An Analysis on Effects of Negative Population Growth on the Chinese Society

Shi Wang(✉)

Dalian American International School, 2 Dian Chi Road, Dalian, Liaoning, China
shiwangDL@outlook.com

Abstract. Starting from 1990, China's population development has been at an unprecedented turning point. Based on the data from the seventh national census in 2020, predictions concerning the country's population structure indicate that the population aging rate is faster than expected. China will soon enter the stage of accelerating negative growth starting in 2025. It is projected that the negative population growth trend will continue to rise and is irreversible. This paper explores the potential risk of adverse effects on Chinese society using the Vector Auto Regression model. The remainder of the paper concentrates on a particular methodology, the Bayesian method, to interpret the correlations between various indices, such as the aging population and economic growth. The estimated results indicate that the aging population contributes to the decline in the effectiveness of government spending and labor market productivity. It also creates the issue of a potential labor shortage. The findings also demonstrated the importance of creating a comprehensive policy that addresses the future risk of an aging population.

Keywords: negative population growth · aging population · Vector Auto Regression model · Bayesian method · labor market · economic growth

1 Introduction

The implementation of the two-child policy in 2016 signaled the end of the one-child policy and the start of a thorough revision and improvement of China's population management strategy. Later in 2021, the three-child policy was implemented as a continuation of the "two-child" policy. The adjustment of the state policy holds significant meaning as it could effectively boost the currently relatively low fertility level and offer families more autonomy.

Data from the seventh national census released in 2021 reveals why the government brought about such adjustments. The total fertility rate of 1.3 is now below the 1.5 threshold, which serves as a warning, entering the stage of deficient fertility level. Moreover, the average household size of 2.62 people reflects the problematic situation. Some regions, like northeastern China, are experiencing a net outflow of population. The floating population of about 376 million in 2021 would only exacerbate the negative population growth in these underdeveloped areas.

Advisor: Professor Shlomo Ta'asan

J. Yen et al. (Eds.): ICBIS 2023, AHCS 14, pp. 503–512, 2023.
https://doi.org/10.2991/978-94-6463-198-2_52

The current trend of the declining birthrate and aging population is escalating, and few consensuses have been reached. The data showed that the "third-child" policy was ineffective in addressing the issue of unwillingness to bear children. Combined with factors including the high cost of childbirth, female employment pressure, and shortage of childcare resources, an increasing number of couples of childbearing age have failed to give birth as they wished.

The consequences of such a phenomenon could lead to a possible labor shortage. It is extremely likely that there will be a high dependence ratio, which indicates that there will be more and more elderly people who need support from the younger workforce. A modified retirement policy that raises the retirement age or a labor force shortage could negatively impact the job market. But there's no doubt neither approach would contribute to China's economic growth and other socioeconomic aspects. With the help of a Bayesian-VAR model, this research will further explore and make predictions on the potentially harmful consequences of negative population growth.

2 Literature Review

This paper offers a critical analysis of books, scientific journals, and research papers that discuss the relationship between population decline and society growth, notably the economy and labor market. The information is derived from generally acknowledged databases, including Google Scholar, ScienceDirect, and Wiley InterScience, using the keywords "negative population growth," "economy," and "Vector Auto Regression model" as their primary search phrases. It is obvious that the factors mentioned above are related and that a declining population directly impacts the number of persons available in the labor market. Economic development is directly affected by lower labor market participation, typically in a negative way. In the meantime, evaluation is done using the mathematical model known as Vector Auto Regression. Two literary source strands are investigated.

To begin with, there's a reciprocal relationship between the aging population and economic development. An aging population structure would impede economic growth to some extent, and the level of economic development also influences the population. It is documented that the population growth rate could affect the industrialization level of society. According to a simulation conducted by Sasaki (Sasaki 2016) [2], if the population growth rate is negative with a relatively small magnitude, the country becomes agrarian. On the other hand, if the population growth rate is negative with a relatively large magnitude, a home country becomes a manufacturing country. The relationship between an aging population and the economy was then further explained by Maestas, Mullen, and Powell (2016) [1], with data showing that a 10% rise in the proportion of people over 60 would result in a 5.5% decline in GDP growth. The decline in productivity growth accounts for one-third of the loss, while the decline in workforce participation accounts for the remaining two-thirds. Connections between an aging population and other socioeconomic factors are indicated by Abdenour and Jang [9], who studied multiple parameters, including health expenditure, life expectancy, and economic growth. An increasing number of elderly means higher life expectancy, therefore, more health expenditure. Since healthcare spending is positively correlated with economic growth, it

