RESEARCH-ARTICLE

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The Mutual Compensatory Effect of Artificial Intelligence Development and Labor Structure Changes

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Abstract

The rise of artificial intelligence has brought a wide and far-reaching impact on the economy and society. This paper uses the industrial robot data of 13 APEC countries released by IFR and uses the instrumental variable method to empirically test the mutually constructed compensation effect of labor structure changes and artificial intelligence development. Based on previous literature research on artificial intelligence, this paper explores the decline in population growth rate and aging intensified aging included in population structure changes, and comprehensively studies its promotion effect on artificial intelligence, and examines whether the development of artificial intelligence can have a compensatory effect on the social economy and obtain the "intelligent dividend" when the "demographic dividend" fades.

CCS Concepts

• **Applied computing** → Law, social and behavioral sciences; Sociology.

Keywords

Artificial Intelligence Development, Labor Structure Change, Population Growth Rate, Aging Compensation Effect

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1 Introduction

With the rapid development of the digital economy and the rapid development of information technologies such as artificial intelligence, the contribution of artificial intelligence technology to social and economic development is becoming increasingly prominent. As an important empowerment tool for digital carbon neutrality, the development of artificial intelligence eases the impact of changes in the labor structure, accelerates industrial optimization and upgrading, reduces industrial carbon emissions, and ultimately promotes comprehensive and high-quality development of society's economy. However, at present, the decline in fertility rate and the deepening of population aging have caused changes in the labor structure, resulting in the decline of the population dividend While artificial intelligence technology improves productivity and improves people's lives, the threats that arise should not be underestimated.[1] In the future, will the rapid development of robotics and artificial intelligence bring challenges or opportunities to mankind? This series of issues has developed into an inevitable global issue.[2]

This issue is not sufficient for the Asia-Pacific region where "aging" has significantly intensified, and the population growth rate has declined. In fact, in recent years, the number of industrial robots in APEC countries has shown a significant growth trend.[3] By the end of 2023, the accumulated inventory of industrial intelligent robots in APEC accounted for more than 70% of the global total.[4] So, is the relationship between population aging and technological progress in major APEC countries having universal significance? To this end, this article will propose research hypotheses based on the review of relevant literature, and use the data of industrial robots in 13 APEC countries (Australia, Canada, Mainland China, Indonesia, Japan, South Korea, Malaysia, Mexico, Russian Federation, Singapore, Thailand, the United States, Vietnam) published by IFR, and use OLS and 2SLS research methods to construct the research metrological model, empirically analyze the mechanism of the action of population growth rate and population aging on the development of artificial intelligence and conduct heterogeneity analysis. Secondly, verify the effect of artificial intelligence on economic growth, draw relevant research conclusions, and put forward countermeasures and suggestions.

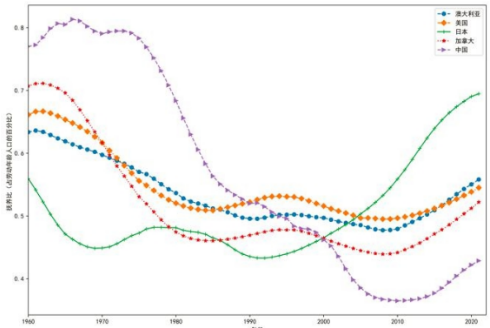

Figure 1: 1960-2021 Asia Pacific Economic (Cooperation Five Population Dividend Trend Chart)

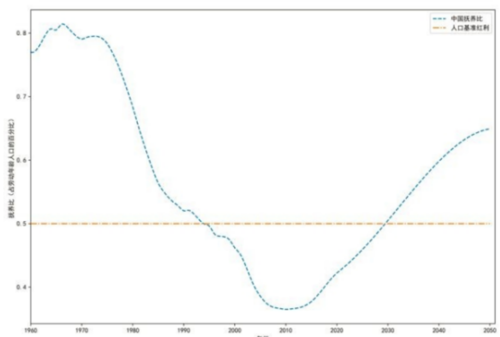

Figure 2: 1960-2050 Judgment of China's (demographic dividend period Chart)

