Empirical Study on Inter-Provincial Differences in the Security Level of China's Pension System for Urban Employees—Based on Cross-Section Data

Chun Wan*[1], Junwei Xia[1], Li Xu[2]

E-mail addresses: wangchungpine@sina.com (C. Wan), 664329604@qq.com (J. Xia), xuli0088686@126.com (L. Xu)

Economy School, Jiangxi University of Finance and Economics, No.168, East Shuanggang Road, Nanchang, Jiangxi Province, PR. China 330013[1]
School of Finance, Jiangxi Normal University, No. 99, Ziyang Avenue, Nanchang, Jiangxi Province, PR. China 330022[2]

Abstract. Promoting the national pooling of the Pension System for Urban Employees (PSUE) is an important strategy for China to cope with population aging, but the problem of inter-provincial differences has become an obstacle. This paper selects 3 primary indexes and 10 secondary indexes to construct an evaluation system of the security level of the PSUE, and empirically analyses the inter-provincial differences based on China's cross-section data of 31 provinces in 2021, using the principal component analysis method. The conclusions include: in terms of overall differences, the security level of the PSUE is diminishing from the east to the west; in terms of structural differences, economic factors, pension fund sustainability, and demographic factors affect the security level of the PSUE with the weights of 37.717%, 29.335%, and 24.348% respectively.

Keywords: Inter-provincial differences, security level, the Pension System for Urban Employees, the principal component analysis method

1 Introduction

Since the birth rate is falling and the old-age dependency ratio is rising, China is facing heavier provision pressure on old-age security. According to the data released by the China National Bureau of Statistics (CNBS), from 2000-2022, China's old-age dependency ratio continued to rise from 9.9% to 21.8%. At the end of 2022, the population over the age of 60 reached 280 million, accounting for 19.8 % of the total. Gaps in many aspects of provinces (which exactly include provinces, autonomous regions, and municipalities directly under the central government), such as labor force migration, economic growth, and demographic structure, are significant (Zhou and Jiang, 2021) [1]. All these expand inter-provincial differences in the security level of the Pension System for Urban Employees (PSUE), which is one of the most important components of China's pension systems. Undoubtedly, the differences will increase the difficulty of solving the problem of population aging.

Some studies focus on pension system differences in regions and sectors. Firstly, because of the regional diversity of economic development, many laborers migrate from the western to

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the eastern provinces to seek more employment opportunities (Galor, 1986) [2]. Then the proportion of the elderly population is not the same between the provinces that laborers migrate in and out, causing differentiated pressure on old-age financial support (Casarico and Devillanova, 2008) [3], and highlighting the imbalance of the pension payment burden. Secondly, retirees in the public sector, compared with those in the non-public sector, enjoy pension advantages, which come from the fact that public sector retirees have invested more human and political capital (Wang, *etc*., 2023) [4]. Additionally, provincial differences in average social wage level also have huge impacts on the contribution of pension funds (Gao and Xue, 2019) [5], not only exacerbates the disparity in the operating efficiency of pension funds(Zhu and Wei, 2019) [6] but also is not conducive to the long-term stable running of pension systems and influences household consumption structure(Wang, *etc*., 2023)[7].

In many countries, the heterogeneity of pension systems is prominent. Though the institutional design of a pension system is similar for everyone, due to the dispersion of the reference wage for all retirees, gender inequalities in pensions exist (Bonnet, *etc*., 2018) [8]. In the United States, interstate population migration produces an impact, which is closely related to the state population density and causes obvious interstate differences, on the implementation of the state pension system reform (Hoang, 2022) [9]. As for Spain, the social security reserve fund is important for the sustainability of the public pension system (Gómez-Déniz, *etc*., 2022) [10].

Summarily, there is a rich literature on pension system differences. Many of them focus mainly on the differences caused by the idiosyncrasy of some single factor. By adopting the principal component analysis method to explore the security level of the PSUE, the possible contributions of this paper include: choosing 10 secondary indexes corresponding to 3 primary indexes, and constructing an index system of the security level of the PSUE to evaluate inter-provincial differences; based on China's cross-section data of 31 provinces in 2021, assessing the security level of the PSUE, and by composite score ranking, explaining the inter-provincial differences in the PSUE to provide valuable references for the national pooling reform of the PSUE.

