Application of Population Ageing in Regional Sustainable Development

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Abstract. This article is based on Chinese provincial panel data from 2006 to 2019, by using the fixed effects model for the improvement of the aging population of the empirical test on the influence of the level of regional innovation, and further examines the east Midwest heterogeneity influence on regional innovation level, after robustness inspection in explaining variables by replacing the basic conclusion remains valid. The results show that there is an obvious inverted U-shaped relationship between the degree of population aging and regional innovation level. Based on the above research, this paper puts forward some corresponding suggestions.

Keywords: Population aging · Regional innovation · Patent application · Regional heterogeneity

1 Introduction

A large number of studies related to population aging have been carried out from the perspective of population structure, but there are few studies on the relationship between the increasing degree of population aging and the level of regional innovation, and no consistent conclusions have been drawn. Therefore, in the context of China, this paper continues to explore the influence relationship between population aging at the macro level and China's regional innovation level through provincial panel data from 2006 to 2019, grasp the development law of the impact of China's population aging on regional innovation level, and provide a basis for better coping with the "silver wave".

2 Research Hypotheses

Hypothesis 1: Population aging can promote the improvement of regional innovation level under certain conditions; After exceeding certain conditions, population aging has a restraining effect on regional innovation level, that is, there is a nonlinear relationship between population aging and regional innovation level.

Hypothesis 2: The impact of population aging on regional innovation level shows certain regional heterogeneity.

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3 Study Design

3.1 Model Settings

Through literature review and theoretical mechanism analysis, to investigate the impact of population aging on regional innovation level, this paper sets the following empirical models:

$$inno_{it} = \beta_0 + \beta_1 aging_{it} + \beta_2 X_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

In model (1), i represents the region and t represents the year; The explanatory variables $inno_{it}$ represent regional levels of innovation; $aging_{it}$ indicates the degree of regional population aging, which is the core explanatory variable of this study. X_{it} represents a series of control variables that affect the variable being explained; μ_i is an individual fixed effect; ε_{it} is a random perturbation term.

Considering that there may be a nonlinear relationship between population aging and regional innovation level, in order to study the influence effect of population aging and regional innovation level, the extended econometric model is constructed as follows

$$inno_{it} = \beta_0 + \beta_1 aging_{it} + \beta_2 aging_{it}^2 + \beta_3 X_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

In model (2), ${aging^2}_{it}$ is the quadratic term of the degree of population aging.

3.2 Variable Selection and Description

Table 1 describes the core variable settings in this topic.

Table 1. Study variable setting

Types of variables	name	Represents a symbol	meaning
The variable being explained	Regional level of innovation	inno	Number of invention patent applications (items)
Explanatory variables	The degree of population ageing	aging	Elderly population dependency ratio (%)
Control variables	Level of economic development	per_gdp	Per capita GDP (yuan)
	Level of urbanization	urban	Urbanization rate (%)
	Degree of openness to the outside world	open	Total import and export of goods (US$ billion)

Source: Compiled by the author himself

Table 2. Descriptive statistical analysis results of variables

variable	mean	standard deviation	minimum	maximum	Number of samples
inno	22231.76	35480.98	79	216469	420
aging	0.13	0.03	0.07	0.24	420
per_gdp	44476.3	26904.7	5787	164220	420
urban	0.54	0.14	0.27	0.90	420
open	1116.16	1981.87	1.60	11651.88	420

Source: Stata 15.0 software processing results, the same below

3.3 Data Sources and Statistical Descriptions

This article studies a total of 30 provinces (municipalities) in addition to the 2006–2019 China Statistical Yearbook, China Science and Technology Statistical Yearbook and Chinese Statistical Yearbook. Table 2 shows the results of a descriptive statistical analysis of each study variable.

4 Empirical Analysis

4.1 Correlation Analysis

Correlation analysis is used to test whether there is a correlation and correlation between variables, and the degree of correlation is generally expressed using a correlation coefficient between −1 and 1. A correlation coefficient of less than 0 is negatively correlated, greater than 0 is positively correlated, its absolute value is less than 0.5 is weakly correlated, between 0.5 and 0.7 is moderately correlated, and more than 0.7 is highly correlated. Table 3 shows the results of variable correlation analysis.