2 LITERATURE REVIEW and research hypotheses

In recent years, the "demographic dividend" of most countries around the world is gradually fading.[5] This trend is particularly prominent in the Asia-Pacific organizations, including Japan, Australia, the United States, Canada and Mexico. Figure 1 shows that the dependency ratio of these countries has shown a significant upward trend since 2010. Figure 2 Take China as an example. In the early 1990s, China's total dependency ratio dropped below 50%, and began to enter the "demographic dividend" period. From 2005 to 2015, China's total dependency ratio basically remained at around 40%. However, since 2015, China's total dependency ratio has been rising year by year. It is expected that by 2030, its total dependency ratio will reach 49.7%①, and the demographic dividend period will basically end.[6]

Economic development is affected by changes in population structure and is mainly reflected in the consumption field, production field, and saving field.[7] The impact of the change in population structure on the production field is mainly labor supply. Generally speaking, after the growth of the working-age population has stopped, the country will face the problem of insufficient labor. As the population weakens, effective demand will decline, and capital savings and accumulation will also decrease. Changes in the labor structure will inevitably have a profound impact on the development of artificial intelligence and will also affect economic growth accordingly.[8] As scholars pointed out, countries that predict slower population growth are generally the first to adopt artificial intelligence technology, that is, for every 1% decrease in population growth, the number of robots installed will increase by nearly 2%.[9] Acemoglu & Restrepo(2018) found through empirical analysis that with the increase in the degree of population aging, the number of enterprises using robot production has also increased.[10] This phenomenon is particularly evident in the middle-aged labor industry. Therefore, this paper proposes the following two hypotheses to be verified:

H1: There is a negative effect between population growth rate and the development of artificial intelligence, while there is a positive effect between aging and artificial intelligence.

H2: Compared with the decline in population growth rate, the deepening of aging has more obvious impact on the development of artificial intelligence.

Not only that, artificial intelligence technology has also profoundly influenced social and economic development. Graetz & Michaels (2018) collected data from many countries from 1993 to 2007, and perceived that the application of robots in the industrial sector increased the annual GDP growth rate of these countries by an average of about 0.37%.[11] Kromann et al. (2020) believes that this value may be above 5%.[12] Artificial intelligence has promoted economic development in at least the following three aspects: First, technologies such as artificial intelligence can complete complex missions by replacing and supplementing human labor, thereby helping to promote the improvement of corporate productivity.[13] Second, artificial intelligence can assist human work through human-computer collaboration, deep learning and other technologies, or make production control decisions independently.[14] Third, artificial intelligence can achieve technological innovation and affect economic development by improving process flow and improving technical performance and even produce a multiplier effect.[15,16] Based on the above analysis, this paper proposes the third hypothesis:

H3: When the "demographic dividend" of labor structure changes fades, the development of artificial intelligence has a significant compensation effect, which produces a "intelligent dividend" for economic growth.

3 Empirical analysis of the impact of population structure changes on artificial intelligence

According to the 2024 International Federation of Robots (IFR) report, as of the end of 2023, the demand for industrial intelligent robots in many emerging technology industries such as electronics has increased rapidly, and the total number of industrial robots operating in factories around the world reached 4.2816 million, an increase of 10% year-on-year. Moreover, the annual installation volume of industrial robots has exceeded 500,000 units for the third consecutive year, with a total volume of 541,000 units in 2023. From a country perspective, Asian countries such as China, Japan, and South Korea are still the main markets for industrial intelligent robots. In 2023, the accumulated inventory of industrial intelligent robots of the APEC will account for more than 70% of the global

Table 1: Descriptive statistics table of cross-border data

Variable	Standard Deviation	Mean	Minimum value	Maximum value
Robot stock density (RSD)	2.0959	1.3410	0	10.2920
Population growth rate (PGR)	0.5645	0.8458	-0.2090	2.4534
Potential support ratio (PSR)	0.0047	0.0229	0.0146	0.0371
GDP growth rate (GDP)	2.4004	3.8257	-1.9727	14.5256
Openness (OPEN)	85.2264	96.1416	26.3142	379.0986
Investment rate (FDI)	3.4187	2.7792	-1.2442	18.8977
Life expectancy (EOL)	4.3225	77.6332	68.8412	84.3563
The proportion of added value of manufacturing (MVA)	7.0893	18.2724	5.6444	32.0648
R&D expenditure proportion (RDE)	1.1696	1.6686	0.0833	4.8101
Crude birth rate (CBR)	22.5589	7.2892	12.5953	21.1388

total. Therefore, this article selects the major developing countries in the APEC as the research object.