2 Research design

2.1 The method of analysis

When we evaluate the comprehensive effectiveness of a system, using too many indexes tends to make the analytical process cumbersome, and it is difficult to define the weight of each index. Therefore, this paper adopts the principal component analysis method, by dimensionality reduction, with the loss of little information, and compresses numerous indexes into fewer simplified comprehensive indexes that can reflect the most important characteristics of the original data. Based on these fewer indexes, analyses can be carried out sequentially.

Eigenvalues and eigenvectors. Denote the j original indexes by vector $X = (X_1, X_2, \cdots, X_j)$. Due to the different units of these original indexes, the principal component analysis method may cause large errors by using the covariance matrix. To solve this issue, we can adopt the correlation coefficient matrix. Denote the correlation coefficient of X_s and X_m by ρ_{sm}, and $s, m = 1 \cdots, j$ repectively. From the original data of a given sample, we can calculate the correlation coefficient matrix $\begin{bmatrix} 1 & \rho_{12} & \cdots & \rho_{1j} \\ \rho_{21} & 1 & \cdots & \rho_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{j1} & \rho_{j2} & \cdots & 1 \end{bmatrix}$, and then get its eigenvalues $\lambda = (\lambda_1,\ \lambda_2,\ \cdots,\ \lambda_j)$ and the corresponding standardized orthogonal eigenvectors $\alpha = (\alpha_1,\ \alpha_2,\ \cdots,\ \alpha_j)$. And also, denote $Z = (Z_1,\ Z_2,\ \cdots,\ Z_j)$ as the result of a dimensionless process (e.g., standardization) of the original indexes X. That is, let $XMI = X - X_{min}$ and $XRA = X_{max} - X_{min}$, X_{min} is the minimum of X, X_{max} is the maximum of X, then Z equals the quotient of XMI divided by XRA. Taking α_{ki} to represent the value of the element in row i of the kth standardized orthogonal eigenvector, the kth principal component F_k can be expressed as:

$$F_k = \alpha_k' \cdot Z = \alpha_{k1}Z_1 + \alpha_{k2}Z_2 + \cdots + \alpha_{kj}Z_j = \sum_{i=1}^{j} \alpha_{ki}Z_i \quad 1 \le k \le j; i = 1, \cdots, j \qquad (1)$$

Where α_k' is the transpose of α_k.

Factor loadings. From Equation (1), it is necessary to determine the value of the coefficient α_{ki} of the index Z_i when we calculate the principal component F_k. The correlation coefficient $\rho(F_k,\ Z_i)$ of F_k and Z_i, also known as the factor loadings, will be:

$$\rho(F_k,\ Z_i) = \sqrt{\frac{\lambda_k}{\sigma_{ii}}}\alpha_{ki} = \sqrt{\lambda_k}\alpha_{ki} \qquad (2)$$

In Equation (2), λ_k represents the kth eigenvalue and σ_{ii} is the main diagonal element of the correlation coefficient matrix. Since these main diagonal elements are all 1, Equation (2) can be simplified as $\sqrt{\lambda_k}\alpha_{ki}$.

Principal components. Dividing the factor loadings in Equation (2) by $\sqrt{\lambda_k}$, we can get α_{ki}. Then substituting it into Equation (1), the corresponding principal component F_k can be measured.

Contribution rates of the principal components. After rotational transformation and dimensionality reduction, the j original indexes will be compressed into fewer principal components, each with a different contribution rate. For the selected principal components, the larger the contribution rate of a single principal component and the cumulative contribution rate of several principal components, the more information of original data is retained. The contribution rate θ_k of the kth principal component and the cumulative contribution rate β_p of the first p principal components (ordered from the largest to the smallest contribution rate) can be written respectively:

$$\theta_k = \frac{\lambda_k}{\sum_{i=1}^{j}\lambda_i} \qquad 1 \le k \le j \qquad (3)$$

$$\beta_p = \frac{\sum_{k=1}^{p}\lambda_k}{\sum_{k=1}^{j}\lambda_k} = \sum_{k=1}^{p}\theta_k \qquad (4)$$

Generally, according to the principle that the cumulative contribution rate is greater than 80%, we can select the first q principal components, and the information of the original data can be well kept.

