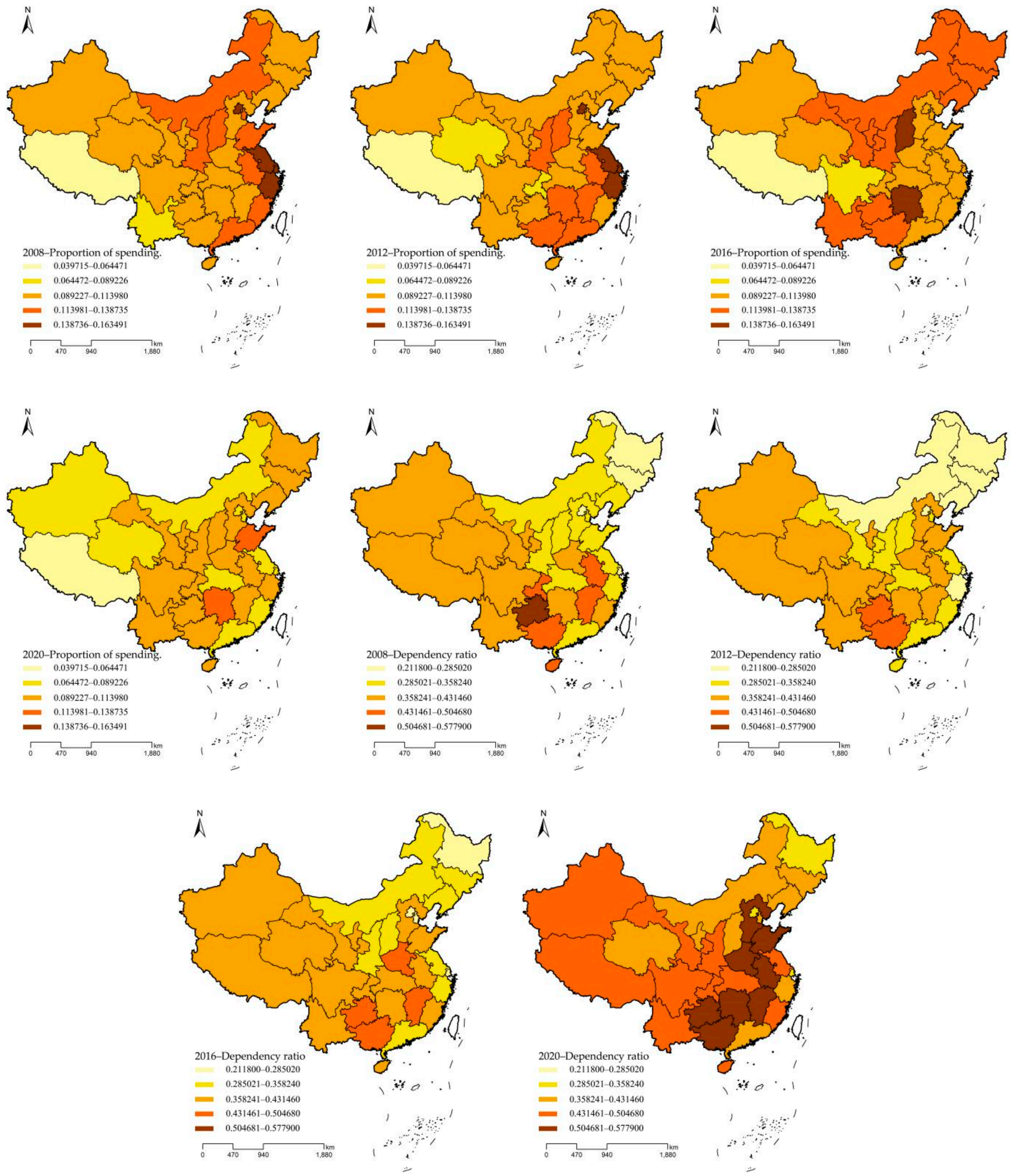

Figure 3. Spatial and temporal evolution of economic factors.

3.3. Spatial and Temporal Evolution of Social Factors

The bearing capacity of fertility support facilities did not change but declined significantly in 2020, possibly related to the large number of medical resources occupied by the COVID-19 pandemic (Figure 4).

