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A REVIEW OF TWO POPULATION GROWTH MODELS AND AN ANALYSIS OF FACTORS AFFECTING THE CHINESE POPULATION GROWTH

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ABSTRACT

This paper reviews two population growth models and tries to find out a proper way to explain and predict population growth. It shows that the exponential growth model and logistic growth model should not be used to predict population growth. The paper highlights the difference between human population growth and biological population growth and analyzes factors affecting population growth based on data available. Evidence from time series analysis indicates that, two factors, the degree of urbanization and the sex ratio, have significant influences on population growth in China.

Keywords
Population growth
Growth model
Factors affecting population growth.

Contribution/ Originality: This study contributes in the existing literature by applying two population growth models to empirically examine the pattern of population growth in China and its influencing factors.

1. INTRODUCTION

A. Background of Population in China

As we all know, China has the largest number of people, which has provided plenty of labor force to promote the development of the Chinese economics since the reform and opening policy in 1970s. However, after our nation developing vigorously for more than thirty years, along with China becoming the world's second-largest economy, the enormous welfare of the population did no longer exist and, on the contrary, such huge population base began to curb the further advancement of China. The population advantage gradually turned to be a population disadvantage.

Therefore, it is vital to figure out an effective model to predict the present and future population growth in China precisely, as well as its structure by applying the available data so as to adjust the speed and the component of population growth to the present all-round situation and meet the China's immense demand for continuous economic splendor. In order to analyze the population deeply and thoroughly and simulate the future growth accurately and fully, the relevant factors together with their influences should be studied and scrutinized, too. It is no wonder that the population problem has been a much-researched subject.

Not only will setting up an effective mathematical model for population growth in China inspire theoretical research successfully, but it will also be beneficial for the government to make corresponding population and economic policies accordingly. All in all, this model will be a powerful auxiliary booster to propel the Chinese economy.

B. A Literature Review of Population Growth in China

As mentioned earlier, there are a number of previous studies related to this field or dwelling on the outskirts of this research area. After combing those related and widely approved papers, we pick out about ten representative works to summarize and evaluate the existing research level. They can be categorized into two main types and they will be summarized below.

i) The factors affecting the population size and its growth

A series of population research explored the impact of several important factors on the population. As early as in 1997, the scholar Shen J and Spence N divided the whole country into different parts and tried to calculate their population respectively. Shen and Spence (1997) About five years later, in 2002, a paper named "Population Growth Rate and Its Spatial Association by Providence in China" (An-min *et al.*, 2002) took the sense of regions into the consideration, too. The research or projections of this kind were conceived because the authors realized the tremendous differentials of populations and their traits in different places in the China due to the unbalanced development. In the meanwhile, people also intended to specify the reason as the urbanization of the big cities in the China, such Beijing, Shanghai and so on as what was explained by Zeng Yi and James W. Vaupel in 1989. JW (1989) Hence, the regional difference was also known as "urban-rural differentials", on which Shen J, Spence N A based their population growth model. (Shen and Spence, 1997)

Apart from considering the spatial differences, the gender and its ratio problem was another newly widely popular factor among the scholars. Lian-zhong L once established a model of population and managed to give out a unified model including men and women. Lian-zhong (2008) Owing to the sexual reproduction of human beings, a balanced or proper sex ratio means the majority of people are able to be paired and breed the offspring easily and without waste. And from a macro perspective, the government can implement birth policy more effectively, whether to boost the population or to curb it. According to the present condition in China, the proportion of the female is still somehow lower than that of the male, to some extent. So, Cai Y and Lavely W expressed their worry about "China's Missing Girls". Cai and Lavely (2003) The scholar, Xue Zhen also placed special emphasis on the sex ratio in his Chinese population growth model. (Zhen, 2008)