Composite score. Substituting the standardized data into Equation (1), we can compute the principal component score F_k, then multiply Y by its corresponding variance contribution rate weight θ_k, and sum up the product to get the composite score *F*:

$$F = \frac{\sum_{k=1}^{p} \theta_k F_k}{\sum_{k=1}^{p} \theta_k} = \frac{(\theta_1 F_1 + \theta_2 F_2 + \ldots + \theta_p F_p)}{\sum_{k=1}^{p} \theta_k} \quad (5)$$

By Equation (5), we can construct the index of security level of the PSUE, and measure and rank the composite score of each province to visualize the inter-provincial differences.

2.2 Index design

To construct a system of evaluation indexes for the security level of the PSUE, this paper selects 3 primary indexes of demographic factors, pension fund sustainability, and economic factors, as well as expands to 10 secondary indexes, as shown in Table 1.

Table 1. Indexes for evaluating the security level of the PSUE

Primary index	Secondary index	Symbol	Interpretation of index	Unit
Demographic factors	Elderly population dependency ratio	X_1	Elderly population/labor force	%
	Percentage of elderly population	X_2	Population aged 65 and over/total population	%
	Total population	X_3	Overall population	10,000 persons
Pension fund sustainability	Percentage of the insured	X_4	Number of employees insured/ number of employees should be insured	%
	Pension fund income	X_5	Contributions to the pension fund	100 million RMB
	Pension fund expenditure	X_6	Pension paid by the pension fund	100 million RMB
	Cumulative pension fund balance	X_7	Cumulative balance of income over expenditure of the pension fund	100 million RMB
Economic factors	Disposable income per capita	X_8	Income available for final consumption expenditure and savings per employee	10,000 RMB
	Consumption per capita	X_9	Consumption expenditure per person	10,000 RMB
	GDP per capita	X_{10}	GDP/total population	10,000 RMB

2.3 Data sources

This paper uses China's cross-section data of 31 provinces in 2021 for analysis. The data on the indexes of total population X_3, disposable income per capita X_8, consumption per capita X_9, and GDP per capita X_{10} are obtained from the *2022 China Statistical Yearbook* and the *Statistical Yearbook* of each province; the data on the indexes of elderly population dependency ratio X_1, pension fund income X_5, pension fund expenditure X_6, and cumulative pension fund balance X_7 are obtained from the *Statistical Bulletin on the Development of Human Resources and Social Security* and *Social Insurance Disclosure* of each province in

2021. Other indexes are calculated by the authors based on the data from the aforementioned yearbooks and bulletins.

3 Empirical analysis

3.1 Feasibility test

It is firstly necessary to make the KMO (Kaiser Meyer Olkin) test and BS (Bartlett Sphericity) test. From Table 2, the KMO value = 0.642 is greater than the acceptable minimum of 0.5, and the p-value of the BS test is significant at the 1% level. So, the selected indexes are suitable for principal component analysis. Using statistical software SPSS27, the following can be done.

Table 2. Results of KMO and BS test

Test type	Meaning	Value
KMO test	The measure of sampling adequacy	0.642
BS test	Approximate chi-square	515.316
	Degrees of freedom	45
	Significance	＜0.01

Source: Authors' calculations.

3.2 Total variance explanation

There are two main principles for extracting common factors: the eigenvalue is greater than 1, and the cumulative variance contribution rate is greater than 80% with little information loss. By Table 3, the eigenvalues of the first 3 principal components are all greater than 1, explaining 91.4% of the total variance of the original variables. After dimensionality reduction, the first 3 factors still have a strong explanatory power. Rotating factors by the maximum variance method, the cumulative variance contribution rate is still 91.4%. That is, through rotation, each principal component is more explicit and easier to explain, without weakening explanatory ability.

Table 3. Factors' explanation of the total variance of original variables

Principal component	Initial eigenvalue			Extract sums of squared loadings			Rotation sums of squared loadings		
	Total (%)	Percentage of variance (%)	Cumulative percentage (%)	Total (%)	Percentage of variance (%)	Cumulative percentage (%)	Total (%)	Percentage of variance (%)	Cumulative percentage (%)
1	5.213	52.127	52.127	5.213	52.127	52.127	3.772	37.717	37.717
2	2.068	20.681	72.808	2.068	20.681	72.808	2.934	29.335	67.052
3	1.859	18.592	91.400	1.859	18.592	91.400	2.435	24.348	91.400
4	0.435	4.353	95.753						
5	0.223	2.229	97.982						
6	0.127	1.268	99.250						
7	0.054	0.544	99.794						
8	0.013	0.130	99.924						

9	0.005	0.053	99.976
10	0.002	0.024	100.000

Source: Authors' calculations.

