The convergence of population aging: Evidence from OECD countries

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Abstract. This study applied the convergence framework to probe the trend in population aging in 38 OECD countries from 1990 to 2020. Also, several social-economic variables were collected as the control factors of population aging convergence. Our results showed that the EPR (share of 65 years and over) gap between OECD countries has narrowed throughout the study period based on sigma-convergence analysis. Further, absolute beta-convergence is revealed, which indicates that the countries with lower levels of EPR have the potential to accelerate the growth compared with those with higher levels of EPR. Moreover, the control variables such as share of health expenditure, disposable income, life expectancy, population size, and education factors can lead to the increase of EPR. Conversely, the increase in the total fertility rate could decrease the EPR.

Keywords: Population aging; convergence, spatial panel analysis, OECD.

1 Introduction

Population aging has emerged as one of the world's most evident demographic challenges, and the elderly population is increasing, making up a growing share of the total population[1]. It is especially evident in developed countries where the age distributions moved from young to old as a result of birth rate and longer life expectancy[2]. The sharp increase in the elderly population has raised intense concerns about the sustainability of social-economic development[3]. In specific, the rapid increase in population aging poses severe challenges for social-economic situations, e.g., health care[4], pension systems[5], and economic growth[6]. For instance, in Europe and Latin American countries with high population aging levels, fiscal pressure is growing incrementally on public transfer systems[7]. The unprecedented increase in the share of the elderly population has aroused widespread concern to ensure sustainable social-economic development, and policy responses in a coming aging society are becoming the central topic of demographic debate[8].

Accordingly, a clear and accurate knowledge of the spatial and temporal change characteristics of population aging is critical to reducing regional life quality dispro-

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portions. A convergence framework was thusly developed to investigate the evolution of biological, social, and economic phenomena. So far, such a framework has been applied to aging population studies to investigate how relative aging differences have evolved. For instance, a prior study examined regional variations in population aging across European countries from 2003 to 2012, and the beta-convergence and its influencing factors were identified; regions that were less aged experience more active population aging than the regions that were initially more aged[9].

Thus, this paper distinguished from previous studies and applied the sigma- and beta- convergence framework to probe the increasing similarity or difference in population aging in 38 OECD countries over time. We performed a convergence–divergence test to analyze how national differences in population aging indicators have changed.

2 Data and methods

2.1 Indicators

2.1.1 Population aging indicator.

The elderly population is defined as people aged 65 and over based on OECD countries' current chronological-age structure criterion[10]. Previous studies have widely applied this indicator[1, 3, 11]. Therefore, the elderly population rate (EPR), i.e., the percentage of the population aged 65 and above, was used as the core indicator to reflect the population aging degree of each country (Table 1).

Table 1. Descriptive statistics of the Variables in the convergence model

	Influential factor	Variable	Abbreviation	Unit	Min	Max	Mean	S.D.
Dependent variables		Elderly population rate	EPR	%	4.160	28.397	14.239	4.266
	Economic development	Per capita Gross domestic product	GDPpc	US dollar	1445.329	118823.600	28526.800	21085.260
	Healthcare	Share of health expenditure (to total GDP)	SHE	%	2.446	16.844	8.100	2.044
Control variables	Social development	Disposable income	DI	US dollar	8339.725	65425.650	28771.550	10818.640
	Social development	Life expectancy at birth	LEB	year	64.256	84.356	77.611	3.645

	Demo-graphic factor	Population size	PS	Thousand	281.200	332639.100	33927.990	55197.360
	Demo-graphic factor	Total fertility rate	TFR	‰	0.920	3.110	1.684	0.366
Control variables	Education	Population with tertiary education	PTE	%	5.597	69.852	34.493	12.953
	Demo-graphic factor	Mortality rate (standardized)	MR	Deaths per 100 thousand	556.300	1543.200	893.048	196.295

2.2 Methodology

2.2.1 Sigma-convergence.

Sigma-convergence can be identified when the dispersion of the variable (σ), e.g., calculated as standard deviation or the coefficient of variation, reduces from t to t+T. This can be measured for two years or trend regression over several years[12]. We consider both the CV and standard deviation of the logarithm (SDlog) to explore the sigma-convergence characteristics of the elderly population rate.

$$\sigma_{i,t} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_{i,t}-\bar{x}_{i,t}\right)^2}}{\bar{x}_{i,t}} \tag{1}$$

In Eq. (1), i and t refer to the country and year, respectively, and n denotes the total number of countries in OECD. x represents the aging indicators and $\bar{x}$ is the mean value of aging indicators for country i in year t. The coefficient of variation (σi,t) expresses the degree of standard variation of the values compared to the average. The CV is not depend on the indicators' measurement unit and measure order[13]. In contrast, there is a sigma-divergence if this coefficient of variation increases over time[14].