Some scholars including Li Q, Reuser M and Kraus C took the factor of the age structure into the consideration when forecasting the future population in China. Li *et al.* (2009) Because the aged tendency of the population becomes more and more prominent nowadays, which are bringing to the whole society more burdens and less labor force, finding the useful solution to the aging population problem is no less important than predicting the proportion of the elderly people. There were some articles probing into the negative influence of aging population on the Chinese economic growth. (Banister *et al.*, 2010)

ii) Various types of the mathematical population growth model

In fact, there are several kinds of functions at hand to set up a mathematical model of Chinese population growth, such as Exponential function, Logistic function and hyperbolic function. Some articles, like "Model of China's Population Growth Considering the Distinction of Age and Sex" (Lian-zhong, 2008) just applied available discrete linear differential equations, for its concentration was not exactly the accuracy of the prediction but the distinction between two variables.

And some other articles were concentrated on comparing the available models to find out which one would fit the data of Chinese population most and be applicable to China's situation most. Xin-hui W, who calculated the error of different population growth model, found that ARIMA model was more accurate than exponential growth model and block growth model. (Xin-Hui, 2012)

However, there were still a third type of scholars, who devoted themselves to improve and perfect the existing models. Xue Zhen forecasted the overall development trends of the population and the number of future medium and long-term population by improving logistic model, classic K-R algorithm and leslie model. Zhen (2008) And the scholar FENG Shou-ping gave the prediction on China population growth model and on short-term, medium-term and long-term trend of China population growth by revising the Logistic model and retarding increase model. (Shouping, 2008)

iii) Summary

Technically speaking, this paper belongs to the second type of the literature referred above. By reviewing two of most widely accepted an acknowledged population growth models, we have found the deficiencies of each kind when it comes to predicting the Chinese population growth. Furthermore, we delve into the subject in depth to locate the most influential intrinsic factors, degree of urbanization and sex ratio. As for the age structure, it is not so significant to predict the future population. And those papers exploring the similar directions did either provide a single factor or lack the correlation with models. In a brief, the paper not only reviews two important population growth models, but also tries to make out the cruxes behind the deficiencies and finally ends up with two relevant factors and corresponding policy advice.

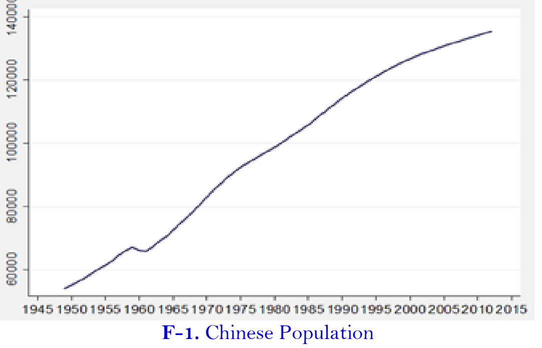
2. POPULATION GROWTH IN CHINA

Population in China has been through a rapid growth period and slows down in recent years.A review of the history of the Chinese population will help the analysis.

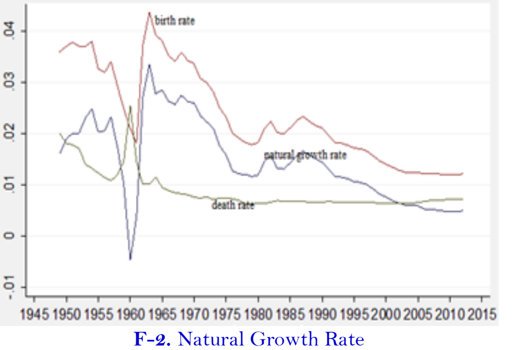
A. Overview of Population in China

As depicted in the Figure 1, despite the period between year 1958 and 1961, Chinese population grew constantly from 1949 to 2012. The population increased more than 2.5 times this period. In recent years, the growth is slowing down, but the total population is nearly 1.4 billion.

If we shift to the respective of growth rate, we can see (as in Figure 2) that the growth rate reduces in period 1970-1980 and period 1987-2012. These reductions are probably because of the birth control policy in China. Other factors, such as the increase of wealth, higher education level and urbanization may have influences too. Compared with the birth rate and death rate depicted in Figure 2, the growth rate change of population is mainly because of change of birthrate.



