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Research on the Development Level of Science and Technology Finance in Anhui Province Based on Principal Component Analysis

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Abstract

The purpose of this paper is to study the development level of science and technology finance in 16 prefecture-level cities in Anhui Province in 2021.Firstly,on the basis of the existing data and previous researches, the evaluation indexsystem of the development level of science and technology finance was constructed. Secondly, the principal component analysis method was used to extract thetwo principal components of innovation and intellectual property index, R&Dinvestment and financial structure index, and the comprehensive score equation was obtained, which comprehensively evaluated the development level of science and technology finance in 16 prefecture-level cities in Anhui Province. Finally, based on the comprehensive scores of each city, the 16 prefecture-level cities were divided into five categories, and it was concluded that the development level of science and technology finance in Hefei and Wuhu was in the leading position in the province, while the development level of science and technology finance in Bozhou, Huainan and Suzhou was relatively backward.

Keywords

The development of science and technology finance;Principal component anal-ysis

1. Introduction

The report of the 20th National Congress of the Communist Party of China included "achieving high-level scientific and technological self-reliance and self-reliance, and entering the forefront of innovative countries" as the overall goal of China's development in 2035. With the continuous expansion of the development scale of high-tech industries, their development is also facing challenges such as shortage of funds, insufficient R&D investment, difficulties in market promotion and great innovation risks. As a form of finance serving scientific and technological innovation, science and technology finance is a powerful driving force to promote the transformation of scientific and technological achievements, which can alleviate difficulties for the development of science and technology enterprises and continuously inject

new financial momentum[1]. As the key role of science and technology finance in promoting scientific and technological innovation and enterprise growth has become increasingly prominent, it has received great attention and extensive attention at the national strategic level. In October 2023, the Central Financial Work Conference listed science and technology finance as the first of the "five major articles", which not only reflects the great importance that the central government attaches to science and technology, but also gives financial services a historical mission of scientific and technological innovation[2]. In January 2024, the State Administration of Financial Supervision (SAFS) issued a notice on strengthening financial services for the whole life cycle of technology-based enterprises, further pointing out the development direction of technology-based finance[3].

As one of the important economic sectors in China, Anhui Province is located in the central region of China, with the geographical advantage of connecting the east and the west, which is of great significance for promoting the coordinated development of the region and realizing the national economic growth. Under the background of China's implementation of the innovation-driven development strategy and the development strategy of the Yangtze River Economic Belt, it is of great significance to study the development level of science and technology finance in Anhui Province to promote the transformation and upgrading of the regional economy and improve the ability of financial services for the real economy.

The research on science and technology finance at home and abroad mainly focuses on two aspects: the measurement of science and technology finance and the research on the influencing factors of science and technology finance. Regarding the measurement of science and technology finance, most scholars construct the index system through different ideas, and then use DEA models to measure the efficiency of science and technology finance or comprehensive evaluation methods to measure the development level of science and technology finance. Cao Hao, You Jianxin (2011) et al. divided the science and technology finance development index into four aspects, namely science and technology financial resources index, science and technology finance expenditure index, science and technology finance output index and science and technology finance loan index according to the idea of "science and technology resources-capital input-output efficiency"[4]. Liu Wenli et al. (2014) borrowed from Cao Hao's ideas, used the index synthesis method to construct an evaluation system of science and technology finance, and analyzed the impact trend of science and technology finance development on regional economic development in 21 provinces, municipalities and autonomous regions in China in the past 13 years[5]. Li Huamin, Liu Fenhua et al. (2015) further combined the differences in industry capital demand and financing channels, as well as the capital demand patterns of enterprises at different stages of development to construct an index system[6]. Wang Haiyun (2019) also emphasized the importance of environmental factors and incorporated the fintech environment into the indicator system[7].

