Study of the Relationship between Population and Economic Growth Based on Fixed Effects Model

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Abstract. Targeting population and economic growth, through literature research and empirical analysis, this paper establishes a panel fixed effects model applied to China’s provincial panel data over the period 2007 - 2016. Based on the model, the paper empirically analyses the specific effects relationship between the urbanization level as well as per capita GDP and population growth, and makes correlation test. The findings show there is a close relationship between population and economic growth.

Introduction

The relationship between population and economic growth has been one of the subjects drawing the attention of many scholars [1] and is also the basis on which the government formulates and improves policies. In his paper An Essay on the Principle of Population, Malthus proposed in his research that the continuous increase of population will inhibit the increase of labour productivity and that the continuous increase in production demand will lead to large-scale destruction of the ecological environment, thus reducing the social investment rate and making it difficult to maintain long-term and stable social and economic development. Increasing population will consume more resources and reduce long-term growth potential [2]. On the other hand, however, some scholars believe that the economic slowdown in developed countries may be partly due to the low population growth [3].

Population growth will have important impacts on the overall economic growth [4] and the impacts are positive [5].

China is a populous country, so the relationship between population and economy is of even greater research value. Existing studies have shown that the differences in social and economic development have resulted in different population growth rates in various provinces and municipalities in China. When studying the relationship between population and economic growth with panel data, this paper uses the Generalized method of moments (GMM) to overcome the endogenous problem in population structure variables. The fixed effects model can be used to test the autocorrelation of variables in space to construct a spatial panel data model. Then after introducing spatial regression analysis, it validates the relationship between population and economic development. This paper uses the fixed effects model to select panel data from various provinces and municipalities in China and explore the relationship between population growth, urbanization levels, and per capita GDP.

Modelling

Baltagi and Hsiao [6,7] pointed out that panel data have many advantages: 1) more measured sample data, giving the model a higher degree of freedom; 2) better avoiding multi-collinearity and controlling the heterogeneity between individuals; 3) panel data comprehensively consider the dynamic changes within individuals and the differences between individuals, providing a realistic basis for studying the unobservable effects existing between variables.

By setting different intercept terms and variable coefficients, the panel data model can describe the spatial and temporal differences, but when setting the differences in intercept items, the
traditional panel data model emphasizes the differences in spatial individuals more, without considering the interactions between individuals in the spatial dimension, i.e. spatial correlation. By introducing the dependent variable or spatial auto-regressive error, and describing the relevance of the individuals in the spatial state, the spatial panel data model makes up for the inadequacies of the traditional panel data model. Unlike in the traditional empirical analysis, using the fixed effects method in the study of population and economic growth, and establishing a corresponding fixed effects model can effectively ensure that the model has a good degree of freedom and accurately describes the correlation between individuals in the spatial state, thus greatly improving the effectiveness and comprehensiveness of the study. Therefore, this paper attempts to analyse the population and economic growth with the fixed effects model.

**Establishment of the Population and Economic Growth Model**

**Distribution of Provincial Population Growth Rates**

According to relevant statistics from the State Statistics Bureau, during the decade from 2007 to 2016, the average growth rate of permanent residents in the 31 provinces and municipalities in China was 0.818%, except for Hong Kong, Macau, and Taiwan, and the population growth was not evenly spatially distributed. Among the many provinces and autonomous regions in China, the average annual growth rate of permanent resident population in Tianjin was the highest - 3.827%. However, in most areas, the average annual growth rate of permanent resident population was less than 0.818%, and in Guizhou and Heilongjiang, the population even experienced negative growth – decreased by 0.234% and 0.73%, respectively. The specific growth rates of population of different provinces and municipalities are classified as shown in the table below:

| Average annual permanent resident population growth rate | Province/municipality/autonomous region |
|---------------------------------------------------------|---------------------------------------|
| >1.636%                                                 | Beijing, Tianjin and Shanghai         |
| 0.818%-1.636%                                           | Hebei, Shanxi, Zhejiang, Guangdong, Hainan, Chongqing, Tibet, Ningxia and Xinjiang |
| < 0.818%                                                | Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu and Qinghai |

Table 1 shows that during the ten years from 2007 to 2017 in all provinces, municipalities and autonomous regions in China, the annual average permanent population growth rate showed a pyramid-type growth trend. The three provinces/municipalities with an average annual population growth rate of greater than 1.636% were Beijing, Tianjin, and Shanghai, all of which are economically developed regions in China; the average annual population growth rates in Guangdong, Zhejiang, and other regions were lower than those of the first grade, but their economic growth was not slow. The relationship between economic growth and annual population growth rate needs to be discussed.