2.2.2 Beta-convergence.

Beta-convergence model means the growth rate of one variable that depends on the initial level[15, 16]. Beta-convergence includes absolute beta-convergence and conditional beta-convergence. The equation of the absolute beta-convergence model is as follows:

$$\ln\left(\frac{x_{i,t+1}}{x_{i,t}}\right) = \mathrm{a} + \beta \ln x_{i,t} + \varepsilon_{i,t} \tag{2}$$

In Eq. (2), ln(xi,t+1/xi,t) is the annual growth rate of the elderly population rate; a is the constant; β denotes the coefficient of lnxi,t; and εi,t represents the error term. When the value of β is significantly negative, this indicates an absolute beta-convergence of the elderly population rate, i.e., the elderly population in the region can reach the equilibrium-state level in the future.

Based on the prior literature, GDPpc, SHE, DI, LEB, PS, MR, TER, and PTE (Table 1) were selected as control variables to estimate the conditional beta-convergence as followings:

$$\ln\left(\frac{x_{i,t+1}}{x_{i,t}}\right) = \mathrm{a} + \beta\ln x_{i,t} + \beta_c b_{i,t} + \varepsilon_{i,t} \tag{3}$$

In Eq. (3), bi, t is the control variable; βc represents the coefficients of control variables; the other variables share the same meanings as in equations (2). The convergence modeling in this study is conducted in Stata 16.

2.2.3 Kernel density estimation.

Kernel density estimation (KDE) mainly applies continuous density curves to describe the random variable distribution. KDE is driven mainly by the data with the advantage of being free of data distribution assumptions[17]. Further, KDE can be used as supplementary materials to measure sigma-convergence over the period[18]. In this study, the variation tendency of EPR is depicted based on KDE, which can be can be modeled as follows[19]:

$$\mathrm{f(x)} = \frac{1}{nh}\sum_{i=1}^{n} k\,\frac{(x_i-\bar{x})}{h} \tag{4}$$

In Eq.(4), n refers to the total number of spatial units(different countries in OECD in this study); xi represents the value of EPR in i th country. h is the bandwidth; k is a kernel density function by using the Epanechnikov kernel estimation method.

3 Results

3.1 Variation of population aging in OECD

Table 2. Descriptive statistics for EPR (%) in OECD countries (Obs.=38)

Year	Min	Max	Mean	Five-year average growth rate (%)
1990	4.160	17.824	11.655	-
1995	4.623	17.508	12.409	1.26
2000	5.151	18.285	13.131	1.14
2005	5.624	19.660	13.884	1.12
2010	6.143	22.498	14.781	1.26
2015	6.725	25.019	15.342	0.75
2020	7.618	29.397	16.008	0.85

Table 2 provides a quick view of the sample statistics of EPR in OECD countries from 1990 to 2020 within a five-year interval. Several key points can be concluded. First, great gaps in EPR can be observed in the OECD countries. Second, the EPR distribution patterns maintained relative stability during the study period through all OECD members experiencing a rapid population aging process. Third, the value of EPR showed a clear increase trend from 1990 to 2010. However, the growth rate of EPR gradually decreased after 2015.

3.2 Sigma-convergence

We first presented the result of sigma-convergence measured by CV and SDlog of annual mean EPR of OECD countries from 1990 to 2020, based on Eq. (1). It showed the CV and SDlog of EPR across OECD countries, which indicated a declining trend in either measure over the period (Fig. 1). Hence, there exists sigma-convergence in EPR of OECD, which means the disparity of different countries of OECD is diminishing gradually. This finding is consistent with Fig 1, demonstrating that the divergence characteristics of EPR of OECD are decreasing and convergence characteristics are increasing year by year. In contrast, the trend of EPR at the global scale presented a significant divergence pattern from 1990 to 2020, measured by CV and SDlog.

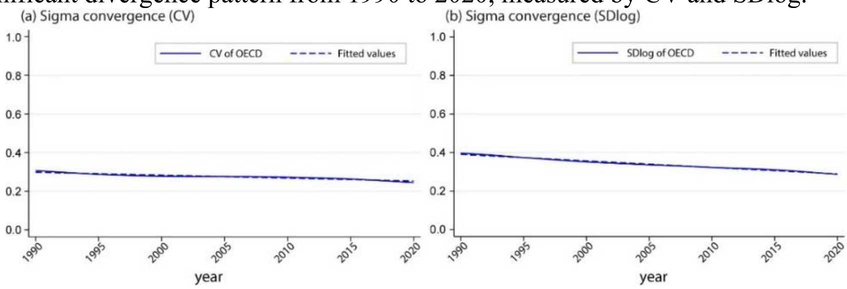

Fig. 1. Sigma-convergence of EPR of OECD countries from 1990 to 2020. (a). Sigma-convergence is indexed by the coefficient of variation (CV). (b). Sigma-convergence is indexed by the standard deviation of the logarithm (SDlog).