F-1. Chinese Population



F-2. Natural Growth Rate

B. Birth Control Policies of Chinese Government

As birth control policies in China have great influence on birth rate, a review of it is worthy. From the end of year 1973, the central government had the intention to implement the birth control policy due to concerns about the rapid growing population. After that, the birth control policy was in effect not strictly carried out until the year 1982. However, since the birth rate was high in the 1960s (because of the Great Production Campaign), it dropped immensely in this period. The years after 1983 saw a strictly enforcement of the birth control policy, and the birth rate reduced again during this period. But since the birthrate was low, the reduction was relatively smooth.

In the last three years, with the aging trend of Chinese society, the government has started to loosen the strict policy of birth control. But the policy effect is to be observed years later.

3. REVIEWOFPOPULATION GROWTH MODELS

Two models –exponential growth model and logistic growth model- are popular in research of the population growth. The exponential growth model was proposed by Malthus in 1978 (Malthus, 1992), and it is therefore also called the Malthusian growth model. The logistic growth model was proposed by Verhulst in 1845. Verhulst (1845) Both originated from observations of biological reproduction process.

Under optimal conditions, biological population will increase at a fixed rate. This constant rate of growth is due to nature of the specific biological species. For some, such as unicellular organism, the reproduction speed is very high. For the others who have to reproduce sexually, the population increases at a low speed. Every species has a constant growth rate under specific conditions.

However, when it comes to human population, whether this constant growth rate can be observed is in doubt. This is mainly because we can hardly define the conditions. Human reproduce sexually and have consciousness. We cannot be sure under what condition will an individual be reproduced. Therefore, it is in doubt whether models based on constant growth rate can explain human population growth. Taking carrying capacity into regards, logistic growth model improves the preceding exponential growth model. However, whether it can describe human population growth is in dispute. We will test the exponential growth model and logistic growth model by population data of China.

A. The Exponential Growth Model

The exponential growth model has the form

(1) $P_t = P_0 e^{rt}$,

where is population in time t, is population at the beginning, is the constant growth rate. With a little mathematical manipulation, Equation (1) can be written as

(2) $\ln P_t = \ln P_0 + rt$

Regress Equation (2) by regression function:

(3) $\ln tpopln_t = \alpha + \alpha_1 t + u_t$

Run this regress on Chinese total population data we have

$$\ln \widehat{tpopln}_t = 10.9563 + 0.0152t$$

$$\text{P value} \quad (0.000) \quad (0.000)$$

$$\text{n} = 64, \quad \text{R}^2 = 0.97, \quad \overline{\text{R}}^2 = 0.97$$

Therefore, the exponential model of Chinese population growth is

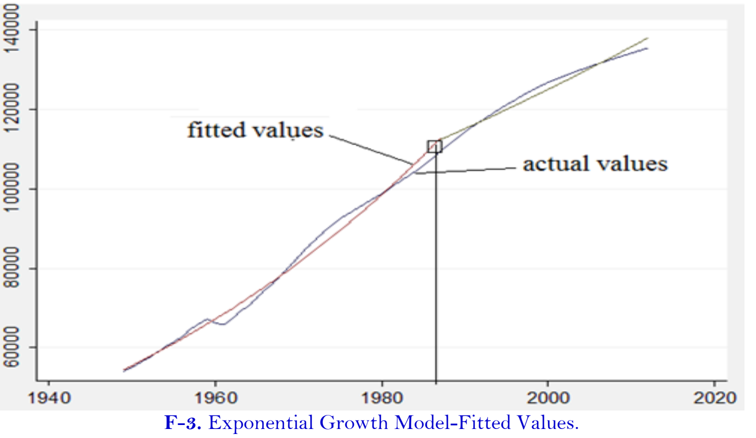
(4) $\hat{P}_t = 57314.947 \times \text{e}^{0.0152475t}$

Since the fitted values of Equation (4) deviate from the actual values of population after 1987, we run the regress (3) with the data before 1987 and after 1987. That gives,

T-1. Exponential Growth Models before 1987 and after 1987

Year	**estimated growth model**
1949-1987	$\hat{P}_t = 53475.797 \times \text{e}^{0.0191t}$
1987-2013	$\hat{P}_t = 81435.927 \times \text{e}^{0.00824t}$

Thus the historical population growth in China follows two patterns (as depicted in Figure 3).



