

# Research on the Impact of Population Aging on China's GDP and Its Composition based on Multiple Linear Regression

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**Abstract.** In today's China, population aging is a more and more serious problem and it can impact economic growth in many aspects. In order to slow down the population aging and reduce its impact on economic growth, this study uses multiple linear regression model to analyze the correlations between them. As the most direct indicator to economic growth, GDP and its 4 compositions are chosen as the dependent variables. This study chooses aging ratio, aging index, labor participation rate and elderly dependency rate as variables to indicate population aging. Based on the analysis of 240 samples from the National Bureau of Statistics, it is found that each dependent variable is corresponded to the 4 variables. After comparing the VIF value and significance of each variable, the equations of multiple linear regression are drawn. It turns out that aging index is the most important influencing factor to China's GDP, so the results can shed light on how to promote national economic growth under the background of population aging.

**Keywords:** Population aging, GDP, economic growth of China, multiple linear regression.

## 1. Introduction

Population aging refers to the phenomenon that the proportion of elderly people in the total population rises, while the young labor force is decreasing. According to the data released by the National Bureau of Statistics, in February 2023, the number of middle-aged and elderly people aged 60 and above reached 280 million, accounting for 19.8% of the total population; The number of middle-aged and elderly people aged 65 and above reached 210 million, accounting for 14.8% of the total population. It is expected that by 2035, the middle-aged and elderly population aged 60 and above will exceed 400 million, accounting for more than 30% of the total population, entering the stage of severe aging [1]. Such aging progress can influence the economic development. For instance, as the proportion of the elderly population increases, the proportion of the working population decreases relatively [2]. But from another perspective, this phenomenon could promote economic growth. This is because when the education level of the population is significantly improved, the advanced knowledge labor force would have a positive effect on economic growth through innovation [3, 4]. As an important indicator to measure a country's economic vitality, gross domestic product (GDP) is undoubtedly a key to study the impact of population aging. This study is going to explore how population aging impacts China's GDP and its composition based on the researches that has been done, and further explore effective strategies that can improve China's population structure to promote sustainable economic development.

According to the past domestic researches, population aging can be reflected in a variety of indicators and it can also impact GDP in different components. Zhang et al. believed that population aging would impact economic growth negatively by reducing mediators such as saving rate, investment rate, labor participation rate and total factor productivity [5]. Zou et al. used the generalized method of moments to determine that the quantity of labor force and the proportion of the working population were correlated with the growth of economic positively, so that population aging would retard China's GDP growth [6]. Population aging may also hinder technological progress because of the decline in innovation ability. In another aspect, due to the increasing proportion of the

elderly population, the government will invest more in social security and thus less in scientific research. For instance, Zhao et al. found that population aging can slow down the technological development of manufacturing industry, by conducting empirical analysis using mediation effect model. In this research, the proportion of elderly people over 65 years old in the total population was chosen as the core explanatory variable. The result showed that population aging has a negative mediation effect on the upgrading of manufacturing structure [7].

Although the impact of population aging is negative in most cases, it can also somewhat promote economic development by transforming the economic structure. Song et al. supposed that population aging had both negative and positive impact on the GDP growth according to the baseline regression, moderation effect and threshold effect models. Through model analysis, they found that population aging will bring about reduction in total social consumption and increase financial burden because of more social security expenditure, but the expenditure had a positive regulatory effect on economic growth. When the aging degree is under an exact threshold value, its impact to GDP tends to be positive, but will turn to negative while the degree is over this value [8].

There are also studies on population aging and GDP in international journals. For example, HyunHoon and Kwanho explored how population aging impacted the output growth per capita of 35 OECD countries with a high old dependency ratio. The paper concluded that the permanent decline in TFP growth rate implied the lasting negative effects of aging on GDP growth per capita [9]. Besides, utilizing panel fixed effects and quantile regression, Ngoc and Hong investigated the impact of population aging on economic growth in 84 developing countries between 1971 and 2015. The findings reveal a negative long-term effect on economic growth associated with a high percentage of young people (14 years old and younger). Conversely, a positive connection is observed between the percentage of those 65 and older and economic performance in the long run [10]. In addition, Yang assessed the impact of population aging on China's GDP using per capita GDP data and the elderly dependency ratio from 31 provinces and cities in China. The findings indicate that the dependency ratio positively influences GDP, but when considering the proportion of the elderly population, the results differ [11]. Maestas et al. found that a 10% increase in the population over 60 aged led to a 5.5% decrease in per-capita GDP by analyzing aging trends across states. Slower employment and labor productivity growth contributed to this decline, resulting in reduced labor compensation and wages. Their estimate suggests that during 1980-2010, population aging decreased the annual growth rate of GDP per capita by 0.3 percentage points [12].