Wang Chenpeng (2022) further subdivided the investment of science and technology finance resources, and used the entropy method to evaluate the development level and trend of science and technology finance in 11 eastern provinces and cities[8]. Fang et al. (2022) emphasized the importance of the service environment, further incorporated the science and technology service environment into the index system, and constructed a symbiosis model to measure the ecological security of China's science and technology finance[9]. Regarding the research on the influencing factors of technology and finance, Chu Xiwei et al. (2024) used the multi-time difference difference method to deeply analyze the impact of science and technology finance policies on the rise of the global value chain of digital enterprises based on the pilot policy of combining technology and finance[10]. Tian Xiaojia (2024) analyzed the direct effects and spatial spillover effects between the synergy between scientific and technological innovation and science and technology finance and high-quality economic development in Henan Province on the basis of constructing the synergistic indicators of high-quality economic development, scientific and technological innovation and science and technology finance in Henan Province[11]. However, at present, research on science and technology finance is primarily focused on provinces or large regions across the country. There are relatively few articles that provide a comprehensive evaluation of the development level of science and technology finance in Anhui Province. This paper will utilize the principal component analysis method to evaluate the development level of science and technology finance in 16 prefecture-level cities in Anhui Province and will conduct cluster analysis based on the evaluation results.

2. Data sources and research design

2.1. Construction of evaluation index system

On the basis of drawing on the reasonable index system of the development level of science and technology finance at home and abroad, and following the principles of objectivity, comprehensiveness and operability, and taking into account the regional and economic characteristics of Anhui Province, this paper selects the proportion of R&D personnel equivalent to full-time equivalent, the proportion of the number of R&D activity units in the total population of the region, the proportion of the internal expenditure of R&D funds in the GDP, the proportion of the balance of loans of financial institutions in the GDP, and the proportion of the number of employees in the financial industry in the total population of the region. The proportion of new product sales revenue in the main business income, the number of patent applications granted and the number of registered trademarks owned by enterprises above the designated size are used as indicators to measure the development level of science and technology finance in Anhui Province (see Table 1).

2.2. Data sourcing and preprocessing

In this paper, the data of 16 prefecture-level cities in Anhui Province in 2021 were selected as the research sample, and the data were mainly derived from the China Urban Statistical Yearbook, the Statistical Yearbook of Anhui Province, and the 2021 Statistical Communiqué on National Economic and Social Development. In terms of data preprocessing, due to the large number of science and technology financial indicators and their large differences, it is necessary to standardize the variable data in order to be effective and accurate in the analysis results.

Table 1 Comprehensive evaluation index system of science and technology finance

Sub-indicators	Metrics	unit	symbol
The development level of science and technology finance in Anhui Province	R&D personnel are equivalent to full-time equivalents	person-years	X1
	The number of units with R&D activities accounts for the proportion of the total population of the region	%	X2
	R&D expenditure as a proportion of GDP	%	X3
	The proportion of the outstanding loans of financial institutions in the gross domestic product (GDP).	%	X4
	The number of people employed in the financial sector accounts for the total population of the region	%	X5
	The proportion of new product sales revenue in the main business income of enterprises above the designated size	%	X6
	Number of patent applications granted	item	X7
	The number of registered trademarks	item	X8

2.3. Research Methods

In this paper, the principal component analysis method is used to reduce the dimensionality of the indicators of the development level of science and technology finance in Anhui Province, extract a small number of indicators containing the most information, comprehensively evaluate the development level of science and technology finance in Anhui Province, and finally carry out cluster analysis.

2.3.1 Principles of Principal Component Analysis

Principal Component Analysis (PCA), also known as "principal component analysis", was first proposed by Hortling in 1933. It is a method of mathematical transformation, which aims to use the idea of dimensionality reduction to transform a given group of related variables into another group of unrelated variables through linear transformation, and these new variables are arranged in the order of decreasing variance, so that the total variance of the variables remains unchanged in the mathematical transformation, so that the first variable has the largest variance, which is called the first principal component; The second variable has the second largest variance and is not related to the first variable, which is called the second principal component. By analogy, one variable has one principal component, and finally multiple indicators are transformed into a few comprehensive indicators to achieve the purpose of dimensionality reduction. When the cumulative variance reaches 85% or higher, we can consider these principal components to represent an