F-3. Exponential Growth Model-Fitted Values.

B. The Logistic Growth Model

The logistic model has the form

(5) $$\frac{dP_t}{dt} = rP_t\left(1 - \frac{P_t}{K}\right),$$

where P_t is the population at time t, r is the constant initial increasing rate, K is the maximum carrying capacity. With population growth, the increasing rate $\frac{dP_t}{dt}$ will reduce constantly due to limited carrying capacity K.

The continuous form is a differential equation and can be solved by

(6) $$P_t = \frac{K}{1 + (\frac{K}{P_0} - 1)e^{-rt}}$$

Some researchers use Equation (2) to estimate population at a specific time once r, K and P_0 are known. After an initial point t=0 is chosen, there will be two unknown non-linear related variables, it is impossible to derive them all based on OLS regression. Some linear way is first set a K discretionally, with an initial population P_0, find out r by OLS. Do this many times, until the OLS R-square is the largest. This can give r and K which fit the data best.

$$r = OLS_1(K), K = OLS_2(K)$$

$$\text{s.t.} \quad \max.R^2$$

Since this result is not of great concern, we omit it.

C. Problems with the Models

a. Description Only

The exponential growth model takes t as the only explanatory variable; this will cause a big problem since it only measures the time trend of population. The conclusion cannot be applied to the long-term population growth since no weak dependent steady relationships exist in the regression. It can only indicate, at most, the historical growth of population in China follows an exponential growth pattern, but it says nothing about the future.So using the exponential growth model to predict the future population in China will be misleading, no matter how close the estimates are to the recent realized population.

Same problems are with the Logistic growth model, because it use time variable as unique explanatory variable too. We will falsify this in a strict empirical way.

b. Empirical Test of Logistic Growth Model

In order to construct weak dependent relationship among r, K, P_t, the proper way is to convert the discrete logistic model to regression model and apply OLS.

The discrete form of equation (1) is

$$\Delta P_t - \Delta P_{t-1} = r\Delta P_{t-1} + s\Delta P_{t-1}^2$$

(7) $$P_{t+1} - P_t = rP_t\left(1 - \frac{P_t}{K}\right) = rP_t - \frac{rP_t^2}{K}$$

Set $$-\frac{r}{K} = s, \Delta P_t = P_{t+1} - P_t,$$

equation (7) becomes

(8) $$\Delta P_t = rP_t + sP_t^2$$

In equation (8), rP_t *is the autonomous growth while* sP_t^2 *is the retardant factor.*

ADF test of all variables shows obvious AR(1) process, we should form first difference to make all variable weak dependent.

Lag Equation (8) for one time period,

(9) $$\Delta P_{t-1} = rP_{t-1} + sP_{t-1}^2,$$

(10)

Equation (8) minus Equation (9) gives

In order to make ΔP_{t-1}^2 *weak dependent, lag (10) another time, we have*

(11) $$\Delta P_{t-1} - \Delta P_{t-2} = r\Delta P_{t-2} + s\Delta P_{t-2}^2$$

Equation (10) less Equation (11) gives

(12) $$\Delta P_t - \Delta P_{t-1} = (1+r)(\Delta P_{t-1} - \Delta P_{t-2}) + s(\Delta P_{t-1}^2 - \Delta P_{t-2}^2)$$

ADF testing (with trend term) all variables gives p-value 0.000 respectively. All explanatory variables are stationary time series.