**Assumptions of the Influence Factor Model**

Spatial autocorrelation reflects how a certain geographical phenomenon or an attribute value in a region is correlated with the attribute value of the same phenomenon in a neighbouring region [8]. Based on this, this paper establishing an influence factor model for population growth rate, and assumes three factors - annual population growth rate (PR), annual per capita GDP growth rate (GR) and annual urbanization growth rate (UR) have different influences on population growth.

\[ PR_n = \frac{(P_n - P_{n-1})}{P_{n-1}}, \text{ where } n=1, 2,...,31 \text{, indicating provinces and municipalities; and } i=2007, 2008, ...2016, \text{ representing year (the same below)}. \]
2) In order to prevent GDP from being affected by population size, per capita GDP is used in this paper. The per capita GDP growth rate (GR) in each province or municipality is calculated to reflect the relationship between population and economic growth.  

\[ GR_n = \frac{(G_n - G_{n-1})}{G_{n-1}}. \]

3) In the demographic statistics in China, the total population is divided into two parts – urban and rural populations. The urbanization level is represented by the proportion of non-rural population in the total population (urbanization index U = urban population / total population). The annual average growth rate of urbanization effectively reflects the internal correlation between population growth and regional economy under the context of urbanization construction in China. 

The annual growth rate of urbanization is calculated like this:  

\[ UR_n = \frac{(U_n - U_{n-1})}{U_{n-1}}. \]  
The statistics of the average growth rate over the ten years are shown in Table 2.

| Province/municipality | PRni  | URni  | GRni  | Province/municipality | PRni  | URni  | GRni  |
|-----------------------|-------|-------|-------|-----------------------|-------|-------|-------|
| Beijing               | 0.029452 | 0.002608 | 0.074392 | Hubei                 | 0.003576 | 0.030763 | 0.139152 |
| Tianjin               | 0.038273 | 0.0093  | 0.086463 | Hunan                 | 0.00793  | 0.030002 | 0.125639 |
| Hebei                 | 0.008179 | 0.031776 | 0.132625 | Guangdong             | 0.014566 | 0.01031  | 0.084088 |
| Shanxi                | 0.009193 | 0.027535 | 0.081625 | Guangxi               | 0.001798 | 0.031968 | 0.125204 |
| Inner Mongolia        | 0.004096 | 0.023701 | 0.102285 | Hainan                | 0.0004096 | 0.027535 | 0.081625 |
| Liaoning              | 0.002056 | 0.014524 | 0.073328 | Chongqing             | 0.003836 | 0.02925  | 0.138742 |
| Jilin                 | 0.000126 | 0.00075  | 0.131626 | Sichuan               | 0.001587 | 0.036646 | 0.126626 |
| Heilongjiang          | -0.00073 | 0.010503 | 0.077584 | Guizhou               | -0.00073 | 0.05131  | 0.159291 |
| Shanghai              | 0.017953 | -0.00097 | 0.06787 | Yunnan                | 0.006171 | 0.040238 | 0.116252 |
| Jiangsu               | 0.003911 | 0.027406 | 0.116318 | Tibet                 | 0.015198 | 0.036457 | 0.122132 |
| Zhejiang              | 0.009082 | 0.017862 | 0.090733 | Shaanxi               | 0.003108 | 0.035018 | 0.12696 |
| Anhui                 | 0.001471 | 0.033734 | 0.136304 | Gansu                 | 0.002676 | 0.036921 | 0.103183 |
| Fujian                | 0.007811 | 0.023987 | 0.122832 | Qinghai               | 0.007994 | 0.02867 | 0.109128 |
| Jiangxi               | 0.005573 | 0.032578 | 0.121346 | Ningxia               | 0.011327 | 0.027724 | 0.117238 |
| Shandong              | 0.006701 | 0.026255 | 0.096026 | Xinjiang              | 0.015133 | 0.02395  | 0.087425 |
| Henan                 | 0.003428 | 0.039152 | 0.102138 | Whole China           | 0.008179 | 0.025656 | 0.137573 |

Note: data are from China Statistical Yearbooks of previous years.