This study will analyze the impact of population aging on GDP and its compositions specifically by constructing multiple linear regression models.

## 2. Methods

### 2.1. Data Source

The GDP annual data and the data on China's population age structure and dependency ratio used are all sourced from the database of the National Bureau of Statistics, which was an authoritative official statistical platform. This could help ensure the accuracy of data and enhance the credibility of research results. China was a populous country, but as it was still a developing country, the aging population had only gradually intensified in recent years. Therefore, the annual GDP data and the aging ratio of China during 2014-2022 were selected for the study. These figures were more representative, and they further enhanced the accuracy and reliability of the research results.

### 2.2. Indicator Selection

Population aging can be measured by a series of indexes. This study chooses aging index, elderly dependency rate, aging ratio and labor participation rate as the variables of population aging. The annual gross domestic product is chosen as the main dependent variable as it is the most intuitive index of GDP growth. Besides, this study wants to further explore the impact of population aging on

different compositions of GDP. So, the secondary dependent variables include resident consumption, government consumption, net exports and capital formation (Table 1).

**Table 1.** List of variables

Type	Variable	Logogram	Meaning
Explanatory	aging index	x1	ratio of elderly to child population
	elderly dependency rate	x2	ratio of elderly to total population
	aging ratio	x3	ratio of elderly to total population
	labor participation rate	x4	ratio of working to total population
Second variable	resident consumption	y1	annual consumption of citizens
	government consumption	y2	annual consumption of government
	capital formation	y3	total value of investment
	nex export	y4	value of export minus its import
First variable	annual GDP	Y	summation

### 2.3. Method Introduction

The study uses multiple linear regression analysis to explore the impact of various aging population indicators on three components of GDP. Firstly, scatter plots are drawn based on data collected from the National Bureau of Statistics to initially understand the distribution of the data. Then, all aging population indicators are used to conduct linear or non-linear regression correlation analysis with one of the GDP components to identify the more significant aging indicators within each GDP component, and relevant recommendations are proposed based on these results. The model of multiple linear regression is:

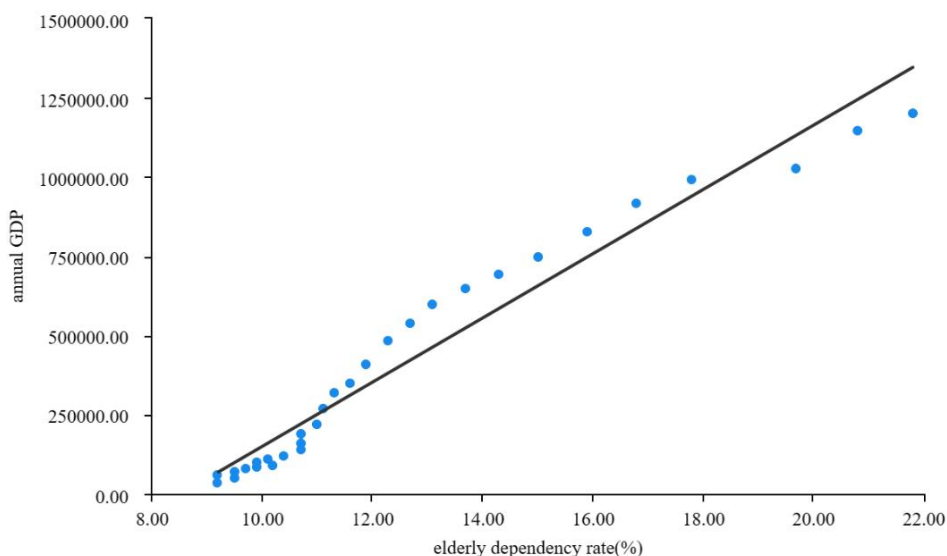
$$Y = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_3 + \beta_4x_4 + \varepsilon \tag{1}$$

In the above formula,  $\beta_0$  is a constant term and  $\beta_i (i = 1,2,3,4)$  is regression coefficient.  $\varepsilon$  is a residual term.