T-2. ADF Test of Logistic Growth Model Variables

Variables	MacKinnon approx. p-value
$\Delta P_t - \Delta P_{t-1}$	0.0000
$\Delta P_{t-1} - \Delta P_{t-2}$	0.0000
$\Delta P_{t-1}^2 - \Delta P_{t-2}^2$	0.0000

Set regression function as

(13) $$\Delta P_t - \Delta P_{t-1} = \alpha_0 + \alpha_1(\Delta P_{t-1} - \Delta P_{t-2}) + \alpha_2(\Delta P_{t-1}^2 - \Delta P_{t-2}^2) + \alpha_3 t58\_61 + u_t$$

where u_t stand for the relative factors other than $(\Delta P_{t-1} - \Delta P_{t-2})$ and $(\Delta P_{t-1}^2 - \Delta P_{t-2}^2)$.

The independent variables are not strict exogenous because there is a first order lag in the regression function. Under the condition of the contemporaneously exogenous and week dependence, the time series OLS estimators are consistent.

The regression result is reported as follows

$$\Delta P_t - \Delta P_{t-1} = -5.2442 + 0.3797(\Delta P_{t-1} - \Delta P_{t-2}) - 0.0000(\Delta P_{t-1}^2 - \Delta P_{t-2}^2) + 48.4529 t58\_61$$

$$p\,value \quad (0.930) \quad (0.728) \qquad (0.732) \qquad (0.842)$$

$$n = 61, \quad R^2 = 0.0025, \quad \bar{R}^2 = -0.0500, \quad pvalue(Ftest) = 0.9859$$

In order to testing for serial correlation, run the regression of the form

(14) $residual_t = \alpha_0 + \beta_1 residual_{t-1} + \beta_2(\Delta P_{t-1} - \Delta P_{t-2}) + \beta_3(\Delta P_{t-1}^2 - \Delta P_{t-2}^2) + \beta_4 t58\_61 + u_t$, *the results are as follows,*

$$residual_t = -11.6900 + 1.4923 residual_{t-1} - 1.2693(\Delta P_{t-1} - \Delta P_{t-2}) - 0.0000(\Delta P_{t-1}^2 - \Delta P_{t-2}^2)$$

$$p\,value \qquad (0.618)$$

$$+40.3979 t58\_61 + u_t$$

The p-value for the hypothesis test of coefficient of $residual_{t-1}$ *is 0.618, thus no obvious error term serial correlation is detected. So the significance tests in the regression (13) result above are valid.*

All the explanatory variables are not statistically significant because of large p-value and jointly not significant as well.

Based on the above reasons, the logistic model is not suitable for population growth in China.

4. FACTORS AFFECTING POPULATION GROWTH

A. Human Population Growth and Biological Population Growth

The logistic model is found when observing biological population growth and it takes the population in the previous period as the only explanatory variable. The logistic model fits the biological population growth well because the natural biological reproduction's conditions can be observed and controlled easily.

However, when it comes to human population growth, it fails to describe the data. This is mainly because there are too many other factors affecting human population growth. With too few observations, the model can explain nothing with population per se as source of independent variables. That is way the regression result has a very small R^2. We have to find other reasons affecting population growth in China.

B. Factors Affecting Chinese Population Growth

One can find the constant growth rate r both in the logistic growth model and the exponential growth model; it is the unimpeded growth rate under ideal conditions.

When it comes to human population growth, the growth rate r will not be constant, because people can't or won't reproduce themselves. People can't give birth to children if they can't get mated. There are many factors blocking this, such as improper sex ratio and social instability. People won't reproduce since high living costs, change of childbearing ideology, government policies and many other factors. This paper chooses several variables to stand for these factors. These factors are emphasized both because they are significant intuitively and they are what we can quantify according to the procurable data. Data chosen will be explained in part IV.

a. Sex Ratio

We assume a balanced sex ratio will cause the fastest population growth. This idea is easy to understand. With proper ratio between male and female, it is easier to mate one to another. This idea is hold by many people and it is why people get worried about the unbalanced sex ratio.