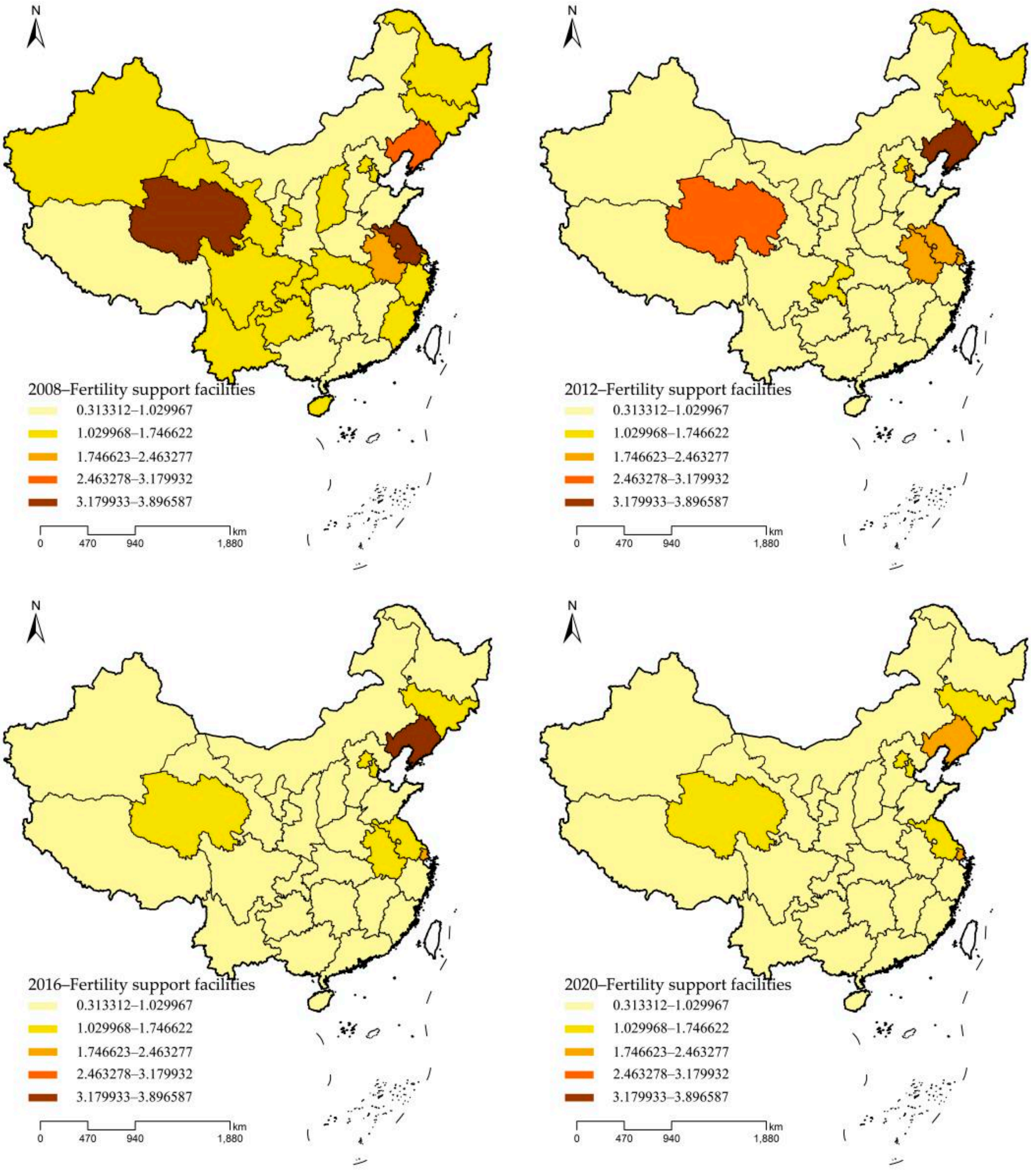

Figure 4. Spatial and temporal evolution of social factors.

3.4. Spatial and Temporal Evolution of Conception's Factors

As can be seen from Figure 5, women's political participation has risen slowly, with a relatively high proportion in the northeast and central areas. The level of educational attainment has been improving among women year by year; the Beijing–Tianjin area and the Yangtze River Delta show the highest levels of education among women in China. Internet coverage has improved rapidly.