Table 3 shows that the level of regional innovation is positively correlated with the degree of population aging, per capita GDP, urbanization rate and openness at the 1% significance level, indicating that under the 1% significance level, the increase of population aging, the increase of per capita GDP, urbanization rate and the degree of openness are all conducive to the improvement of regional innovation level.

Table 3. Results of variable correlation analysis

	lninno	lnaging	lnper_gdp	lnurban	lnopen
lninno	1.000				
lnaging	0.571***	1.000			
lnper_gdp	0.728***	0.312***	1.000		
lnurban	0.213***	0.218***	0.255***	1.000	
lnopen	0.855***	0.357***	0.709***	0.142***	1.000

Note: *, **, *** * indicate significant at the statistical levels of 10%, 5% and 1%, respectively

4.2 Regression Analysis

In this article Stata 15.0 is used to empirically analyze the degree of population aging and regional innovation level, the F-test and Hausman test are used to test the three estimation methods, and the Hausman test statistics: $chic^2$ (6) = 64.63, Prob > $chic^2$ = 0.000, strongly reject the null hypothesis, so it is finally determined to use the fixed-effect model for regression estimation, and the full-sample regression results are shown in Table 4.

Model (1) [Column (1) of Table 4] is the benchmark model, and the per capita GDP and urbanization rate in the control variables significantly positively affect the regional innovation level at the statistical level of 1%, However, the impact of openness on regional innovation level is not statistically significant.

Model (2) [Table 4, column (2)] includes the core explanatory variable of population aging degree on the basis of model (1), and the results show that the impact of population aging on regional innovation level is estimated at 0.351, which is significant at the 5% statistical level, indicating that the degree of population aging increases by 1% and the regional innovation level increases by 0.351%.

Model (3) [column (3) of Table 4] includes the square term of the variable of population aging on the basis of model (2) to verify the nonlinear relationship between population aging and regional innovation level. The results show that the estimation coefficient of the square term of population aging is significantly negative at the statistical level of 1%, and the coefficient of the primary term is significantly negative, which

Table 4. Estimation results of full-sample basic regression

variable	(1) lninno	(2) lninno	(3) lninno
lnaging		0.351**	− 3.378***
		(2.57)	(−2.70)
ln^2aging			− 0.943***
			(−3.00)
lnper_gdp	1.919***	1.842***	1.838***
	(24.37)	(28.76)	(28.98)
lnurban	0.0487***	0.0399***	0.0371***
	(5.10)	(3.01)	(2.82)
lnopen	0.0318	0.0508	0.0625*
	(0.96)	(1.46)	(1.81)
_cons	− 11.39***	− 9.999***	− 13.67***
	(−14.36)	(-14.03)	(−9.69)
R-squared	0.8999	0.9016	0.9038
N	420	420	420

Note: (1) Source: Stata 15.0 software processing results; (2) *, **, *** * indicate significant at 10%, 5% and 1% statistical levels, respectively; (3) The value of t is in parentheses.

Table 5. Test results for regional heterogeneity

region	eastern			Central			westward		
variable	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	lninno	lninno	lninno	lninno	lninno	lninno	lninno	lninno	lninno
lnaging		0.356**	−2.885*		0.804***	3.73		1.409***	−7.181***
		(2.31)	(−1.66)		(2.72)	(1.01)		(3.92)	(−2.64)
ln^2aging			−0.837*			0.701			−2.069***
			(−1.87)			(0.76)			(−3.20)
lnper_gdp	1.857***	1.763***	1.767***	1.996***	1.766***	1.692***	1.687***	1.399***	1.401***
	(22.29)	(19.5)	(19.71)	(16.25)	(12.2)	(11.41)	(15.99)	(12.26)	(12.67)
lnurban	0.0402**	0.0303	0.0266	0.0463*	0.0266	0.0256	0.0661**	0.0404	0.0393
	(2.21)	(1.63)	(1.43)	(1.84)	(1.02)	(0.94)	(2.37)	(1.36)	(1.36)
lnopen	0.131***	0.171***	0.186***	−0.00379	0.0506	0.0762	0.160**	0.230***	0.268***
	(2.66)	(3.38)	(3.65)	(−0.05)	(0.72)	(1.06)	(2.52)	(3.69)	(4.38)
_cons	−11.40***	−9.956***	−13.21***	−11.60***	−7.920***	−4.267	−9.925***	−4.397***	−13.39***
	(−16.14)	(−10.75)	(−6.72)	(−11.49)	(−4.81)	(−1.03)	(−10.91)	(−2.94)	(−4.17)
R^2	0.9214	0.9224	0.9246	0.904	0.9074	0.9071	0.8827	0.8757	0.8835
N	154	154	154	112	112	112	154	154	154