3.3 Rotated factor loading matrix and component score coefficient

As shown in the left of Table 4, the factor loading matrix reflects the correlation between each original index and the principal component, and the larger its value, the higher the degree of relevance is. (*I*) X_4, X_8, X_9, *and* X_{10} *have high loadings on the first principal component* F_1. X_4 evaluates the participation rate of the PSUE, while the other 3 indexes measure the provincial economic development level. So, F_1 can be interpreted as "the factor of the economic development level and the participation rate of the PSUE". (*II*) X_3, X_5, X_6, *and* X_7 *have high loadings on the second principal component* F_2. X_3 measures the resident population of each province, while the other 3 indexes reflect the income, expenditure, and accumulated balance of the provincial pension funds. Then, F_2 can be interpreted as "the factor of the total population and pension fund sustainability". (*III*) X_1 *and* X_2 *have high loadings on the third principal component* F_3. X_1 reflects the comparison of the elderly and the working population, which assesses the current old-age security provision pressure, and indicates whether the working population is sufficient or not. X_2 measures the comparison of the elderly and the total population, and reflects the old-age security provision pressure in the long term, as the total population includes minors under working age. Therefore, F_3 can be named "the demographic factor".

By the regression estimation method, component score coefficients can be obtained, as shown in the right of Table 4.

Table 4. Results of rotated factor loading matrix and component score coefficient

Index	Rotated factor loading matrix			Component score coefficient		
	Component 1	Component 2	Component 3	Component 1	Component 2	Component 3
X_8	0.958	0.182	0.078	0.284	-0.050	-0.054
X_9	0.954	0.198	0.107	0.278	-0.045	-0.042
X_{10}	0.939	0.169	0.046	0.282	-0.051	-0.066
X_4	0.771	0.040	0.303	0.223	-0.106	0.078
X_3	-0.160	0.921	0.218	-0.184	0.387	0.032
X_5	0.411	0.876	0.218	0.008	0.297	-0.008
X_7	0.325	0.814	-0.316	0.029	0.329	-0.245
X_6	0.336	0.726	0.511	-0.020	0.217	0.148
X_1	0.096	0.129	0.971	-0.060	-0.044	0.435
X_2	0.213	0.094	0.961	-0.016	-0.073	0.424

Source: Authors' calculations.

3.4 Principal component score and composite score

Substituting the values of component score coefficients, the expressions of the 3 principal components can be written as:

$$F_1 = -0.06X_1 - 0.016X_2 - 0.184X_3 + \cdots + 0.282X_{10} \quad (6)$$
$$F_2 = -0.044X_1 - 0.073X_2 + 0.387X_3 + \cdots - 0.051X_{10} \quad (7)$$

$$F_3 = 0.435X_1 + 0.424X_2 + 0.032X_3 + \cdots - 0.066X_{10} \quad (8)$$

Next, putting the original data of each index into equations (6) through (8), we can calculate the principal component scores, multiply by the corresponding weights which are the variance contribution rates of principal components, and finally add up the products to get the composite score of the security level of the PSUE, seeing Equations (9). Since F_3 "the demographic factor" reflects the burden of population aging and is negatively correlated with the security level of the PSUE, when calculating the composite score F, it is necessary to add a negative sign in front of the principal component F_3. Then:

$$F = [(0.37717F_1 + 0.29336F_2 + (-0.24348F_3)]/\,0.914 \quad (9)$$

The results are shown in Table 5. The principal component scores and composite scores come from the process of standardized indexes. So, scores greater than 0 indicate that they are higher than the national average, and vice versa.