is essential for national economic development and personal well-being. And maintaining decent health would increase productivity and labor participation. However, healthcare systems worldwide are now facing difficulties due to increased service costs and expanding demand. Thus, adjustments to retirement policy and the delivery of healthcare services that reduce health spending are put on the agenda.

Additionally, the Vector Auto Regression model is used extensively in the literature to assess the time-series implications of negative population growth. By investigating the American population, Lu 2020 explained why the VAR model is a valuable tool for analyzing dynamic interactions between variables and how the Bayesian method may be used to improve estimation results and further elaborates on how the Bayesian method optimizes the VAR model. Next, Haroaki (2016) uses the model to analyze a particular scenario of Japan's economic policies, while Nicolini (2007) [8] uses it to analyze industrial England and compare her findings to the Malthus theory.

It is widely accepted in society that an aging population has detrimental effects on economic development. However, a lack of study manifests the range and magnitude of such influence. And the contribution of this paper includes studying the correlations among multiple variables, including the availability and productivity of the labor force and economic growth. The computation processes include applying the Vector Auto Regression model, optimized by the Bayesian method. Forecast Error Variance Decomposition (FEVD) model is also utilized to evaluate the forecasting performance.

3 Methodology

3.1 Basic Analysis of Current Population in China

According to China's National Bureau of Statistics data, population growth has declined rapidly during the last few decades. Figure 1 shows that while China is outpacing the world trend, it will undoubtedly soon enter a phase of negative population growth beyond 2020. With this in mind, the VAR mathematical model by predictions is also employed to further analyze other parameters, such as the population's crude birth rate, natural growth rate, age composition, dependency ratio, and labor participation rate.

3.2 The Vector Auto Regression Model and Bayesian Method

The Vector Auto Regression model is a popular and powerful tool for analyzing population-related issues (Nicolini 2007; Miyamoto 2020) [8]. It's a straightforward and accurate model when it comes to computing and forecasting a time-series event. This model performs effectively with datasets that don't contain a lot of variables. However, because of the data noise and insufficient data, it has a high risk of "overfitting." It appears as though the road is not flat in front of the driver or that the driver is unfamiliar with the path. In the end, they're all responsible for the "accident" of overfitting, which leads to poor forecasting performance.

Since the Chinese National Bureau of Statistics statistical yearbook only contains information on the Chinese population from 1978 to 2020, the issue of insufficient data is also relevant in this scenario. With priors, the Bayesian Method could therefore increase

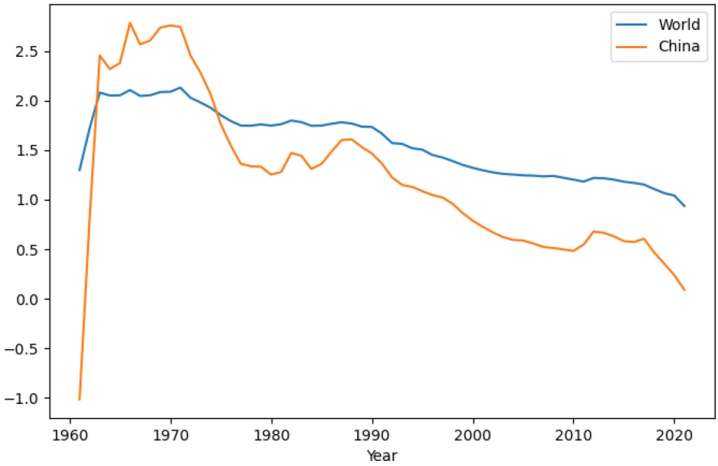

Fig. 1. The Overall population trend in China vs. World from 1960–2020

the estimation accuracy. They can reduce the noise in data with too many parameters and identify patterns from data with too few parameters. Priors are essential components of the model because loose priors lead to overfitting of data while tight priors prevent detecting patterns from data. As a result, it is crucial to configure the priors in accordance with various informational contexts. The Bayesian VAR model has been proven to be an effective methodology with large datasets (Lu 2020) [7].