analytical method in which multiple analytical variables in the original index data reflect the overall situation for analysis and research[12]. Namely:

$$\begin{cases} Y_1 = \partial_{11}X_1 + \partial_{12}X_2 + \cdots + \partial_{1p}X_p \\ Y_2 = \partial_{21}X_1 + \partial_{22}X_2 + \cdots + \partial_{2p}X_p \\ \vdots \\ Y_m = \partial_{m1}X_1 + \partial_{m2}X_2 + \cdots + \partial_{mp}X_p \end{cases}$$

2.3.2 Principal component analysis steps

Firstly, the original index data was constructed, the sample matrix was standardized transformed, and the correlation coefficient matrix was obtained. Secondly, the eigenvalues and corresponding eigenvectors of the matrix are obtained, and the first m eigenvalues of the covariance matrix are the variances corresponding to m components, so that we can obtain the variance contribution rate $\beta_m = \lambda_m / \sum_{m=1} \lambda_m$ and the cumulative variance contribution rate of each component, that is $x = \sum_{i=1}^{m} \beta_m$, the contribution rate of the mth component, and the cumulative variance contribution rate.

3. Principal component analysis of the development level of science and technology finance in Anhui Province

3.1. Descriptive statistical analysis

Firstly, the descriptive analysis of the standardized variables is carried out, as shown in Figure 1, it can be seen from the figure that the mean values of the eight variables are all around 0, among which the overall distribution of the data of the three variables of R&D personnel converted to full-time equivalent, the number of patent applications granted and the number of registered trademarks is relatively concentrated, but there are two abnormally high values, indicating that there are individual prefecture-level cities (such as Hefei, Wuhu, etc.) that perform prominently in these three aspects. The data distribution of the other five variables (X2-X6) was scattered, but there were no outliers

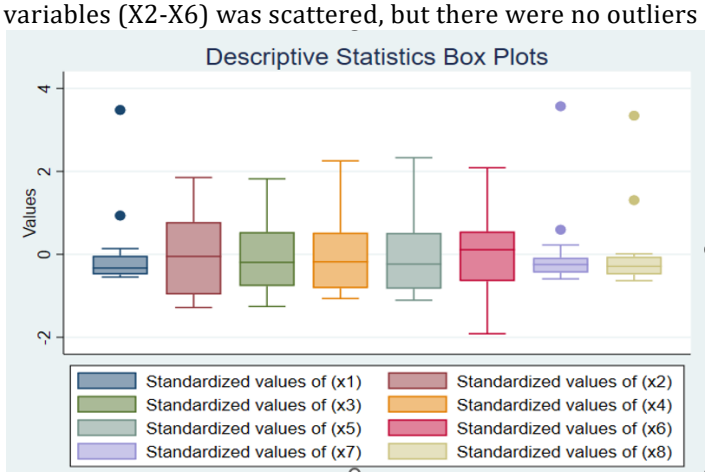

Fig.1 Box plot of each indicator of the development level of science and technology finance in Anhui Province

3.2. Principal component analysis

3.2.1 Applicability analysis

In this paper, the correlation coefficient matrix, KMO value and Bartlett's spherical test of various indicators of the development level of science and technology finance in Anhui Province are obtained by stata software, and the results are shown in Fig. 2 and Fig. 3:

Table 2. Correlation coefficient matrix of science and technology financial environment indicators in Anhui Province

variable	X1	X2	X3	X4	X5	X6	X7	X8
X1	1	0.1145	0.3764	0.4549	0.6399	0.5032	0.9904	0.9701
X2	0.1145	1	0.697	0.5187	0.4831	0.4406	0.0461	0.0293
X3	0.3764	0.697	1	0.1056	0.7303	0.3736	0.2967	0.3201
X4	0.4549	0.5187	0.1056	1	0.0265	0.2006	0.5027	0.5176
X5	0.6399	0.4831	0.7303	0.0265	1	0.3909	0.5592	0.6353
X6	0.5032	0.4406	0.3736	0.2006	0.3909	1	0.4929	0.4602
X7	0.9904	0.0461	0.2967	0.5027	0.5592	0.4929	1	0.9632
X8	0.9701	0.0293	0.3201	0.5176	0.6353	0.4602	0.9632	1