## 3. Results and Discussion

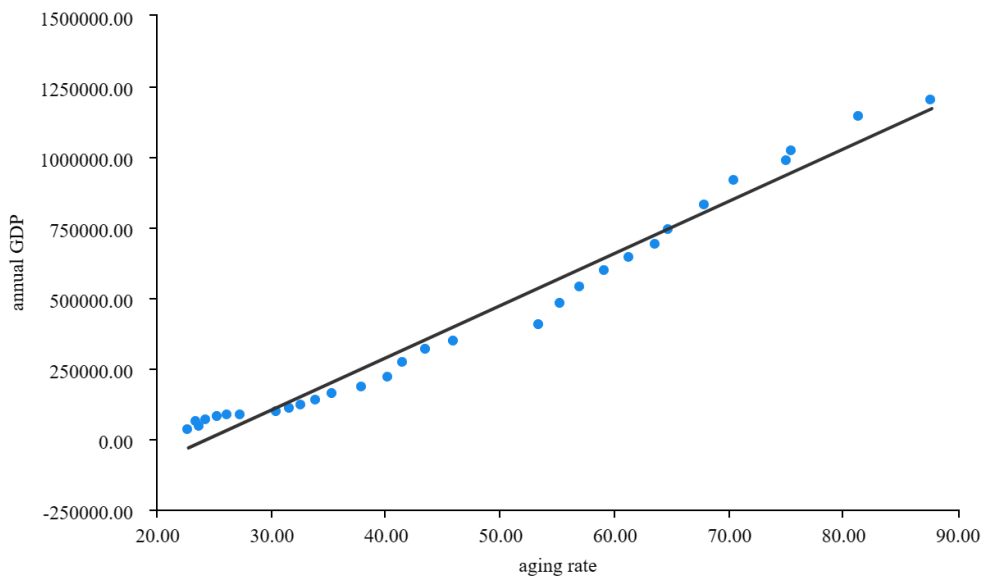
### 3.1. Descriptive Analysis

Figure 1 is about the effect of elderly dependency rate on annual GDP, with the elderly dependency in the range from 9 to 22. Obviously, there is a strong linear relationship between these two indicators. As the elderly dependency rate grows, GDP continues to rise, and the degree of data dispersion strengthens, but overall, it fluctuates on the fitted regression line.



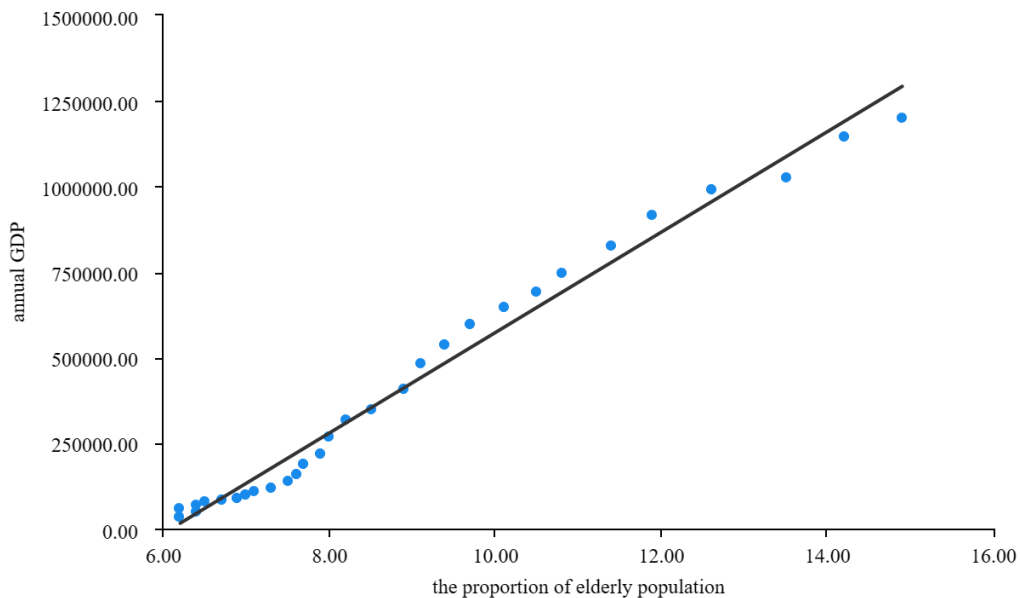
**Fig. 1** Scatter plot of elderly dependency rate and annual GDP

Figure 2 is about the effect of aging rate on annual GDP. Most of the data is concentrated in the aging rate between 20-48 and 55-80, showing an overall upward trend with strong linear characteristics.