The standard Vector Auto Regression Model:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t$$

In this case, c is a constant that serves as the intercept of the model, A_i is the coefficient of a $(K \times K)$ matrix, P indicates the maximum number of lags and e_t is the error term.

VAR can also be written in a matrix form:

$$y = Ax + U$$

i. y_t $(y_1 \ldots y_t)$. Dimension of matrix is T × N (Number of observations × dependent variables)
ii. X $(X_1 \ldots X_t)$. Number of observations × lagged dependent variable
iii. A $(c, A_1 \ldots A_p)$ Number of constants × lagged dependent variable
iv. U $(u_1 \ldots u_p)$ number of error terms × dependent variable

The matrix must first be specified before being replaced by an estimate $\sum_e$. There are two approaches in total: utilizing the residual variances determined from fitting VAR models for each series or assuming the matrix is diagonal and all coefficients are equal to zero. Generally, the second approach is more popular since it significantly reduces the computing workload when there is no relationship between the model's equations' coefficients.

After defining the matrix $\sum_e$, the next step is to specify the prior covariance. The following four scalars can help choose the hyperparameters from the matrix:

i. λ_1 regulates the weighting of the sample, the priors, and displays the variance of the first lag. A low value indicates that lags are overshadowed by the priors. On the other hand, if the value is approaching infinity, then priors cease to be useful.
ii. λ_2 establishes the weighting for the lags
iii. λ_3 controls the weighting of exogenous variables, like the constant c
iv. λ_4 accounts for data's variability and different types of decay. For example, a value of one can denote a linear function.

Such priors are frequently employed in forecasting because they are simple to compute and understand, but they overlook any uncertainty related to the matrix. Fixed residual matrix is one of the flaws.

3.3 Data

The dataset contains the following variables of population, labor, and economic growth: natural growth rate (NGR), age 65 and over population (EP) and old dependency ratio (ODR) as demographic indicator, annual GDP growth rate (GDPGR) as an economic indicator and labor participation rate (LPR) as labor market indicator. Natural growth rate is the number of births minus the number of deaths divided by the annual average population. Since the crude birth rate falls, the overall indicator also declines over time. The old dependency ratio refers to the ratio of the elderly population to the working-age population. A high old dependence ratio indicates a serious aging population problem. GDP measures a nation's overall economic health, and the labor force participation rate shows the proportion of its employed population. A higher score for both measures indicates that the economy is in good shape.

The sample retrieved from the National Bureau of Statistics of China spans from 1978 to 2018. Since the "reform and opening up" in 1978, China's society has undergone significant transformations. However, the paper only shows GDP growth and labor participation rate over the past decade due to data availability.

One notable demographic trend in the world population is the aging of the population, which is characterized by a rising proportion of elderly individuals relative to the working-age population. This phenomenon has been driven by multiple factors, including a decrease in fertility rates and advancements in healthcare and medical technology that have led to increased life expectancies. According to the summary statistics in Table 1, China's high EP% and ODR% indicates a heavier dependency burden on the society, which hinders the economic development of the country, as the GDPGR% reflects.

4 Results

Bayesian-Vector Autogestion Analysis with Forecast Error Variance Decomposition (FEVD) and Impulse Response Function (IRF)

Figure 2 depicts the overall trend of the different variables in the study, including age 65 and over population (EP) and old dependency ratio (ODR), annual GDP growth

Table 1. Summary Statistics

	NGR%	EP%	ODR%	GDPGR%	LPR%
Mean	9.29	7.85	10.7	7.19	69.81
Median	8.66	17.26	24.43	7.15	70.09
Max	16.61	11	16.8	10.6	71.07
Min	3.81	4.9	8	2.20	68.06
St.dev	4.10	1.82	2.21	2.24	1.00

rate (GDPGR), and labor participation rate (LPR). The areas inside the dotted line are the Bayesian credible intervals.