3.3 Beta-convergence

3.3.1 Absolute beta-convergence.

Table 3 exhibited the absolute beta-convergence estimates of EPR across OECD countries. The fixed-effect model (FE), Generalized Method of Moments (GMM), and common correlated effect mean group (CCEMG)were applied, respectively. As shown in Table 3, the coefficients in Model 1-3 are all significant and negative, indicating absolute beta-convergence of EPR across OECD countries from 1990 to 2020. In other words, the countries with low EPR showed the trend to catch up with the high EPR countries in the long run, which indicated the regional disparity of EPR across was diminishing.

Table 3. Absolute and conditional beta-convergence of EPR in OECD countries, 1990-2020

Regression approach	Absolute convergence			Conditional convergence	
	Model 1 (FE)	Model 2 (GMM)	Model 3 (CCEMG)	Model 4 (FE)	Model 5 (GMM)
L.EPR	-0.023**	-0.073**	-0.049**	-0.011**	-0.050***
	(-8.300)	(-2.980)	(-2.450)	(0.880)	(-3.610)
Ln (GDPpc)				-0.008	0.006
				(-2.040)	(0.680)
Ln (SHE)				0.003	0.016**
				(0.610)	(2.030)
Ln (DI)				0.015**	-0.019
				(2.370)	(-1.390)
Ln (LEB)				0.157*	0.251**
				(2.060)	(1.920)
Ln (PS)				0.078***	0.003
				(6.340)	(0.280)
Ln (TFR)				-0.016**	-0.049***
				(-2.360)	(-3.370)
Ln (PTE)				0.002	0.016**
				(0.470)	(2.360)
Ln (MR)				-0.001	0.042
				(-0.090)	(1.570)
Convergence rate	0.024	0.076	0.039	0.101	0.510
Observations	1140	1140	1140	1140	1140
AR (1)	-	0.001	-	-	0.002
AR (2)	-	0.220	-	-	0.421
Hansen test	-	0.735	-	-	0.501

Note: [1] Standard errors in parentheses; [2] ***p<0.01, **p<0.05, *p<0.1.

3.3.2 Conditional beta-convergence.

Table 3 exhibits the conditional beta-convergence estimates of EPR across OECD countries. The fixed-effect model (FE) and generalized Method of Moments (GMM) were applied. A conditional beta-convergence model was constructed by introducing several control factors.

In Model 4 (FE), the results indicated that coefficient β is significantly negative when several control factors are added to the model, demonstrating that the convergence mechanism of EPR across OECD countries still exists. As for as convergence rate, the conditional beta-convergence in Model 4 (FE) was remarkably higher than the absolute beta-convergences in Model 1-3. This indicated that control variables can accelerate the convergence rate of EPR to equilibrium states. In Model 4 (FE), the coefficient of DI was significant and positive, indicating that disposable income drives the elderly population growth. The same was true for the coefficient of LEB and PS, indicating that the growth-stimulating effects of the elderly population rate are derived from an increase in life expectancy at birth and population size. On the contrary, the coefficient of TFR was significantly negative, indicating that the higher TER, the higher the convergence speed to the equilibrium level, and it was conducive to decreasing the elderly population rate.

In Model 5 (GMM), the results have suggested that coefficient β is still significantly negative when several control factors are added into the model, demonstrating that the convergence mechanism of EPR in OECD still exists. As for as convergence rate, the conditional beta-convergence in Model 5 (GMM) was remarkably higher than the absolute beta-convergences in Model 1-3. This indicated that control variables can accelerate the convergence rate of EPR to equilibrium states. In Model 5 (FE), the coefficient of SHE was significant and positive, indicating that the share of health expenditure drives the growth of the elderly population. The same was true for LEB and PTE coefficients, indicating that the increase in LEB and the population with tertiary education can increase the elderly population rate. In addition, the coefficient of TFR in Model 5 (GMM) was consistent with the result of Model 4 (FE), demonstrating that the increase in total fertility rate was negative for aging to converge to an equilibrium level.

4 Conclusions

1)Convergence followed the estimated kernel densities, which gradually show a single peak trend and normal-like distribution of EPR during the study period.

2) Compared with countries with higher EPR levels in OECD countries, countries with lower EPR levels have the potential to accelerate growth.

3) Variables such as health expenditure, disposable income, life expectancy, population size, and education level can increase the EPR. On the contrary, the increase in the total fertility rate will reduce the EPR of OECD countries and further balance the aging population.

Citing Related Work

This section cites a variety of journal [2,4,5,6,7,8,9,10,12,13,14,15,16,18,19], and magazine [1,3,11,17].

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