We shouldn't take sex ratio directly as an explanatory variable, because it is how the sex ratio is compared to unity that we care, not the absolute value. Therefore, the difference between sex ratio and unity should be used to describe the relative sex ratio. This will be explained in part IV.

b. Degree of Urbanization

Urbanization is a significant factor in developing countries like China. With more and more people transformed into urban residents, the birth rate of the whole country will change. Empirical evidence shows that urban areas have very different birth rates from countries.

This effect is partly because living costs and income are higher in cities, and partly because of the limited urban spaces. People in urban areas tend to have small family since the living costs and living spaces are limited.

c. Employment and Income

Employment will affect birth rate because most people get income from work. It can be a proxy variable for income. People can afford a larger family if they get more income. However, employment will have a negative effect on the birth rate since people will be too busy to raise a family. The analysis of these effects' is left to the empirical research.

d. Government Policies

Government policies apparently have great impact on birth rate, especially in China. As the beginning of new regime in 1949, the central government encouraged childbirth with the idea "Strength in Numbers" in mind. Chinese population starts to grow at a high speed between 1949 and 1975. After implementing the birth control policy in the 1970s, the growth rate of birth rate slows down immediately (See Figure 2). This shows clear influences of the birth policy on population growth in China.

e. Other Factors

Other factors like disasters and wars will cause the change of growth rate too. However, they are not constant functioning factors. Therefore, except for the natural disasters that lasted from 1958 to 1961, we ignore the others because they are hard to be measured.

5. EMPIRICAL EVIDENCES

A. Data and Variables

First of all, we have to build up a model based on the analysis before. For the factors mentioned in part III, we need choose available data and proper variables to measure them.

With the concern about the proper size of the sample, many variables and data cannot be chosen. For example, GDP per capita is a candidate to measure the living standard of people, but GDP records before 1978 are unavailable. It is meaningless to run time serial regressions on only 35 sample points. Hence, we only choose data available in time range from 1949 to 2012, so that a probable largest sample space is ensured. It is not enough though, yet it is the largest one can get for now. We choose proper variables based on the data we have. We have to define new variables that can be derived from the original data to better describe the relationship analyzed in part III. Specifically, all the relevant variables are defined as follows.

$$\log(P_t) = \beta_0 + \beta_1 urbratio_t + \beta_2 sexratiodev_t + \beta_3 emrt_t + \beta_4 lfisexp_t + \beta_5 t58\_61 + \beta_6 t + u$$

i) Set $sexratiodev = (malepopulation / femalepopulation - 1)^2$. We choose this as one explanatory variable since it magnifies the vitality of the sex ratio relative to unity. This will make it more sensitive to the change of population growth. We assume that, with a balanced sex ratio, the population growth rate will be high.

ii) Set. $urbratio = urbanpopulation / totalpopulation$ This is obvious, if the structure of the population change, it will cause change on population growth rate.

iii) Set $emrt = employedpopulation / totalpopulation$, this approximately measures the employment rate in a year. This variable has both positive and negative effect on population growth.

$$\Delta\log(P_t) = \alpha_0 + \alpha_1 \Delta urbratio_t + \alpha_2 \Delta sexratiodev_t + \alpha_3 \Delta emrt_t + \alpha_4 \Delta fisexp_t + \alpha_5 t58\_61 + \alpha_6 t + u$$

iv) Set $lfisexp = \log(fiscal\ expenditure)$, this measures the government policies. The idea here is generally the more the fiscal expenditure, the more government policies in birth control. Taking logarithm form of the fiscal expenditure is good for making it approximately Normal distributed. However, this variable can only stand for part of the birth control policy since it includes too much other fiscal expenditure.

v) Set dummy variable $t58\_61 = 1$ if the variable year equals to 1958, 1959, 1960 or 1961, set $t58\_61 = 0$ if not. This variable indicates the natural disasters happened during year 1958 and 1961.