3.1 Data source and variable structure

This article mainly focuses on the impact of the two backgrounds of population growth rate and population aging on the development and application of artificial intelligence. On this basis, it further analyzes whether there is heterogeneity in artificial intelligence due to population growth rate and population aging. This part empirically selects data from different databases. The data on robot stocks comes from the data on robot stocks of 13 major member states in the APEC from 2014 to 2023 released by the IFR in 2024. Data on total population, dependency ratio, life expectancy at birth, investment rate, openness, the proportion of manufacturing growth value in GDP, the number of people aged 15-64, the number of people aged 65 and above, labor market size, employment rate (Employment Rate), GDP (USD), crude birth rate (lagged 15-50 years), medical personnel/per thousand people (lagged 1) and other data are all from the World Bank database, and data for the year corresponding to the IFR data are selected. This paper selects "population growth rate (lagging phase)" as the instrumental variable in Model 1 (the impact of population growth rate on artificial intelligence) and Model 3 (the impact of artificial intelligence on the economy in the context of slowing population growth rate); the crude birth rate (lagging 15-50 years) is selected as the instrumental variable in Model 2 (the impact of aging on artificial intelligence) and Model 4 (the impact of artificial intelligence on the economy in the context of intensifying aging). A small amount of missing data is filled with linear interpolation method. The descriptive statistical results of the main variables (transnational data) are shown in Table 1.

3.2 Model setting of the impact effect of population structure changes on artificial intelligence

This paper uses the linear regression of the Ordinary Least Squares (OLS), fixed effect and two-stage least squares method (2SLS) models to verify the impact of population growth rate and population aging on artificial intelligence.The benchmark regression model is:

$$\mathrm{RSD_{it}} = \beta 0 + \beta 1 * \mathrm{PGR_{it}} + \ell \mathrm{X_{it}} + \Phi_\mathrm{i} + \lambda_\mathrm{t} + \varepsilon_\mathrm{it} \quad (1)$$

$$\mathrm{RSD_{it}} = \beta 0 + \beta 1 * \mathrm{PSR_{it}} + \ell \mathrm{C_{it}} + \Phi_\mathrm{i} + \lambda_\mathrm{t} + \varepsilon_\mathrm{it} \quad (2)$$

Model 1 is used to test the effect of artificial intelligence on population growth rate. Model 2 is used to test the effect of aging on artificial intelligence. Among them, RSDit is the robot stock density per thousand people in i country in t year, PGRit is the population growth rate of i country in t year, and PSRit is the potential support ratio of i country in t year (the potential support ratio is defined as: the number of people aged 15 to 64 divided by the number of elderly people aged 65 and above, which is the reciprocal of the "dependence ratio of elderly population". The lower this indicator, the higher the aging level of the country in which the country is located), Xit includes a series of control variables including openness, investment rate, life expectancy and the proportion of R&D investment in the lagging phase of R&D investment in GDP. Cit includes a series of control variables such as openness, investment rate, manufacturing added value to GDP, and the proportion of R&D expenditure in the lagging phase of R&D expenditure in the lagging phase of GDP. Φi and λt are fixed effects at the national level and year level respectively.

3.3 The regression results of population structure changes on artificial intelligence

3.3.1 OLS and IV regression results of population growth rate on artificial intelligence. Table 2 shows the OLS estimates of the population growth rate per 1,000 people employed in robot stock density. It can be seen from benchmark regression model 1.1 that the correlation between population structure and robot stock density per thousand people employed is statistically significant. Based on Model 1.2, fixed effects are appropriately added to Model 1.1, and further added control variable openness, investment rate, life expectancy, and proportion of R&D expenditures that are lagging behind in Model 1.3. Comparing the R2 amplitude value of model 1.1-1.3, it can be seen that after the fixed effect is added, the accuracy of the results is further improved. Model 1.1 to Model 1.3 is estimated using the general least squares method. The data from Model 1.3 shows that when the population growth rate increases by 1%, the robot stock density will decrease by 0.215%.