As can be seen from Tables 2 and 3, the correlation between most of the indicators of science and technology finance in Anhui Province is relatively strong. The KMO value was 0.708, which was greater than 0.5, and the p-value of Bartlett's spherical test was also 0.000, which was much less than 0.05. Therefore, the test results of each index meet the standards and can be analyzed by principal component analysis.

Table 3. KMO and Bartlett's spherical tests

variable	numeric value
Sample a sufficient amount of the Kaiser-Meyer-Olkin measure	0.708
Bartlett sphericity test approximate chi-square	132.727
df	28
P value	0.000

3.2.2 Information Extraction

During the analysis, the information content of the extracted principal components was mainly measured by variance, and the number of extracted principal components was determined by the eigenvalue greater than 1, so as to extract as few principal components as possible containing most of the information, and Table 4 is the principal component analysis results output by stata.

Table 4. Results of principal component analysis

ingredients	eigenvalue	difference	Variance contribution rate	Cumulative variance contribution rate
First principal component	4.249	2.063	0.531	0.531

The second principal component	2.186	1.471	0.273	0.804
The third principal component	0.715	0.232	0.089	0.894
The fourth principal component	0.483	0.261	0.060	0.954
The fifth principal component	0.222	0.111	0.028	0.982
Sixth principal component	0.111	0.081	0.014	0.996
The seventh principal component	0.031	0.027	0.004	1.000
Eighth principal component	0.004	0.000	0.001	1.000

According to the results in Table 4, the variance contribution of the first principal component is 53.1%, which explains more than half of the information in the population, and the variance contribution of the second principal component is 27.3%, which explains 27.3% of the information. The first two principal components explain more than 80% of the information overall, so we extract the first two principal components.

Let the extracted first principal component and the second principal component be $Y_1$and Y_2 respectively, and the scoring model is obtained according to the factor loading matrix in Table 5 as follows:

$$Y_1 = 0.4595X_1 + 0.1569X_2 + 0.2875X_3 + 0.1928X_4 + 0.3822X_5 + 0.3145X_6 + 0.4449X_7 + 0.4488X_8$$

$$Y_2 = 0.1541X_1 + 0.6003X_2 + 0.4356X_3 + 0.5119X_4 + 0.2509X_5 + 0.1245X_6 + 0.2095X_7 + 0.2045X_8$$

According to the principal component load diagram in Figure 2, it can be intuitively seen that the first principal component is positively correlated with all indicators, especially with the full-time equivalent of R&D personnel (X1), the number of patent applications granted (X7) and the number of registered trademarks (X8), and also has a high correlation with the proportion of the number of employees in the financial industry in the total population of the region (X5). The second principal component has a high correlation with the proportion of the number of R&D activity units in the total population of the region (X2), the proportion of R&D expenditure in the GDP (X3), the high negative correlation with the proportion of the balance of loans of financial institutions in the GDP, and the negative correlation with the full-time equivalent of R&D personnel (X1), the number of patent applications authorized (X7) and the number of registered trademarks (X8).