Establishment of the Specific Research Model

In fact, there is no model that can include all variables that affect population growth. When a missing variable remains substantially constant over the estimated time range, its effect is included in the fixed effect \( \alpha \); but when a missing variable changes significantly within the estimated time range, the time dummy variable can be introduced to control it. The model is established as follows:

\[ PR_{ni} = \alpha + \beta GR_{ni} + \gamma UR_{ni} + \varepsilon_{ni}, \]

where, \( n \) and \( i \) indicate the specific province and time, respectively; \( PR_{ni} \), as an explained variable, refers to the growth rate of province \( n \) in the year \( i \) over the previous year (starting from 2007); the \( GR_{ni} \), as the explaining variable, represents the GDP growth rate of province \( n \) in year \( i \); \( UR_{ni} \) represents the urbanization growth rate of province \( n \) during year \( i \); and \( \alpha \) and \( \varepsilon_{ni} \) represent the intercept and the standard error, respectively. The F-statistic is used in the testing.

Spatial Correlation Analysis of Population Growth Rate

During the establishment of the panel data model, it is necessary to consider whether there is a fixed or random effect. If the model setting is inaccurate, the model parameter estimation will be invalid. When studying the population and economic growth, this paper uses data from all 31 provinces and municipalities, and thus the fixed effects model can be directly used. The fixed effects model controls all constant variables, and economic development and urbanization are its own control
factors. Compared with the random effects model, the fixed effects model will have greater standard errors, mainly because in the analysis of the process data set, little information is actually utilized. The standard error sometimes can be too large, so before the empirical research, the panel data model must first consider fixed and random effects. Random effects are usually pre-tested using the LM test method. The fixed effects model usually uses the F-statistic, that is, to compare the residual between the fixed effects model and the mixed data model and construct the test statistic as the criterion.

Prior to empirical analysis, spatial correlation analysis is performed on the individual variables. This paper uses the most commonly used Moran’s I index, which is an important indicator used to measure spatial correlation and can reflect the similarities between the values of cell attributes in spatially adjacent or neighbouring regions. It is expressed as follows:

$$Moran's\ I = \frac{1}{n} \sum_{i}^{n} \sum_{j \neq i} w_{ij} \left( x_{i} - \bar{x} \right) \left( x_{j} - \bar{x} \right) \left( \sum_{i}^{n} w_{ij} \right)^{-1}$$

(2)

where, $w_{ij}$ is a spatial weight matrix. If the i-th and j-th spaces are adjacent, then $w_{ij} = 1$; otherwise, $w_{ij} = 0$. $x_i$ and $x_j$ denote the spatial observed objects where i and j are located, i.e., the i-th and j-th provincial variables; $\bar{x}$ represents the mean of $x_i$. Similar to the correlation coefficient in general statistics, normally the value will be in the range of ±1. Based on this, the neighbour information table 4 is obtained. If the value of Moran’s I is positive, it indicates that the observed values have a significant positive correlation, and the closer Moran’s I is to 1, the more aggregated the individuals are in the spatial region, and the more significant the correlation is. Conversely, if the Moran’s I value is negative, the observed values have a significant negative correlation, and the closer it is to −1, the more discrete the individuals are in the spatial region, but the correlation is still significant. Through testing with the SPSS analysis software, if Moran’s I is equal to the expected $E(I)$, it means that there is no spatial autocorrelation, and that the observations are mutually independent and distributed in a random manner. Subject to the random distribution assumption, the formula for calculating the expected value is as follows:

$$E(I) = -\frac{1}{n-1}$$

(3)

If there is no spatial autocorrelation between the observed individuals, then look up the table for the significance level based on the $Z_t$ value and make inference.