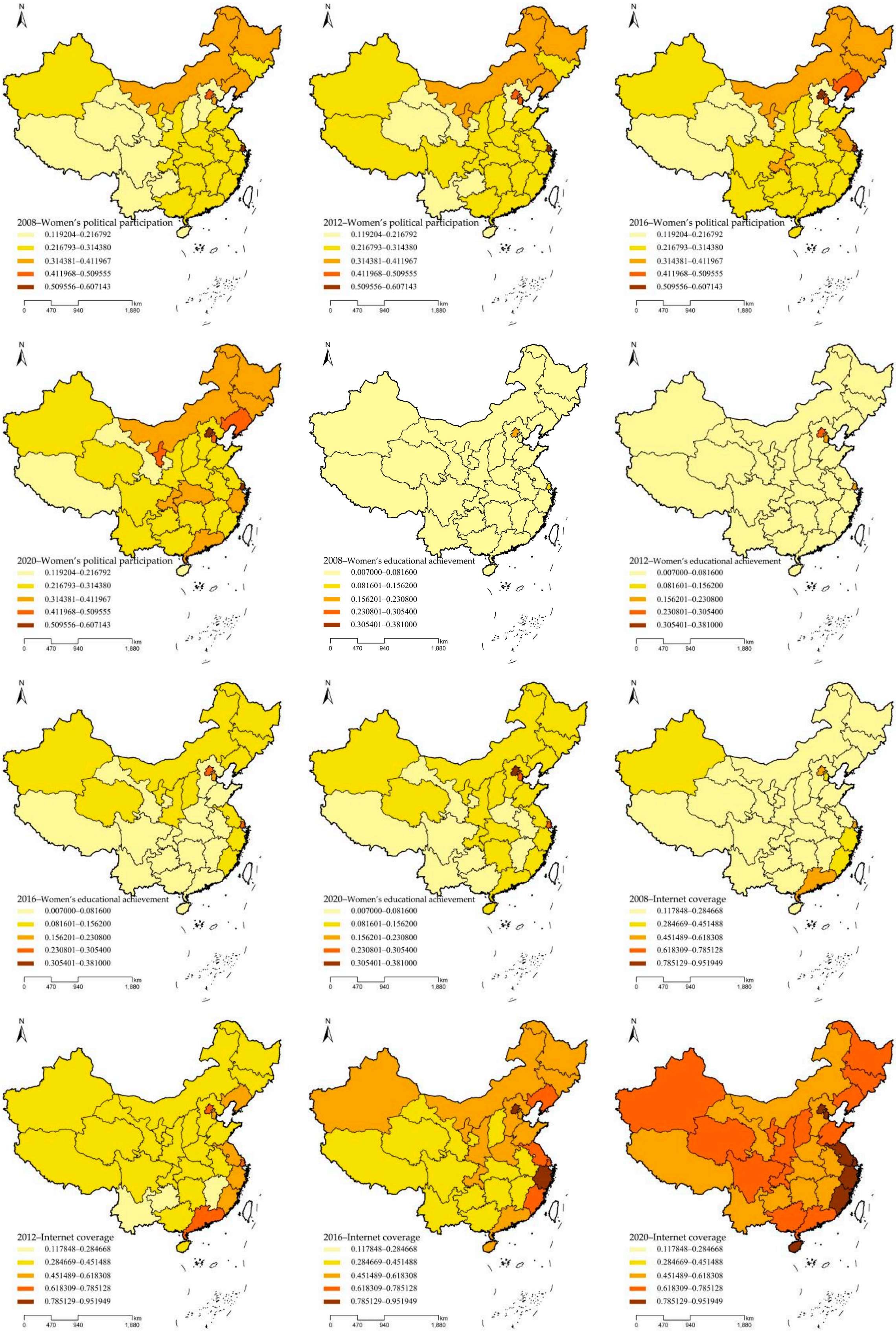

Figure 5. Spatial and temporal evolution of conception's factors.

4. Influencing Factors of China's Population Growth Transition

4.1. Data and Methodology

4.1.1. Data Sources

Population-related data came from the bulletin of China's seventh population census along with the census bulletins from provinces, municipalities, and autonomous regions. Data related to economy, education, people's livelihoods, and infrastructure construction come from various statistical yearbooks, such as the China Statistical Yearbook, the China Social Statistical Yearbook, the China Labor Statistical Yearbook, the China Population and Employment Statistical Yearbook, and so forth. The epidemic data were from the development record of the COVID-19 epidemic in China in 2020.

This study selects cross-sectional data from four years: 2008, 2012, 2016, and 2020. The sample for the study is 31 provincial administrative units in China.