Table 3 shows the IV estimation results. Model 1.4-1.6 is the result of the two-stage least squares method (2SLS) of the instrumental variable method. Model 1.6 results show that the population

Table 2: Impact of population growth rate and population aging on artificial intelligence

Impact of population growth rate on artificial intelligence				Impact of population aging on artificial intelligence			
Variable		OLS		Variable		OLS	
	Model1.1	Model1.2	Model1.3		Model2.1	Model2.2	Model2.3
Population growth rate	-0.39***	-0.357***	-0.215**	Potential support ratio	0.186**	-0.416**	-0.456***
	(-4.80)	(-4.28)	(-2.48)		-2.14	(-2.44)	(-3.35)
Openness			-0.778***	Openness			-1.306***
			(-3.01)				(-5.84)
Investment rate			-0.02	Investment rate			0.033
			(-0.30)				-0.53
Life expectancy			-0.241	The proportion of GDP of			0.836***
			-0.76	manufacturing added value			-3.74
R&D expenditure			0.887***	R&D expenditure			1.102***
GDP share			-4.7	GDP share			-6.45
Constant terms	0	-0.127	-0.889***	Constant terms	0	-0.872***	-0.727**
	(-0.00)	(-0.70)	(-2.83)		(-0.00)	(-5.16)	(-2.19)
obs	130	130	130	obs	130	130	130
R-squared	0.152	0.913	0.938	R-squared	0.035	0.903	0.948
F-test	23.007	50.801	59.819	F-test	4.586	45.302	72.732
Prob > F	0	0	0	Prob > F	0.034	0	0
Individual fixed effect	No	Yes	Yes	Individual fixed effect	No	Yes	Yes
Year fixed effect	No	Yes	Yes	Year fixed effect	No	Yes	Yes

growth rate will increase by 1%, and the robot stock density ratio will decrease by 0.677%. This also means that both IV estimates and OLS estimates show that the density of robot stocks is significantly negatively affected by the population growth rate. In other words, countries with a higher population growth rate will need fewer industrial intelligent robots, while countries with a lower population growth rate will need more robot applications.

3.3.2 The results of OLS and IV regression of artificial intelligence by aging. Table 2 shows the OLS estimates of robot stock density per 1,000 people employed in the OLS. Model 2.1 is the simplest monolithic linear regression, which shows that the correlation between population aging and the density of robot stocks per 1,000 people employed is statistically significant. Model 2.2, based on Model 2.1, appropriately adds fixed effects, and Model 2.3, adds control variable openness, investment rate, manufacturing added value in GDP, and the proportion of R&D lag in phase 1. In addition, Table 2 shows that R2 has been greatly improved by adding a fixed effect data model. The results of Model 2.3 indicate that the potential support ratio will increase by 1%, and the robot stock ratio will decrease by 0.456%.

Table 3 shows the IV estimation results. Model 2.4-2.6 is the estimation result of the instrumental variable method two-stage least squares method (2SLS). Model 2.6 results show that for every 1 percentage point increase in the potential support ratio, the robot stock ratio will drop by 1.225%. Both the OLS model and the 2SLS model indicate that there is a significant positive correlation between the degree of aging and the stock of robots. This result also explains that countries with a high degree of population aging require a large number of industrial intelligent robots, while countries with a low degree of population aging require a relatively small number of robots.

3.3.3 The effect of population growth rate and aging on the heterogeneity of artificial intelligence. Comparing the empirical results in the table above, we can draw the following conclusions: the population growth rate increases by 1%, and the density of the artificial intelligence stock decreases by 0.215% to 0.677%; for every percentage point increase in the potential support ratio, the density of the artificial intelligence stock decreases by 0.456% to 1.225%. This shows that compared with the population growth rate, the impact of population aging on artificial intelligence is more significant.

To sum up, the population growth rate is significantly negatively correlated with the development of artificial intelligence, while aging is significantly positively correlated with the development of artificial intelligence, which verifies Hypothesis 1. At the same time, the empirical results also show that compared with the decline in population growth rate, the national conditions of deepening aging have more significant impacts and demands on artificial intelligence, which verified Hypothesis 2.