Table 3. Neighbour information of 31 provinces and municipalities.

| No. | Province/municipality | Neighbouring provinces/municipalities | No. | Province/municipality | Neighbouring provinces/municipalities |
|-----|-----------------------|--------------------------------------|-----|-----------------------|--------------------------------------|
| 1   | Beijing              | 2,3                                  | 17  | Hubei                | 12,14,16,18,22,27                   |
| 2   | Tianjin              | 1,3,15                               | 18  | Hunan                | 14,16,17,18,22,24                   |
| 3   | Hebei                | 1,2,4,5,6,15,16                      | 19  | Guangdong            | 13,14,18,20,21                     |
| 4   | Shanxi               | 3,5,16,27                           | 20  | Guangxi              | 18,19,24,25                         |
| 5   | Inner Mongolia       | 3,4,6,7,8,27,28,30                   | 21  | Hainan               | 19 (assumed)                        |
| 6   | Liaoning             | 3,5,7                               | 22  | Chongqing            | 17,18                              |
| 7   | Jilin                | 5,6,8                               | 23  | Sichuan              | 22,24,25,26,27,28,29               |
| 8   | Heilongjiang         | 5,7                                  | 24  | Guizhou              | 18,20,22,23,25                     |
| 9   | Shanghai             | 10,11                               | 25  | Yunnan               | 20,23,24,26                        |
| 10  | Jiangsu              | 9,11,12,15                         | 26  | Tibet                | 23,25,29,31                        |
| 11  | Zhejiang             | 9,10,12,13,14                       | 27  | Shaanxi              | 4,5,16,17,22,23,28,30              |
| 12  | Anhui                | 10,11,14,15,16,17                   | 28  | Gansu                | 5,23,27,29,30,31                   |
| 13  | Fujian               | 11,14,19                           | 29  | Qinghai              | 23,26,28,31                        |
| 14  | Jiangxi              | 11,12,13,17,18,19                   | 30  | Ningxia              | 5,27,28                            |
| 15  | Shandong             | 2,3,10,12,16                       | 31  | Xinjiang             | 26,28,29                           |
| 16  | Henan                | 3,4,12,15,17,27                    | 32  |                      |                                      |

$$Z_t = \frac{I - E(I)}{\sqrt{Var(I)}}$$

(4)
Before the spatial analysis is introduced into the model, unit root test and co-integration test are performed on the panel data in the fixed effects model by the LLC, IPS and Fisher test method with the help of the software Eviews. Although all the three testing methods have their own assumptions, the results all show that if the original assumptions are accepted, unit root does exist in the panel data; otherwise, it does not exist in neither of them. So the panel data are highly stable and the results are consistent.

**Empirical Test**

**Unit Root Test**

If the panel data are not sufficiently stable, the model will experience spurious regression, which will affect the effectiveness of the research. Therefore, the software Eviews is used to test the unit roots of the selected panel data. The results are shown in Table 4. It can be seen that, the three variables - population growth rate PRni, per capita GDP growth rate GRni, and urbanization growth rate URni, all have unit roots, expressed in I(2). In order to further improve the stability of the data, it is also necessary to perform co-integration test.

| Testing method | Raw data | PRni | GRni | URni |
|----------------|----------|------|------|------|
|                | Coeffici | P    | Coeffici | P    | Coeffici | P    |
|                | ent     | value | ent     | value | ent     | value |
| LLC            | -9.465  | 1.000 | -11.740 | 0.998 | -5.450  | 0.000 |
| IPS            | -9.958  | 1.000 | -11.270 | 0.968 | -5.066  | 0.298 |
| ADF-Fisher     | 121.140 | 1.000 | 139.304 | 1.000 | 54.320  | 0.000 |
| PP-Fisher      | 180.397 | 1.000 | 149.320 | 0.972 | 129.592 | 0.000 |