These resources are available via the following websites [32–34]:

- http://www.stats.gov.cn/tjsj/ndsj/ (accessed on 3 October 2022).
- http://www.nhc.gov.cn/xcs/xxgzbd/gzbd_index.shtml (accessed on 1 October 2022).
- https://data.cnki.net/HomeNew/index (accessed on 3 October 2022).

4.1.2. Metrology Model

Based on theoretical analysis, with an increase in productivity, the causes of population growth focus on economy and conception. In addition, there may be different characteristics due to external reasons. Therefore, we used the Geographic Detector model to explore the influence mechanism and to verify the leading factors of China's current population growth [35,36]. The Geographic Detector model is used in spatial statistical analyses. It is based on the theoretical perspective of spatial stratification heterogeneity to judge the similarity of spatial distributions for two variables. Specifically, if an independent variable x_i has a significant impact on the birth rate y, then the spatial differentiation of y should be similar to that of x_i [37]. Geographic Detector modeling has been used in spatial analysis as well as in empirical research [38–40].

For this paper, we used factor detection and interaction of factors detection in a Geographic Detector model to analyze the influencing factors of population growth and their interaction on the provincial scale in China. Factor detection means detecting the explanation degree of factor x_i for the spatial differentiation of y, which is expressed by the q statistic. The formula is as follows:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST} \tag{1}$$

$$SSW = \sum_{h=1}^{L} N_h \sigma_h^2;\ SST = N\sigma^2 \tag{2}$$

In the formula, h is the number of layers of x_i or y, also known as the number of subregions. N_h and N are the number of units in layer H and the whole area, respectively. σ_h^2 and σ^2 are the variances of the h layer and the entire y area, respectively. SSW is the sum of intra-layer variance and SST is the total variance of the entire region. The factor detection value is represented by q, whose value range is 0–1. The closer the value is to 1, the more pronounced the spatial differentiation of y is. If this differentiation is caused by x_i, the q-value represents the explanatory factor power of x_i to y. The larger q is, the greater the explanatory power. In an extreme case, when the value is 1, factor x_i thoroughly explains y, and when the value is 0, it means the factor x_i is independent of y.

The interaction of factors detection shows the interaction of different factors. For example, after an interaction between x_i and x_j, estimating its explanatory power for the dependent variable y is enhanced or weakened and the degree of its enhancement or weakening is observable. Of course, these two factors may also have independent effects on y [35]. Specifically, the model needs first to calculate the q-values of both factors x_i and x_j, concerning y, as $q(x_i)$ and $q(x_j)$. Then, the two factors interact; that is, the two layers of x_i and x_j are superimposed, a new polygon distribution is formed after the tangent and $q(x_i \cap x_j)$ is obtained. Finally, $q(x_i)$, $q(x_j)$, and $q(x_i \cap x_j)$ are compared. Table 2 shows the interaction results from the two factors in our analysis.

Table 2. The interaction of factors detection.

Interaction of Factors	Principle
$q(x_i \cap x_j) < \mathrm{Min}[q(x_i), q(x_j)]$	Weakness, nonlinear
$\mathrm{Min}[q(x_i), q(x_j)] < q(x_i \cap x_j) < \mathrm{Max}[q(x_i), q(x_j)]$	Univariate weakness, nonlinear
$q(x_i \cap x_j) > \mathrm{Max}[q(x_i), q(x_j)]$	Bivariate enhancement
$q(x_i \cap x_j) = q(x_i) + q(x_j)$	Independence
$q(x_i \cap x_j) > q(x_i) + q(x_j)$	Enhancement, nonlinear

4.2. Analysis of the Factors Affecting China's Population Growth

4.2.1. Descriptive Statistics and Multicollinearity Tests

This study used four years' data to perform a descriptive statistical analysis. It then used the variance inflation factor (VIF) method to diagnose the multicollinearity of independent variables to avoid the potential bias in model fitting caused by the multicollinearity among variables (Tables 3 and 4).

Table 3. Results of descriptive statistics.