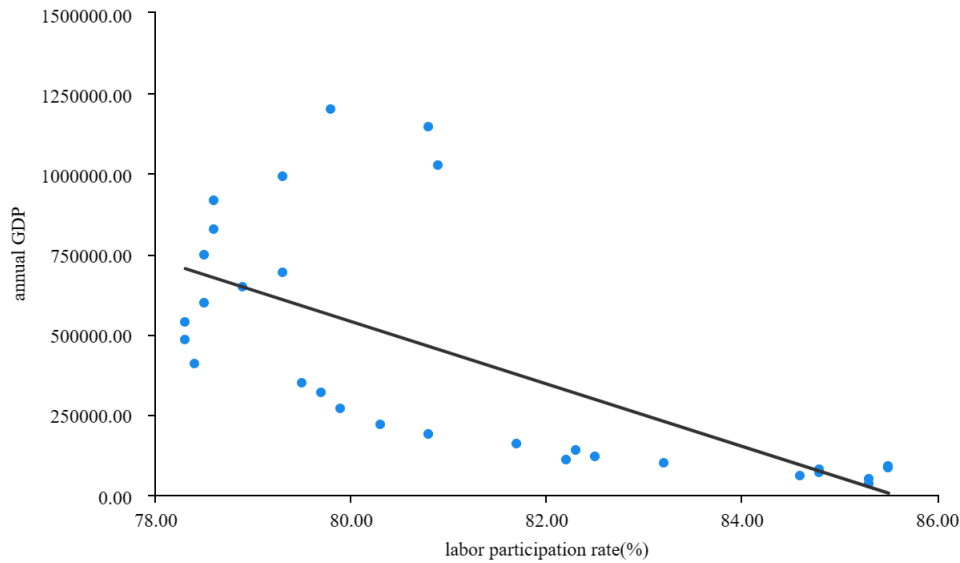
**Fig. 2** Scatter plot of aging index and annual GDP

Figure 3 is about the effect of the proportion of elderly population on annual GDP, with the independent variable varies from 6 to 16. The dispersion of data begins to increase after 8. However, it is apparently that as the ratio of elderly population increased, there was also an upward trend in annual GDP. Therefore, the linear relationship between them is strong.



**Fig. 3** Scatter plot of the proportion of elderly population and annual GDP

In terms of figure 4, which describes the impact of labor participation rate on annual GDP, the image presents a completely opposite trend. The data is apparently more dispersed, especially between 78%-81%, with the majority of the data below the regression line, indicating that the fit is not very good.



**Fig. 4** Scatter plot of the proportion of labor participation rate and annual GDP

### 3.2. Multiple Linear Regression Analysis

#### 3.2.1 Procedure introduction

Through preliminary data analysis, this article identifies the aging ratio, aging index, elderly dependency ratio, and labor force participation rate as independent variables, and household consumption, government consumption, total capital formation, net exports of goods and services and GDP as dependent variables respectively, conducting multiple linear regression analysis. It is found that there is multicollinearity issue in all five variables (VIF values are significantly greater than 5). Therefore, stepwise regression analysis is performed to obtain the indicators that have significant impact in each category.

#### 3.2.2 Resident consumption

The model passed the F-test ( $F=1774.478, p=0.000<0.05$ ), indicating its effectiveness. The results indicate that the aging ratio has a significantly positive impact on Household Consumption, while the other three independent variables do not have a significant impact on household consumption (Table 2). Regarding resident consumption, the formula for the stepwise regression model is:

$$y_1 = -333219.584 + 55082.843x_3 \tag{2}$$

**Table 2.** Parameter estimates of resident consumption

	B	Std. Error	Beta	t	p	VIF	Tolerance
Constant	-333219.584	12157.417		-27.409	0.000		
Aging Ratio	55082.843	1307.618	0.992	42.125	0.000	1.000	1.000
R <sup>2</sup>				0.984			
Adj R <sup>2</sup>				0.984			
F				F (1,28)=1774.478, p=0.000			
D-W				0.506			

Dependent Variable: Resident Consumption

#### 3.2.3 Government consumption

The model passed the F-test ( $F=1289.049, p=0.000<0.05$ ), indicating its effectiveness. The results indicate that and labor participation rate have a significantly positive impact on government consumption, while the other two variables do not have a significant impact on government consumption (Table 3). Regarding government consumption, the stepwise regression formula is:

$$y_2 = -595634.640 + 3644.670x_1 + 6043.008x_4 \quad (3)$$

**Table 3.** Parameter estimates of government consumption

	B	Std. Error	Beta	t	p	VIF	Tolerance
Constant	-595634.640	63268.529		-9.414	0.000		
Labor Participation Rate	6043.008	735.075	0.255	8.221	0.000	2.499	0.400
Aging Index	3644.670	95.756	1.179	38.062	0.000	2.499	0.400
R <sup>2</sup>				0.990			
Adj R <sup>2</sup>				0.989			
F				F (2,27)=1289.049, p=0.000			
D-W				0.769			