Figure 2 makes it abundantly evident that since 1982, China's elderly population and old dependence ratio have been on the rise. Both variables' 10% growth revealed a prominent aging population. Between 2010 and 2020, the workforce participation rate quickly declined from a high of almost 70% in 2010. The number of elderly people who aren't working is growing, considerably diminishing the available workforce and causing a labor shortage. The three variables mentioned above were a part of the declining GDP annual growth rate. The growth rate has decreased from more than 10% to barely 2% between 2010 and 2020. It demonstrates how the workforce scarcity brought on by the aging population prevents society's economy from developing. Furthermore, Fig. 3

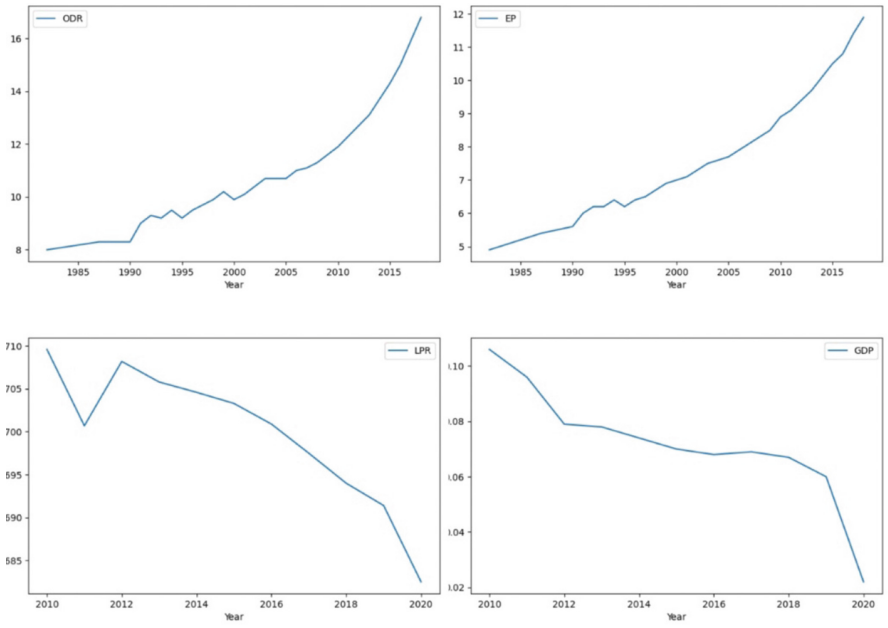

Fig. 2. The overall trend of ODR, EP, LPR, GDP in China

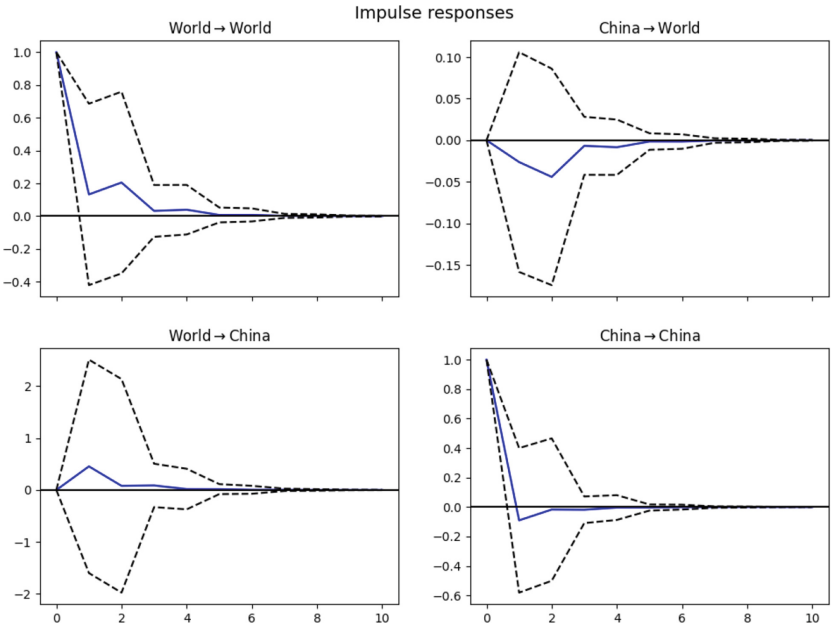

Fig. 3. Impulse responses of the different variables

shows how the system reacts to an impulse in its variables. To examine how the overall population response to an aging population, we could gain insights from the figure that aging population have greater effects on China rather than the world.