Table 5. Results of principal component scores, composite scores, and rankings

Province	Component F_1		Component F_2		Component F_3		Composite score F	
	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking
Guangdong	0.478	7	3.831	1	-2.248	30	2.026	1
Beijing	3.145	1	-0.045	14	-0.686	23	1.466	2
Shanghai	2.872	2	-0.427	20	0.716	8	0.857	3
Zhejiang	1.263	4	0.719	6	0.101	16	0.725	4
Jiangsu	0.694	5	1.503	2	0.808	7	0.554	5
Fujian	0.676	6	-0.550	22	-0.750	24	0.302	6
Tianjin	1.368	3	-1.253	31	0.521	12	0.024	7
Shandong	-0.446	21	1.252	3	1.003	5	-0.049	8
Ningxia	0.014	10	-1.150	30	-0.999	27	-0.097	9
Hainan	0.084	9	-1.118	29	-0.828	26	-0.104	10
Sichuan	-0.458	22	1.211	4	1.319	2	-0.151	11
Jiangxi	-0.394	18	-0.197	15	-0.261	21	-0.156	12
Hubei	-0.296	17	0.335	8	0.579	11	-0.169	13
Qinghai	-0.270	15	-1.095	28	-1.054	28	-0.182	14
Inner Mongolia	-0.014	11	-0.612	25	-0.056	18	-0.187	15
Henan	-0.923	29	0.800	5	0.458	14	-0.246	16
Shaanxi	-0.265	14	-0.278	18	0.181	15	-0.247	17
Hunan	-0.402	19	0.259	9	0.621	10	-0.248	18
Shanxi	-0.477	23	-0.222	17	-0.024	17	-0.261	19
Anhui	-0.613	24	0.229	10	0.459	13	-0.302	20
Guizhou	-0.776	26	-0.346	19	-0.452	22	-0.311	21
Guangxi	-0.936	30	-0.040	13	-0.156	20	-0.358	22
Hebei	-0.850	27	0.438	7	0.629	9	-0.377	23
Chongqing	0.169	8	-0.555	23	1.178	3	-0.422	24
Liaoning	-0.113	12	-0.012	12	1.745	1	-0.515	25
Gansu	-0.943	31	-0.608	24	-0.129	19	-0.550	26
Heilongjiang	-0.285	16	-0.453	21	1.150	4	-0.569	27
Xinjiang	-0.242	13	-0.219	16	-1.551	29	-0.583	28

Yunnan	-0.915	28	0.030	11	-0.827	25	-0.588	29
Jilin	-0.428	20	-0.647	26	0.880	6	-0.619	30
Tibet	-0.719	25	-0.783	27	-2.329	31	-1.168	31

Source: Authors' calculations.

From Table 5, among the top 10 provinces, except for Ningxia, the remaining 9 provinces belong to the eastern region, namely: Guangdong, Beijing, Shanghai, Zhejiang, Jiangsu, Fujian, Tianjin, Shandong, and Hainan; those ranking 10th-20th include all the provinces in the central region: Jiangxi, Hubei, Henan, Hunan, Shanxi, Anhui, and the remaining 4 in the western region are Sichuan, Qinghai, Inner Mongolia and Shaanxi; Among the last 11, except for Hebei in the eastern region and Heilongjiang, Jilin, and Liaoning in the northeastern region, the remaining 7 provinces belong to the western region.

In terms of overall inter-provincial differences, gaps in the security level of the PSUE are significant. Only 7 provinces are above the average, while the remaining 24 are below the average. The general trend is that the security levels of the PSUE decrease from the eastern to the western region, with a large drop-off. From the composite scores, most provinces with higher security levels of the PSUE are concentrated in the eastern region, and the following are in the central region, while provinces in the western region and the 3 northeastern provinces have lower security levels of the PSUE, seeing Fig. 1.

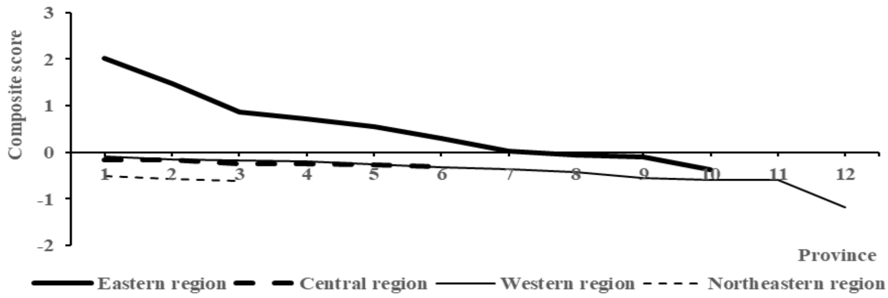

Fig. 1. Provincial composite scores in different regions.