Dependent Variable: Government Consumption

### 3.2.4 Capital formation

The model passed the F-test (F=1706.943, p=0.000<0.05), indicating its effectiveness. The results indicate that the aging index and labor participation rate have a significantly positive impact on total capital formation. However, the other two variables do not have a significant impact on total capital formation (Table 4). Regarding the total capital formation, the stepwise regression formula is:

$$y_3 = -1207299.515 + 9350.841x_1 + 11677.322x_4 \quad (4)$$

**Table 4.** Parameter estimates of capital formation

	B	Std. Error	Beta	t	p	VIF	Tolerance
Constant	-1207299.515	147110.455		-8.207	0.000		
Labor Participation Rate	11677.322	1709.178	0.184	6.832	0.000	2.499	0.400
Aging Index	9350.841	222.649	1.132	41.998	0.000	2.499	0.400
R <sup>2</sup>				0.992			
Adj R <sup>2</sup>				0.992			
F				F (2,27)=1706.943, p=0.000			
D-W				0.861			

Dependent Variable: Capital Formation

### 3.2.5 Net exports of goods and services

The model passed the F-test (F=46.793, p=0.000<0.05), indicating its effectiveness. The aging index has a significant positive impact on net exports of goods and services (in hundred million yuan). However, the R-squared value of 0.626 suggests that the aging index (%) can only explain 62.6% of the variation in net exports of goods and services. Therefore, this study may not have found more suitable related variables to explain the remaining variation (Table 5). Regarding net exports of goods and services, the stepwise regression formula is:

$$y_4 = -7105.365 + 399.264x_1 \quad (5)$$

**Table 5.** Parameter estimates of net exports

	B	Std. Error	Beta	t	p	VIF	Tolerance
Constant	-7105.365	2979.865		-2.384	0.024		
Aging Index	399.264	58.367	0.791	6.841	0.000	1.000	1.000
R <sup>2</sup>				0.626			
Adj R <sup>2</sup>				0.612			
F			F (1,28)=46.793, p=0.000				
D-W				0.615			

Dependent Variable: Net Exports

### 3.2.6 Annual GDP

The R-squared value of 0.993 indicates that the Aging Index and Labor Participation Rate (%) can explain 99.3% of the variation in Expenditure-based GDP. Moreover, the model passed the F-test (F=2041.790, p=0.000<0.05), indicating its effectiveness. The Aging Index and Labor Participation Rate have a significant positive impact on Expenditure-based GDP, while the aging ratio and the elderly dependency ratio do not have a significant effect on GDP (Table 6). Finally, regarding GDP, the formula for stepwise regression is:

$$Y = -3214477.554 + 21736.015x_1 + 32143.650x_4 \quad (6)$$

**Table 6.** Parameter estimates of annual GDP

	B	Std. Error	Beta	t	p	VIF	Tolerance
Constant	-3214477.554	305358.010		-10.527	0.000		
Labor Participation Rate	32143.650	3547.750	0.223	9.060	0.000	2.499	0.400
Aging Index	21736.015	462.154	1.160	47.032	0.000	2.499	0.400
R <sup>2</sup>				0.993			
Adj R <sup>2</sup>				0.993			
F			F (2,27)=2041.790, p=0.000				
D-W				0.903			

Dependent Variable: Annual GDP

## 4. Conclusion

Using the multiple linear regression, this study shows that labor participation rate and aging index will impact annual GDP, government consumption and capital formation positively. Aging ratio will impact resident consumption positively and aging index will impact net export positively. Thus, among the 4 variables, aging index can be the most significant influencing factor. According to the result of this study, the author finds that the rise of labor participation rate can lead to higher capital formation because there is more labor force to create and accumulate social assets. The rise of elderly population can lead to higher resident consumption because the majority of people will spend more money on travel and medical treatment. The rise of aging index can lead to higher government consumption because the government will invest more on the construction of social security to ensure a steady life for the elderly. The rise of aging index can also improve and upgrade the industrial structure thus promoting competitiveness in the global market and then increase national net export. These conclusions point out the ways to reduce population aging and ease the negative impact to the economic growth while enhance the positive impact.

However, there are still some deficiencies in this study. For instance, some variables may have correlations between each other, which can lead to multicollinearity that affect the accuracy of the regression model. Besides, the chosen variables may not cover all of the indicators of population

aging. To further investigate the methods to reduce population aging and promote economic growth, more indicators should be taken into consideration and the composition of GDP should be divided more detailed.

## Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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