Note: (1) Source: Stata 15.0 software processing results; (2) *, **, *** * indicate significant at 10%, 5% and 1% statistical levels, respectively; (3) The value of t is in parentheses.

preliminary indicates that there is an inverted U-shaped relationship between the degree of population aging and the level of regional innovation. In order to further test whether there is an inverted U-shaped relationship between the two, this paper performs test after the regression result of model (3), and the null hypothesis is that there is a monotonic or U-shaped relationship, and the alternative hypothesis is the existence of an inverted U-shaped relationship. The test result statistics were t-value = 1.83, P > |t|=0.0338, indicating that the null hypothesis was rejected at the 5% statistical level, that is, and hypothesis 1 was tested.

4.3 East, Midwest, and West Heterogeneity Testing

In order to further investigate the influence of population aging on regional innovation level, this paper divides each province (municipality directly under the central government) into three regions: eastern, central and western, and group regression is carried out to test the impact of regional heterogeneity. Fixed effects were selected for regression coefficient estimation and the results are shown in Table 5.

The results of Table 5 show that for the eastern, central, and western regions, there is regional heterogeneity between the aging degree of population and the level of regional innovation in various regions, which is manifested as "western > eastern > central", and the degree of inhibition effect is different, and hypothesis 2 is tested.

4.4 Robustness Test

In this paper, the robustness test is performed by substituting the explanatory variables, and the results are shown in Table 6.

Table 6. Robustness test

variable	(1)	(2)	(3)
	lnpatent	lnpatent	lnpatent
lnaging		0.377***	−6.047***
		(3.18)	(−5.81)
$\ln^2$aging			−1.621***
			(−6.21)
lnper_gdp	1.245***	1.219***	1.213***
	(13.83)	(13.66)	(14.23)
lnurban	2.583***	2.302***	2.291***
	(7.88)	(6.86)	(7.15)
lnopen	−0.0263	−0.00419	0.0165
	(−0.89)	(−0.14)	(0.57)
_cons	−1.198	−0.474	−6.822***
	(−1.12)	(−0.44)	(−4.69)
R-squared	0.9080	0.9104	0.9185
N	420	420	420

Note: (1) Source: Stata 15.0 software processing results; (2) *, **, *** * indicate significant at 10%, 5% and 1% statistical levels, respectively; (3) The value of t is in parentheses.

This paper replaces the total number of patent applications as a measure of regional innovation levels. The total number of patent applications includes the sum of the number of patent applications for invention patents, design patents and utility model patents. It can be seen from Table 6 that the results are again tested by test to obtain the test statistics t-value = 4.54, $P > |t| = 3.70e{-}06$, which is close to zero, so the null hypothesis is rejected, that is, there is an inverted U-shaped relationship between the aging of the population and the level of regional innovation.

5 Conclusions

From the macro level, the results show that the inverted U-shaped relationship between population aging and regional innovation level is still significant in the eastern and western regions. For the central region, population aging has a significant positive effect on the regional innovation level, but the inverted U-shaped relationship estimation coefficient between the two is not statistically significant. The reason for the insignificant coefficient may be that the provinces within the central region have a complex industrial structure and a small trend of population structure, so the nonlinear relationship between population aging and regional innovation in the region is not significant.

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