Source: Graphing based on the data in Table 5.

In Fig. 1, provincial composite scores are divided into 4 groups (drawn on 4 lines) from the eastern to the northwestern region. The 10 provinces in the eastern region are in the first group, and their composite scores are between -0.377 and 2.026. The 6 provinces in the central region are in the second group, and their composite scores vary from -0.302 to -0.156. The 13 provinces in the western region are in the third group, and their composite scores, some are close to those of the provinces in the central region, change between -1.168 and -0.097. The 3 provinces in the northwestern region are in the last group, and their composite scores grow from -0.619 to -0.515.

In terms of the structural inter-provincial differences, (*I*) *the provinces with high composite scores also have high scores of the principal component* F_1. For example, Beijing's F-score and F_1-score are both higher, at 1.466 (ranking 2nd) and 3.145 (ranking 1st) respectively. This indicates that in a certain region, a positive relationship exists between the security level of the PSUE and the local economic development level as well as the participation rate of the PSUE.

(*II*) *the security level of the PSUE is also determined by the principal component* F_2. Some provinces, such as Shandong and Sichuan, have lower scores of F_1 at -0.446 (ranking 21st) and -0.458 (ranking 22nd) respectively, but their scores of F_2 are high at 1.252 (ranking 3rd) and 1.211 (ranking 4th), and their composite scores are high at -0.049 (ranking 8th) and -0.151 (ranking 11th). Therefore, the pension fund sustainability affects the security level of the PSUE greatly, i.e. the stronger the pension fund sustainability, the more power security the PSUE will provide. (*III*) *The principal component* F_3, *which measures the provision pressure of the old-age security, is negative with the composite scores*. Liaoning and Jilin, with high F_3 scores at 1.745 (ranking 1st) and 0.88 (ranking 6th), have low composite scores at -0.515 (ranking 25th) and -0.619 (ranking 30th). These provinces are under heavier provision pressure of the old-age security, due to a large proportion of elderly people or a small proportion of young labor force. This is closely related to the background that many workers were laid off and migrated out in the process of reforming China's state-owned enterprises, or the excess labor force in the populous provinces was transferred to other provinces.

3.5 Further discussion

The inter-provincial differences in the security level of the PSUE are the result of the long-term interaction of relevant factors. Choosing Beijing, Jiangxi, Gansu, and Heilongjiang as representative provinces in the eastern, central, western, and northeastern regions, we use three representative indexes of demographic factors, pension fund sustainability, and economic factors: institutional dependency ratio = number of employees ÷ number of retirees in the PSUE, pension fund accumulation per retiree = pension fund accumulation ÷ number of retirees in the PSUE, and GDP per capita, to visualize the inter-provincial differences in the influencing factors, seeing Fig. 2-4.

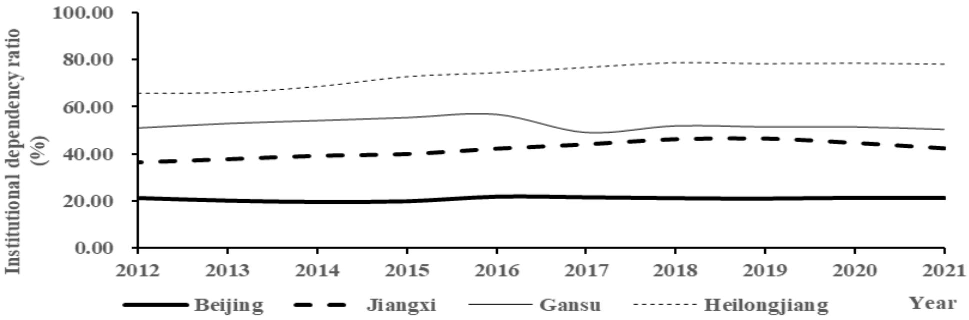

Fig. 2. Trends in institutional dependency ratios (2012-2021).