4 Empirical analysis of the impact of artificial intelligence on economic growth

As mentioned earlier, the problem of aging intensified aging during the change of population structure has a more profound impact on the development of artificial intelligence. So can the development of artificial intelligence effectively alleviate the problem of aging aging, compensate for the adverse impact of the decline of demographic dividend on the weakening of the driving effect of economic growth, and ultimately generate a "smart dividend". The regression equation is:

$$\begin{aligned} \mathrm{PRGDP_{it}} &= \beta_0 + \beta_1 \times \mathrm{RSD_{it}} + \beta_2 \times \mathrm{PSR_{it}} + \beta_3 \times \mathrm{RSD_{it}} \times \mathrm{PSR} \\ &+ \gamma \mathrm{X_{it}} + \delta_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{it}} \end{aligned} \quad (3)$$

Table 3: Solutions to the endogenous problems of the impact of population growth rate and population aging on artificial intelligence

Impact of population growth rate on artificial intelligence				Impact of population aging on artificial intelligence			
One-stage regression				One-stage regression			
IV		0.509***		IV		0.439***	
		-7.18				-4.69	
R-squared		0.9208		R-squared		0.9606	
Prob > F		0		Prob > F		0	
Individual fixed effect		Yes		Individual fixed effect		Yes	
Year fixed effect		Yes		Year fixed effect		No	
Two-stage regression				Two-stage regression			
Variable	Model1.4	Model1.5	Model1.6	Variable	Model2.4	Model2.5	Model2.6
Population growth rate	-0.391***	-0.675***	-0.677***	Potential support ratio	-21.146	-2.479***	-1.225***
	(-4.53)	(-4.13)	(-4.78)		(-0.18)	(-4.94)	(-5.35)
Openness			-0.054	Openness			-0.878***
			(-0.16)				(-3.72)
Investment rate			-0.124	Investment rate			-0.009
			(-1.63)				(-0.15)
Life expectancy			0.002	The proportion of GDP of manufacturing added			0.573***
			-0.01				-2.66
R&D expenditure GDP share			0.916***	R&D expenditure GDP share			1.239***
			-4.82				-7.5
Constant terms	0	0.338	-0.042	Constant terms	0	-2.08***	-1.296***
	(-0.00)	-1.39	(-0.10)		(-0.00)	(-5.55)	(-3.78)
obs	130	130	130	obs	130	130	130
R-squared	0.152	0.901	0.921	R-squared	0	0.755	0.929
Chi-square	20.511	1197.274	1549.472	Chi-square	0.033	482.097	1719.983
Prob > chi2	0	0	0	Prob > chi2	0.855	0	0
Individual fixed effect	No	Yes	Yes	Individual fixed effect	No	Yes	Yes
Year fixed effect	No	Yes	Yes	Year fixed effect	No	No	No

Among them, PRGDPit is the GDP growth rate of country i in t year. RSDit is the robot stock density per thousand people employed in the country in t year, PSRit is the potential support ratio of countries in t year, Xit is the proportion of added value GDP of manufacturing, and δi and λt are fixed effects at the national level and year level, respectively.

4.1 The regression results of artificial intelligence on economic growth

From the results of Table 4, we can see that in the context of intensifying aging, every percentage increase in the stock density of robots drives the GDP growth rate to rise by 2.515% to 2.755%, showing a positive correlation. In other words, the development and application of artificial intelligence have better compensated for the slowdown in economic growth due to the decline of demographic dividends, forming a "smart dividend" that continues to promote economic growth and produces a significant compensation effect. Assumption 3 is proved.

5 Conclusions and suggestions

This paper uses the industrial robot stock density of APEC countries, combines the robot data released by IFR and uses the tool variable method to test the mutual compensatory effect of labor structure changes and artificial intelligence development. The intensified aging and the decline in population growth rate have promoted the development of artificial intelligence. At the same time, the development of artificial intelligence has compensated for the slowdown in economic growth caused by the decline of the demographic dividend. At present, the government should increase its efforts to support the development of artificial intelligence-related industries, stimulate the "smart dividend" brought by technological progress, and bring significant positive effects to the economic growth of developing countries.

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Table 4: Compensation effect of artificial intelligence on economic growth

Variable	OLS	2SLS
Robot stock density	2.515**	2.755***
(number of employment per thousand)	-2.31	-2.72
Potential support ratio	0.326	-0.208
	-1.24	(-0.42)
Interaction items	-2.731**	-3.023***
	(-2.62)	(-3.09)
The proportion of GDP	0.669*	0.522
of manufacturing added value	-1.8	-1.45
Constant terms	1.556**	1.004
	-2.32	-1.32
obs	130	130
R-squared	0.792	0.783
F-test	15.811	473.566
Prob > F	0	0
Individual fixed effect	Yes	Yes
Year fixed effect	Yes	Yes

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