B. Chinese Population Growth Model and Regression Model

First we assume the relationship exists for population growth in China.

(15)

ADF testing (with trend term) all the variables separately show clear evidence of AR(1) process.

T-3. ADF Test of Regression Model (15) Variables

Variables	MacKinnon approx. p-value
$\log(P_t)$	1.0000
$urbratio_t$	1.0000
$sexratiodev_t$	0.4487
$emrt_t$	0.8113
$lfisexp_t$	0.9797

Lag the growth model one time period to form first difference of Equation (15),

(16)

ADF testing (with trend term) all variables separately give small p-values respectively. All explanatory variables can be considered as stationary time series.

T-4. ADF Test of Variables in Regression Model (16)

Variables	MacKinnon approx. p-value
$\Delta\log(P_t)$	0.0087
$\Delta urbratio_t$	0.0000
$\Delta sexratiodev_t$	0.0000
$\Delta emrt_t$	0.0000
$\Delta lfisexp_t$	0.0000

Run OLS regression on the data we have, the regression result is reported below,

$$\Delta\log\hat{(}P_t) = 0.0284 - 0.2211\Delta urbratio_t - 4.7546\Delta sexratiodev_t + 0.0414\Delta emrt_t + 0.0134\Delta fisexp_t$$
$$P-value \quad (0.000) \quad (0.085) \quad (0.787) \quad (0.473) \quad (0.016)$$
$$-0.0179t58\_61 - 0.00038t$$
$$P-value \quad (0.000) \quad (0.000)$$
$$n = 60 \quad R^2 = 0.7276 \quad \bar{R}^2 = 0.6968$$

We add lagged terms of each variable to catch lagged effects. With the new regression function, the regression result is

$$\Delta\log\hat{(}P_t) = 0.0292 + 0.0227\Delta urbratio_t - 0.2514\Delta urbratio_{t-1} - 13.6161\Delta sexratiodev_t + 8.5027\Delta sexratiodev_{t-1}$$
$$P-value \quad (0.000) \quad (0.859) \quad (0.054) \quad (0.451) \quad (0.623)$$

$$+0.0703\Delta emrt_t + 0.1333\Delta emrt_{t-1} + 0.0000\Delta fisexp_t - 0.0000\Delta fisexp_{t-1} - 0.0176t58\_61 - 0.00038t$$
$$P-value \quad 0.246 \quad (0.029) \quad (0.749) \quad (0.983) \quad (0.000) \quad (0.000)$$

$$n = 60 \quad R^2 = 0.6959 \quad \bar{R}^2 = 0.6641$$

Remove those terms with p-values bigger than 5%, and add lagged terms of the dependent variable to reduce probable error term serial correlation, we have a new regression model and its first difference form:

(17) $\log(P_t) = \beta_0 + \beta_1\log(P_{t-1}) + \beta_2 emrt_{t-1} + \beta_3 lfisexp_{t-1} + \beta_4 t58\_61 + \beta_5 t + v_t$

(18) $\Delta\log(P_t) = \beta_0 + \beta_1\Delta\log(P_{t-1}) + \beta_2\Delta emrt_{t-1} + \beta_3\Delta lfisexp_{t-1} + \beta_4 t58\_61 + \beta_5 t + w_t$

In this regression model, v_t stand for the factors except employment and fiscal expenditure affecting the change of the increment of population in a year. The independent variables are not strict exogenous because there is a first order lag of the dependent variable in the regression function. They aresequentially exogenous as in the logistic model. v_t isonly correlated with the time series variables before time t. With $E(v_t \mid \mathbf{x_t}, \mathbf{x_{t-1}}, \ldots, \mathbf{x}_1) = 0, t = 1,2,\ldots$ and $E(v_t \mid \mathbf{x_t}) = 0, t = 1,2,\ldots$, the OLS estimators are still consistent if the variables are weak dependent.