In the meantime, according to Fig. 4, the Bayesian VAR model's accuracy is verified by comparing the actual and forecasted trends. The actual dataset from the Chinese National Bureau of Statistics also strengthened the validity of the forecasting model. It further indicated how the aging population strongly negatively affects society's economy, as shown by the constantly decreasing line (Fig. 5).

The FEVD model makes it possible to look more closely at how each variable is weighted. Over 70% of the world's and China's economic progress is attributable to the aging population. According to the graph, China's population aging problem is worse than in some wealthy nations. According to the FEVD model and the IRF function, the world's aging population significantly impacts other factors, although these effects only become more noticeable in China. In China, the negative impact of an aging population on economic growth weighs in at about 90%, compared to a global average of only about 70%. According to these graphs, China is more adversely affected by the aging population than the rest of the world, despite the fact that it is a significant concern on both sides.

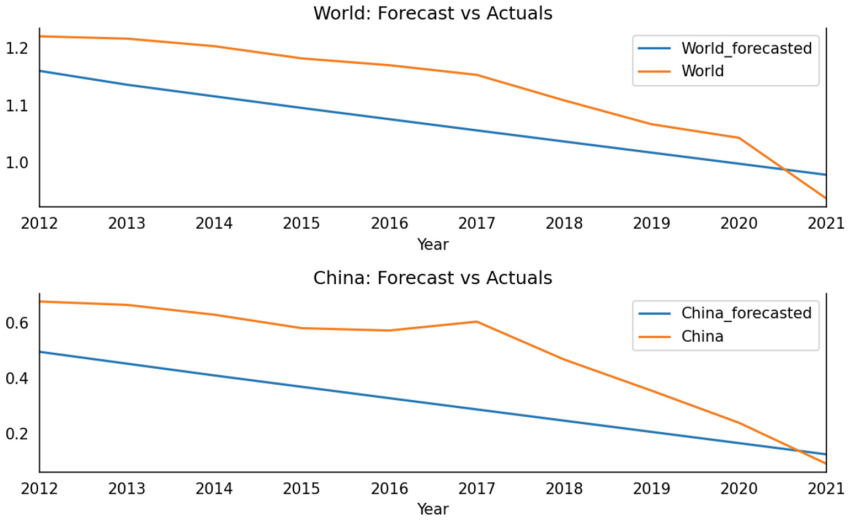

Fig. 4. The forecasted vs. the actual results in China and around the globe

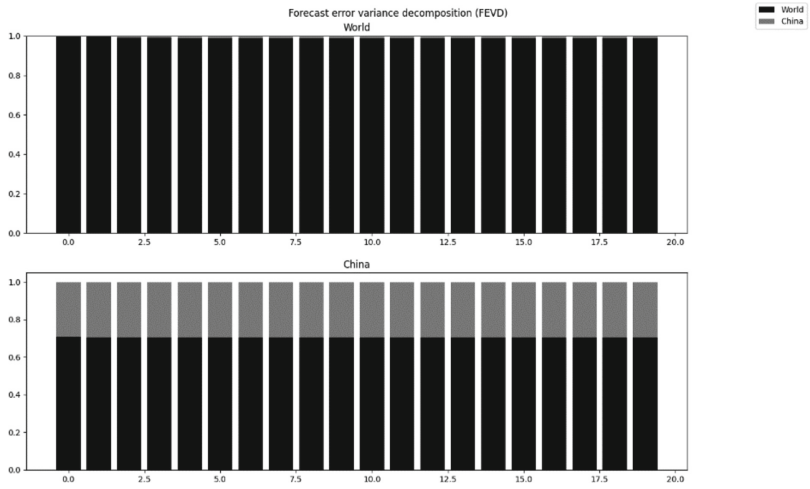

Fig. 5. The FEVD model on the aging population affecting economic growth of China vs. the World

5 Discussion

Compared to other literature sources that only examines the relationship between two variables, this paper incorporates three different variables, including the aging population, economic growth, and labor participation, using the Bayesian VAR approach. The priors were also set according to the unique characteristics of the dataset and improved the overall forecasting accuracy. Overall, it yields better outcomes than conventional VAR models or VAR models with unfitting priors. Additionally, compared to the rest of

the globe over the same period, the data show that economic progress typically encourages an increase in life expectancy, which results in an aging population, with China being more influenced by it from 1978 to 2016.