Variable	**Mean**				**S.D.**			
	2008	**2012**	**2016**	**2020**	**2008**	**2012**	**2016**	**2020**
y	0.011	0.011	0.011	0.008	0.003	0.003	0.003	0.002
x_1	0.113	0.113	0.111	0.094	0.020	0.022	0.019	0.015
x_2	0.369	0.345	0.364	0.446	0.065	0.069	0.061	0.066
x_3	1.365	1.128	0.942	0.774	0.752	0.697	0.645	0.482
x_4	0.275	0.286	0.302	0.316	0.095	0.091	0.099	0.076
x_5	0.028	0.061	0.095	0.121	0.035	0.056	0.062	0.069
x_6	0.237	0.423	0.509	0.691	0.121	0.118	0.133	0.140
x_7	–	–	–	2592	–	–	–	11945
Variable	Min				Max			
	2008	2012	2016	2020	2008	2012	2016	2020
y	0.006	0.006	0.006	0.004	0.016	0.015	0.016	0.014
x_1	0.050	0.049	0.040	0.041	0.150	0.163	0.152	0.125
x_2	0.250	0.212	0.257	0.336	0.519	0.473	0.479	0.578
x_3	0.716	0.490	0.390	0.313	3.897	3.589	3.618	2.366
x_4	0.119	0.174	0.182	0.179	0.584	0.538	0.607	0.568
x_5	0.007	0.023	0.042	0.068	0.168	0.299	0.305	0.380
x_6	0.118	0.281	0.296	0.452	0.553	0.705	0.844	0.952
x_7	–	–	–	1	–	–	–	66907

Table 4. Results of multicollinearity tests.

VIF	x_1	x_2	x_3	x_4	x_5	x_6	x_7
2008	1.56	1.75	1.05	3.11	4.74	3.12	–
2012	1.36	2.33	1.34	3.50	3.45	3.04	–
2016	1.02	2.11	1.51	3.83	4.33	1.82	–
2020	1.56	2.02	1.86	4.31	4.45	2.42	1.20

The standard deviations and extrema of each variable were within a reasonable range, demonstrating the variables' reliability.

In the multicollinearity test of independent variables, the VIF values for these variables were within five. According to the judging principle of VIF, these variables passed the multicollinearity test to avoid the interference of collinear factors on the estimation results.

4.2.2. Factor Detection

The results of factor detection for the four years are reported in Table 5.

Table 5. Results of factor detection.

***q*-Value**	x_1	x_2	x_3	x_4	x_5	x_6	x_7
2008	0.2137	0.6300 ***	0.1063	0.4735	0.3095	0.1962	–
2012	0.1887	0.6378 ***	0.4561 **	0.3376	0.1692	0.2565	–
2016	0.1943	0.6711 ***	0.2494	0.5608 ***	0.3708 **	0.3229	–
2020	0.3787	0.4041	0.2807 *	0.3782	0.3719 **	0.2038	0.1945

Note: ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

(1) Dependency ratio has always been the primary factor, but it changed in 2020.

The results from 2008 showed that the primary factor was the dependency ratio, with a q-value of 0.6300, which was very significant and showed high explanatory power. This high explanatory power was an outstanding manifestation of an aging society, proving that China began to face the dilemma of population aging as early as 2008. This had a lot to do with China's one-child policy. The heavy burden of raising children affected families' fertility decisions and inhibited population growth. This mechanism continued to appear in the 2012 and 2016 results, the dependency ratio remaining the primary factor and its explanatory power increasing. It follows that the aging process of China's population is accelerating, adding to the burden on young people and further inhibiting their desire to have children. It is evident that the younger generation in China pays more attention to quality of life; as the burden of care increases the distance between their ideal lives and their reality, they are careful about choosing to have children. This generation often have one child per household and their elderly population dependency ratio is already heavy. They will continue to be more careful about choosing to have children; this is the main reason why China's new birth policy cannot significantly promote population growth.

The explanatory power of influencing factors at all levels was weakened in 2020. The dependency ratio, which had the most substantial explanatory power in the past, became insignificant, and the primary factor became women's levels of education achievement. However, the significance level was deficient and the persuasion was limited.

(2) Secondary factors have different characteristics in each year.

The 2008 results showed a lack of secondary factors, reflecting the independent effect of the dependency ratio. The secondary factor was the bearing capacity of fertility support facilities in the 2012 results, with $q = 0.4561$, possibly showing a strong interaction with the dependency ratio. That is, the fertility support facilities reduce the burden of dependency and have a positive impact on family fertility decisions.

In the 2016 results, the factors showed diversified characteristics. The secondary factors were women's political participation ($q = 0.5608$) and women's educational achievement ($q = 0.3708$). This was mainly due to the transformation of China's economic and social development around 2016 and the complex changes in the factors affecting population growth.