Source: Authors' calculations based on the data from the *2022 China Statistical Yearbook.*

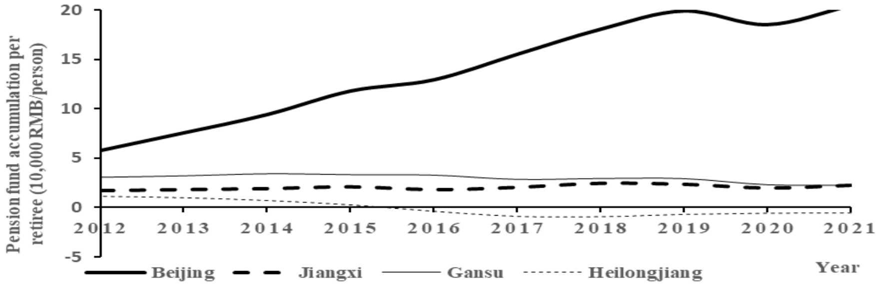

Fig. 3. Trends in the sustainability of pension funds (2012-2021).

Source: Authors' calculations based on the data from the *2022 China Statistical Yearbook*.

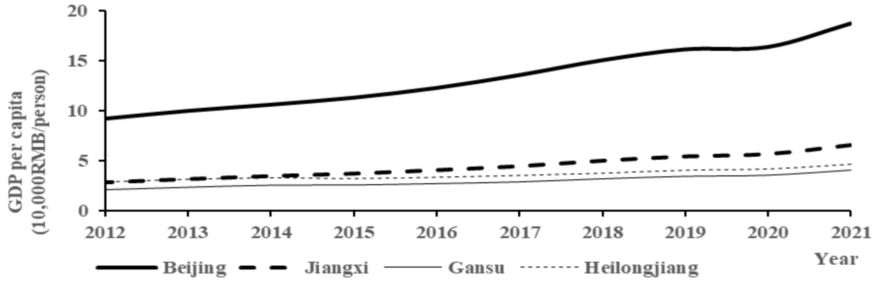

Fig. 4. Trends in GDP per capita (2012-2021).

Source: the *2022 China Statistical Yearbook*.

Fig. 2 to Fig. 4 reflects that both overall and structural inter-provincial differences during 2012-2021 are clear: as for institutional dependency ratio, Beijing (eastern region)<Jiangxi (central region)<Gansu (western region) < Heilongjiang (northeastern region); as for the sustainability of pension funds, Beijing > Gansu > Jiangxi > Heilongjiang, but Jiangxi maintains growing while Gansu does the opposite, to 2021 Jiangxi> Gansu; as for GDP per capita, Beijing > Jiangxi > Heilongjiang > Gansu.

4 Conclusions

From overall inter-provincial differences, the composite scores of the security level of the PSUE in China's 31 provinces show a decreasing trend from the eastern region to the western region, which wholly coincides with the regional economic development level.

From inter-provincial structural differences, the security level of the PSUE is related to a variety of factors. The first is economic factors. According to the previous calculation, the variance contribution rate of the principal component F_1 is 37.717%, indicating that the imbalance of provincial economic development level is a key factor affecting the inter-provincial differences in the security level of the PSUE. The second is pension fund sustainability. By the rankings of principal component F_2, it can be seen that some provinces realize pension fund surplus with strong sustainability, but most provinces can only maintain the short-term balance, and some provinces even can’t keep the long-term accumulated balance and need fiscal transfers from the central government. The third is demographic factors. Some provinces with high F_3 scores (implying a heavy provision burden of old-age security) have a serious labor outflow. While some provinces attract a large number of laborers by economic advantages. Labor mobility widens the demographic inter-provincial differences, and aggravates the inequality of the provision burden of old-age security.

Promoting the national coordination of the PSUE is an important strategy for China to cope with the aging population, but the problem of inter-provincial differences must be paid attention to and solved. By strengthening policy research and practical exploration, we are expected to find an effective way to solve this problem and contribute more to China’s social security cause. What should be done is to establish a unified transfer and connection mechanism among provincial pension systems, simplify the transfer and connection process, and improve the efficiency and convenience of transfer and connection; improve the return on investment of pension funds by optimizing investment strategies and strengthening investment risk management; create jobs and promote provincial economic development to enhance the employees’ contribution ability to pension systems.

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