Run OLS regress on the data based on the model. We have the reported regression results as

$$\Delta\log\hat{(}P_t) = 0.0180 + 0.4222\Delta\log(P_{t-1}) + 0.10221\Delta emrt_{t-1} - 0.0098\Delta lfisexp_{t-1} - 0.0150t58\_61 - 0.0002t$$
$$P\text{-}value \quad (0.000) \quad (0.000) \quad (0.041) \quad (0.026) \quad (0.000) \quad (0.000)$$
$$n = 59, \ R^2 = 0.796, \ \bar{R}^2 = 0.776$$

We have the original model

(19) $\log\hat{(}P_t) = 0.0180 + 0.4222\log(P_{t-1}) + 0.10221 emrt_{t-1} - 0.0098 lfisexp_{t-1} - 0.0150t58\_61 - 0.0002t$

In order to ascertain the validity of the t-test of the regression, we should test for serial correlation. Regress residuals on the lagged residuals and all the independent variables, we have,

$$\hat{residual}_t = -0.0008 - 0.049 residual_{t-1} + 0.024 \Delta \log(P_t) - 0.0004 \Delta emrt_{t-1} - 0.0006 \Delta lfisexp_{t-1} + 0.0004 t58\_61 + 0.0000 t$$

P-value (0.795)

$$n = 58, \; R^2 = 0.0014$$

The p-value for the estimates of coefficient of the lagged residual is 0.759.That indicates the coefficient is not very different from 0 and therefore no clear error term serial correlation is detected. This can guarantee the validity of the t-test in the regression result.

C. Regression Conclusions

As the regression results Equation (19) shows, the employment rate and fiscal expenditure one period before has statistically significant influence on the increase of present population. This is actually happened in the same time period, because $\Delta P_t = P_t - P_{t-1}$ in the regression. So change of a year's employment rate and fiscal expenditure will cause this year's change of population growth.

Specifically, according to Equation (19), if population grows by 1% above its long-run trend, population in the next year will increase 0.42%. When the employment rate increases by 1% above its long-run trend, population increases by 0.10%. If the fiscal expenditure increases by 1% above its long-run trend, population decreases by about 0.01%.

6. CONCLUSIONS

A. Factors Affecting Chinese Population Growth

Chinese population growth follows a two-stage exponential growth model, but the model can't explain the decrease of the population growth rate. This is why in recent years, with the slowing down of population growth, the exponential model's fitted values deviate from the actual population further and further.

We have explained through empirical evidence that the growth model based on the constant growth rate cannot explain the behavior of population growth. This is mainly because human population growth doesn't have a fixed growth rate or optimal growth rate as in the case of bacteria growth. We have also explained statistically that no matter how good the constant-growth-rate based models fit the historical data, they have no prediction power of the future because they use time variable as an explanatory factor. They cannot explain the factors affecting population growth behind time series data.

This paper tries to find out the factors affecting the change of growth rate of population by empirical analysis. It turns out that, with the available data concerning population growth in China, after removing long-run trend, population of the previous year and the employment rate in the same year have positive effects on the growth of population in China. The fiscal expenditure, on the contrary, has negative effect.

Above its long-run trend, population grows at a lower rate than the previous year. This indicates the population growth is slowing down in China. Population increases when the employment rate increases above its long run trend and decreases when the fiscal expenditure increases above its long-run trend. We can't be sure about the fiscal expenditure's effect on population growth because it contains a lot of other factors that we can't separate with limited data.

B. Policy Implication

According to the conclusion above, Chinese population growth is on a slowing down track in the long run. However, we cannot predict population in the future precisely on a solid scientific basis. It may reach a growth rate trough in the future, but we do not know when. We cannot predict that based any projection from historical data.

Increasing employment rate will be a long-run method to increase population in China, but the more the population, the harder it will be to increase employment rate. There will be an optimal employment rate for long-run population growth.

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