In the 2020 results, the explanatory power of all factors was weakened. The secondary factors were the bearing capacity of fertility support facilities, but the significance level was low and the persuasion was limited.

4.2.3. Interaction of Factors Detection

All independent variables showed different interactions, as shown in Tables 6–9.

Table 6. Results of interaction of factors detection (2008).

	x_1∩	x_2∩	x_3∩	x_4∩	x_5∩	x_6∩
x_1	0.2137					
x_2	0.7861	0.6300				
x_3	0.5380	0.7987	0.1063			
x_4	0.6884	0.8164	0.6566	0.4735		
x_5	0.5863	0.7747	0.5878	0.5370	0.3095	
x_6	0.4236	0.8866	0.5665	0.7468	0.6869	0.1962

Note: Single underlines mark nonlinear enhancement and double underlines show bivariate enhancement.

Table 7. Results of interaction of factors detection (2012).

	x_1∩	x_2∩	x_3∩	x_4∩	x_5∩	x_6∩
x_1	0.1887					
x_2	0.9223	0.6378				
x_3	0.7938	0.8232	0.4561			
x_4	0.4954	0.7334	0.6054	0.3376		
x_5	0.5183	0.7525	0.7199	0.4713	0.1692	
x_6	0.6713	0.8344	0.6824	0.4507	0.3780	0.2565

Note: Single underlines mark nonlinear enhancement and double underlines show bivariate enhancement.

Table 8. Results of interaction of factors detection (2016).

	x_1∩	x_2∩	x_3∩	x_4∩	x_5∩	x_6∩
x_1	0.1943					
x_2	0.8337	0.6711				
x_3	0.6192	0.7784	0.2494			
x_4	0.6813	0.8729	0.7507	0.5608		
x_5	0.7485	0.7934	0.7691	0.7181	0.3908	
x_6	0.5804	0.7192	0.6688	0.6599	0.7248	0.3229

Note: Single underlines mark nonlinear enhancement and double underlines show bivariate enhancement.

Table 9. Results of interaction of factors detection (2020).

	x_1∩	x_2∩	x_3∩	x_4∩	x_5∩	x_6∩	x_7∩
x_1	0.3787						
x_2	0.6559	0.4041					
x_3	0.7554	0.5963	0.2807				
x_4	0.6810	0.7578	0.7325	0.3782			
x_5	0.6070	0.6464	0.7264	0.5951	0.3719		
x_6	0.5351	0.6363	0.5969	0.6709	0.5962	0.2038	
x_7	0.5929	0.6620	0.5357	0.6422	0.6483	0.4853	0.1945

Note: Single underlines mark nonlinear enhancement and double underlines show bivariate enhancement.

As can be seen from these tables, the phenomenon of bivariate enhancement accounted for most of the four years. In other words, the influencing factors had more substantial explanatory power after the interaction, indicating the spatial distribution of China's population growth results from the joint influence of multiple factors. Moreover, the total strength of the interaction is rising, indicating that the strength of the combined action of multiple factors is increasing.

An interaction value greater than 0.80 is defined as a strong interaction. The strong interaction in these four years was mainly concentrated in the interaction with the dependency ratio, where $x_2 \cap x_4$ and $x_2 \cap x_6$ marked strong interactions in multiple years. In the results for 2008, $x_2 \cap x_6$ and $x_2 \cap x_4$ were strong interactions, their interaction values at 0.89 and 0.82, respectively. This reflects the strong interaction effect of the dependency ratio with internet coverage and women's political participation. That is, the popularization of the internet and the promotion of women's political participation helped to consolidate social forces around sharing the burden of youth care, thus enhancing labor participation rates and slowing down population aging.

There was a change in the results from 2012, where $x_1 \cap x_2$, $x_2 \cap x_6$, and $x_2 \cap x_3$ were strong interactions, their values at 0.92, 0.83, and 0.82, respectively. The interaction between the dependency ratio and internet coverage was still strong, showing a certain continuity in the interaction. It is worth noting that in the 2012 results, the interaction strength of the dependency ratio and the bearing capacity of fertility support facilities was as high as 0.82, thus verifying the strong interaction between the two variables mentioned above. In comparison, the interaction of $x_1 \cap x_2$ did not pass the significance test for 2012; its interaction had no practical significance.