**First-order difference test**

| Testing method | Raw data | PRni | GRni | URni |
|----------------|----------|------|------|------|
|                | Coeffici | P    | Coeffici | P    | Coeffici | P    |
|                | ent     | value | ent     | value | ent     | value |
| LLC            | -18.952 | 0.000 | -15.103 | 0.000 | -26.075 | 0.000 |
| IPS            | -18.967 | 0.001 | -17.453 | 0.000 | -25.446 | 0.000 |
| ADF-Fisher     | 220.115 | 0.002 | 214.016 | 0.000 | 195.570 | 0.000 |
| PP-Fisher      | 249.947 | 0.000 | 241.830 | 0.000 | 162.955 | 0.000 |

**Co-integration Test**

Yixing Zhou et al. [9] analysed the census data in China and summarized the pattern between urbanization, economic growth, and population growth. He believed that a large number of rural workers are migrating to municipalities, making the urbanization levels of all provinces and municipalities increasingly higher. Looking at the actual situation in China, with the socio-economic development of various regions, the level of urbanization has been further rising and at the same time the overall quality of the workforce has also been continuously improved. It can be seen that there is no spurious regression in model. For the three-variable first-order difference co-integration test, when the significant level is 10%, there is no unit root, and after the first-order difference, the data are stable and subject to I(1). After the LLC, IPS, ADF-Fisher, and PP-Fisher tests on the OLS estimation residuals in the fixed effects model, it is found that the P value is 0.000, 0.030, 0.008, and 0.000, indicating that there is no unit root in the residual term of the model and that the explained and explaining variables are co-integrated.

**Spatial Autocorrelation Test**

Spatial analysis is performed on relevant variables. The samples are selected from the population growth rate PRni, per capita GDP growth rate GRni, and urbanization growth rate URni of 31 provinces and municipalities in China from 2007 to 2016. The Moran’s I value is calculated using
the software Stata12.0, and tested using SPSS. The expected values of $E(I)$ and $Zt$ over the years are obtained according to equations (3) and (4), with the results shown in the table below:

Table 5. Spatial autocorrelation moran’s $I$ of the annual growth rates of the three variables and the significance levels during 2007-2016.

| Year | PR$_{ni}$ | GR$_{ni}$ | UR$_{ni}$ | Moran’s $I$ | PM | Pk-s | Moran’s $I$ | PM | Pk-s | Moran’s $I$ | PM | Pk-s |
|------|-----------|-----------|-----------|-------------|----|------|-------------|----|------|-------------|----|------|
| 2007 | 0.747     | 0.056     | 0.036**   | 0.571       | 0.994 | 0.024** | 0.560       | 0.975 | 0.081*  |
| 2008 | 0.690     | 0.011     | 0.008*** | 0.631       | 0.810 | 0.038** | 0.649       | 0.911 | 0.061*  |
| 2009 | 0.526     | 0.043     | 0.084*    | 0.703       | 0.556 | 0.093** | 0.740       | 0.609 | 0.061*  |
| 2010 | 0.788     | 0.233     | 0.036**   | 0.456       | 0.818 | 0.033** | 0.579       | 0.328 | 0.050** |
| 2011 | 0.744     | 0.097     | 0.030**   | 0.683       | 0.479 | 0.041** | 0.435       | 0.813 | 0.036** |
| 2012 | 0.643     | 0.093     | 0.038**   | 0.731       | 0.839 | 0.018** | 0.550       | 0.998 | 0.095*  |
| 2013 | 0.672     | 0.067     | 0.082*    | 0.662       | 0.821 | 0.033** | 0.552       | 0.933 | 0.094*  |
| 2014 | 0.711     | 0.095     | 0.033**   | 0.677       | 0.558 | 0.046** | 0.673       | 0.657 | 0.056** |
| 2015 | 0.732     | 0.057     | 0.034**   | 0.573       | 0.814 | 0.038** | 0.582       | 0.812 | 0.061*  |
| 2016 | 0.702     | 0.094     | 0.084*    | 0.642       | 0.822 | 0.046** | 0.594       | 0.813 | 0.081*  |

Note: *, ** and *** means it is significant at the level of 10%, 5% and 1%, respectively. PM is the significance level of the $Zt$ value and Pk-s is the significance level of the K-S statistic value.