These findings are consistent with the predictions made by (Zhang 2020; Wang 2008) [5, 6] that the aging population has a detrimental impact on economic growth. Moreover, this paper cites actual data rather than simulations to illustrate how the aging population in the world's most populated nation impacts the economy. (Roser 2013) [4] China has "grown old before getting rich" due to the rapidly increasing geriatric population share (Wang, 2008). [5] China's GDP growth rate is still positive and strong, but the decreasing trend indicates the high unlikelihood of maintaining such growth.

Two practical solutions are generating long-term financial strategies that sustain health infrastructures and developing a healthcare system that puts a premium on routine primary care (Wang 2006). [3] China's urban and rural inhabitants have made positive strides in this regard (Hiroaki 2020) [10]. Encouragement of a retirement policy reform is a different tactic, as (Wang 2008) [5] highlights. However, this necessitates a comprehensive strategy that goes beyond merely raising the retirement age and considers a variety of aspects like physical condition, finances, and individual life events. For instance, community initiatives that assist the elderly in maintaining their economic engagement by offering them alternatives for education and employment, flexible work hours, and well-paid pensions after retirement.

6 Conclusion

This research explored the connections between China's aging population, economic development, and labor force participation. Based on the Bayesian Vector Auto Regression model (B-VAR model), this paper computes the Forecast Error Variance Decomposition (FEVD) and Impulse Response Function (IRF) for China throughout 1982–2020, while part of the data only includes 2010–2020. This B-VAR model is particularly effective because it outperforms the conventional VAR model and can handle data from a limited time series.

The results that have been presented may, in some instances, aid in decision-making. It is undoubtedly required to conduct extensive research, particularly on a daily basis, in order to establish or evaluate a particular policy, yet the variabilities taken into account here need to be directly translated into policy measures. The fact that only one nation and the short time span (1982 to 2018) were taken into account in this study is another drawback. Larger data sets, more extended time series, and the inclusion of more nations will be beneficial for future research on the reliability of the findings and the universality of the policy implications. Future research is left to address these challenges.

References

1. Maestas, Nicole, et al. "The Effect of Population Aging on Economic Growth, the Labor Force and Productivity." 2016,
2. Sasaki, Hiroaki, and Keisuke Hoshida. "The Effects of Negative Population Growth: An Analysis Using a Semiendogenous R&D Growth Model." *Macroeconomic Dynamics*, vol. 21, no. 7, 2016, pp. 1545–1560.,

3. Sen, WANG. "The Characteristic, Prospect and Policies of Population Aging in China", *Journal of Shijiazhuang University of Economics* (2006): 36–39
4. Roser, Max et al. "World population growth", *Our World in Data* (2013)
5. Feng, Wang et al. "A Preliminary Study of China's Negative Population Growth Momentum in the 21st Century", *Population Research* (2008): 9–19
6. Zhang, Xianling et al. "Trends and Patterns of Negative Population Growth in China", *Population Research* 44.3 (2020): 3–20
7. Lu, Max. "Vector Autoregression (VAR) - an Approach to Dynamic Analysis of Geographic Processes." *Geografiska Annaler, Series B: Human Geography*, vol. 83B, no. 2, 2001, pp. 67–78.
8. Nicolini, E. A. "Was Malthus Right? A Var Analysis of Economic and Demographic Interactions in Pre-Industrial England." *European Review of Economic History*, vol. 11, no. 1, 2007, pp. 99–121.
9. Haddou, Abdenour, and Ji-Young Jang. "A Comparative Analysis on Effects of Fiscal and Monetary Policy Using Panel Structural VAR." *Korea International Trade Research Institute*, vol. 16, no. 5, 2020, pp. 155–167.,
10. Miyamoto, Hiroaki, and Naoyuki Yoshino. "A Note on Population Aging and Effectiveness of Fiscal Policy." *Macroeconomic Dynamics*, vol. 26, no. 6, 2020, pp. 1679–1689.,