In the 2016 results, $x_2 \cap x_4$ again became the most substantial interaction, with an interaction value of 0.87, possibly because of the expansion of women's political participation. The interaction value of $x_1 \cap x_2$ was next, at 0.83. Since x_1 again did not pass the significance test, its interaction had no practical significance. $x_2 \cap x_5$ also had a strong interaction value (0.79), indicating that the interaction between women's level of education attainment and the dependency ratio was still significant. The 2020 results showed no strong interaction because the explanatory power of each factor was substantially diluted.

5. Conclusions and Recommendations

5.1. Conclusions

The overall birth rate of China's population has remained low for a long time. The birth rate is relatively high in northwest China, followed by the central region; it is low in northeast China. Since the COVID-19 pandemic began in 2020, the birth rate has fallen sharply, especially in the northwest and in eastern China.

The dependency ratio has a long-term, significant impact on China's population growth, which is the primary factor. This shows the burden of raising children will significantly affect families' fertility decisions and play a role in inhibiting population growth. Secondary factors showed various changes in stages. However, under the impact of the COVID-19 pandemic, the explanatory power of traditional factors is diluted. The dependency ratio, which in the past had the most substantial explanatory power, became insignificant. At the same time, the bearing capacity of fertility support facilities and women's level of education attainment became important. Still, the significance level was low, so the persuasive power is limited.

The explanatory power of any two factors after the interaction was more substantial, showing that the spatial distribution of China's population growth is actually the result of the joint influence of many factors. The strongest interactions were mainly concentrated in the interaction with the dependency ratio, where $x_2 \cap x_4$ and $x_2 \cap x_6$ were strong interactions in multiple years. This reflects the strong interaction effect between the dependency ratio and women's educational achievement and internet coverage.

5.2. Recommendations

Since July 2021, China's existing policy is guided by the government's decision to optimize its fertility policy and to promote long-term, balanced population development. This policy points to the future direction of China's fertility policy optimization. However, some details of existing policies still need to be optimized and improved, mainly in three aspects.

(1) Striving to stabilize economic development and mitigate the impact of the COVID-19 pandemic on ordinary people.

Under the impact of the COVID-19 pandemic, the birth rate fell sharply, especially in northwest and eastern China. On this issue, the government should first recognize the essential characteristics of China's population development (which is still in a transitional stage) and then fully consider the impact of the COVID-19 pandemic on the macro economy. Specific measures are as follows:

- The government should try to implement its rebate policy in more industries, easing financial pressure on businesses and thus easing their burdens. At the same time, the government should make proper use of special local government bonds, expand the size and coverage of government-financed guarantee services, focus on industries heavily affected by the pandemic, and provide preferential policies to small and micro-sized enterprises. These measures will stabilize employment and ensure stable incomes for ordinary people.
- Administration departments should implement a policy, for people and individual businesses affected by the pandemic, of deferring arrears in paying water, electricity, and gas bills. In addition, social security departments should work to ensure that the basic living standards of low-income groups are not lowered by price increases.
- Quarantine authorities should implement flexible, regular policies to mitigate the impact of COVID-19 on the general public.

(2) Multi-pronged approach to reduce the life pressure of young people.

Members of the younger generation in China today face tremendous pressure in life and social communication. Therefore, they may actively choose to defer (or even avoid) marriage and childbearing. This phenomenon inhibits population growth; the countermeasures are as follows.

- Society as a whole should promote a modern conception of marriage, reduce parents' influence on young people's marriages, and combat such habits as setting and accepting sky-high bride prices.
- The government should offer cash incentives to young people who have two or three children.
- Grassroots communities can try to organize social gatherings and youth volunteer activities to help young people break down social communication barriers and guide them toward optimistic attitudes in life.

(3) Mobilizing society to help young people share the burden of family care.

Through this paper's analysis, we have seen a strong interaction between the bearing capacity of fertility support facilities and the dependency ratio. Fertility support facilities reduce the burden of dependency and thus have a positive impact on families' fertility decisions. Therefore, improving fertility support facilities and reducing young people's burden of care are also important measures to promote population growth.

- To ease the burden of childcare, the government should provide cash grants or tax incentives to young people raising children. At the same time, the government should protect the rights and interests of pregnant and lactating women and, from a legal point of view, it should prevent pregnancy-related unemployment.
- Grassroots communities should establish institutions supporting childcare, elderly care, and so forth.
- The government can use tax incentives and other means to encourage enterprise investments in non-profit family care services.

These measures would help to mobilize Chinese society in support of young people, in sharing the burden of family care, and in promoting population growth.

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