From the above table, we can see that the annual average population growth rates of all provinces and municipalities in China have significant positive spatial correlations, and the economic correlations between provinces and municipalities are often very significant. A populous province/municipality tends to have great influences on the population growth rates of its neighboring regions. Neighboring provinces often utilize their geographical advantages and convenient transportation to promote accumulation of capital and labor, thereby increasing the spatial correlation of the population growth rates in these neighboring provinces and municipalities. In addition, like the population growth rate, per capita GDP and urbanization growth rates also have positive spatial correlations. Therefore, spatial analysis can be introduced in the analysis of the influencing factors to population growth.

Model Estimation

Based on the spatial correlation test, the spatial panel data are used to estimate the relationships between the three variables, namely the annual population growth rate $P_R$, per capita GDP growth rate $GR$, and urbanization rate growth rate $UR$ in provinces and municipalities. With the population growth rate as the explained variable and urbanization growth rate and per capita GDP growth rate as explaining variables, the model uses the fixed effect estimation method to carry out the estimation, with the help of the software Eviews, as shown in Table 6.

Table 6. Empirical results of the influencing factors to provincial/municipal population growth rate.

|          | 0.009 26 |
|----------|----------|
| $\alpha$ |          |
| $\beta$  | -0.007 40|
| $\gamma$ | -0.103 04|
| R-squared| 0.723 77  |
| Prob.    | 0.000 00  |
| Method   | Panel EGLS (cross-section weight) |
| Sample   | 2007-2017 |

The fixed effects model is as follows:

$$\hat{P}_R = 0.00926 - 0.0074\hat{G}_R - 0.10304\hat{U}_R + \epsilon_m + \epsilon_{\text{iid}} + (0, \sigma^2)$$

In terms of fitting, $R^2=0.723$ 77, meaning the fitting result of the spatial autoregressive model is good. The model shows that the population growth rate is negatively correlated with the per capita
GDP growth rate and urbanization level growth rate. This means that as the economic development in the provinces and municipalities and the level of urbanization increase, the population growth rate gradually declines. According to the model, an increase of 1% in the per capita GDP growth rate will lead to a decrease of 7% in the population growth rate, and an increase of 1% in the urbanization growth rate will lead to a decrease of about 10% in the population growth rate. Therefore, accelerating economic development and promoting urbanization will bring positive impacts on population growth control. In fact, in the overall layout and development planning of China, the proportion of urban population has always been one of the most important indicators. To some extent, it can truly reflect the urbanization construction status and urbanization level in China. Therefore, in the accelerated urbanization process, promoting full-scale socio-economic development is also helpful to controlling the population growth rate.

Conclusions

Through spatial correlation analysis, it is found that the average annual population growth rates show positive spatial correlations. A populous province would often drive the population growth rates in the neighboring regions. The per capita GDP growth rate and urban growth rate also have positive spatial correlations. Therefore, the interactions between variables would affect the strength and significance of spatial correlation. Based on the spatial correlation test results, the influencing factors to the population growth rate in each province/municipality are studied using the fixed effects model. The empirical results show that the level of urbanization and GDP per capita has negative impacts on population growth. The higher the per capita GDP and urbanization are, the slower the population growth will be, mainly because the economic efficiency will make the population flow faster. Overall, there is a certain cause-and-effect relationship between the three.

Compared with the per capita GDP growth rate, the level of urbanization is less elastic. After the introduction of spatial correlation between provinces, it is found that the level of urbanization has a more pronounced effect on the reduction of population growth rate. With the flow of capital and labour force between provinces and municipalities, the increase in the per capita GDP growth has a relatively smaller effect on the reduction of the population growth rate. In economically developed urban areas such as Beijing and Shanghai, with the increase in the growth rates of per capita GDP and urbanization level, the population growth rate increased rapidly in the first few years, but after 2015, due to the great pressure brought by population growth to the society, the government issued policies to control population flows, and then the population growth started to slow down. The level of urbanization is already high in these areas, so the growth rate tends to be flat, but the per capita GDP in these areas still grows very fast.

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