Table 5. Factor load matrix

Variable	First principal component	The second principal component
X1	0.4595	0.1541
X2	0.1569	0.6003
X3	0.2875	0.4356
X4	0.1928	0.5119
X5	0.3822	0.2509
X6	0.3145	0.1245
X7	0.4449	0.2095
X8	0.4488	0.2045

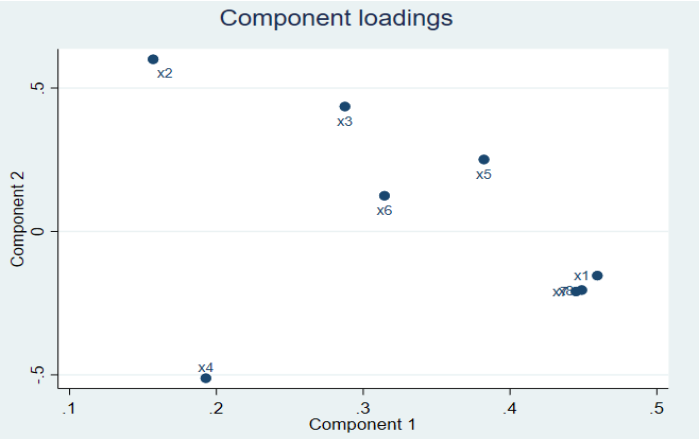

Fig.2. Principal component load diagram

3.2.3 Comprehensive evaluation

By extracting the eigenvalues of the principal components and performing the weighted summation, the comprehensive score model is obtained:

$$Y_c = 0.6603Y_1 + 0.3397Y_2$$

As a result, the comprehensive score ranking of 16 prefecture-level cities in Anhui Province is obtained, as shown in Table 6:

Table 6 Comprehensive scores of science and technology finance in Anhui Province

City	Comprehensive score	First principal component	The second principal component	Overall ranking
Hefei	3.323028	6.319912	-2.502435	1
Wuhu	2.626393	2.988333	1.92284	2
Ma'an-shan	1.240544	0.6143429	2.45778	3
Chuzhou	0.9020498	0.648333	1.395235	4
Xuancheng	0.5104918	0.0192765	1.465336	5
Tonglin g	0.3220433	-0.1182037	1.177813	6
Huang-shan	-0.1096604	-0.4611016	0.573485	7
Chizhou	-0.2348847	-0.9423377	1.14029	8
Bengbu	-0.3869092	-0.5117387	-0.1442605	9
Huaibei	-0.4697038	-0.2422147	-0.9119061	10
Anqing	-0.9037432	-1.244448	-0.2414685	11
Lu'an	-0.9361759	-0.7012147	-1.392903	12
Fuyang	-1.26629	-1.15227	-1.487926	13
Suzhou	-1.322305	-1.483416	-1.009131	14
Huainan	-1.602151	-2.082397	-0.668629	15
Bozhou	-1.692727	-1.650856	-1.774119	16

From the comprehensive score ranking, it can be seen that Hefei City, Wuhu City and Ma'anshan City have high comprehensive scores, and the development level of science and technology finance ranks among the top three in the province. However, the development level of science and technology finance in cities such as Bozhou,

Huainan and Suzhou is low, and the development level of science and technology finance is in a relatively backward position in the province. In order to fully understand the development of science and technology finance in each city, it is also necessary to understand the scores of the first principal component and the second principal component of each city.

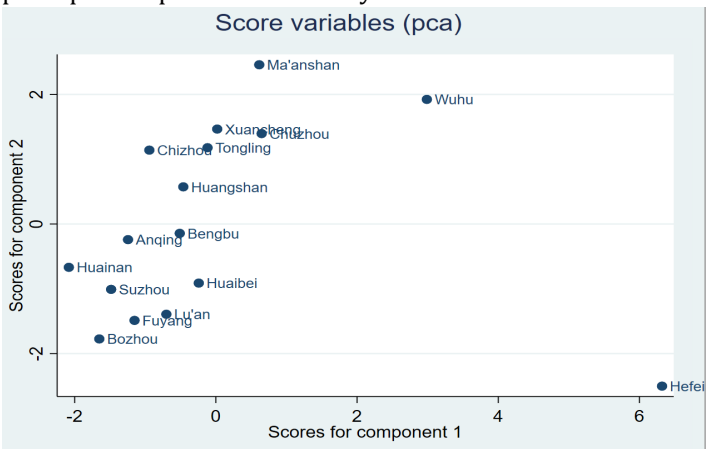

Fig.3 Factor scores of each city

It can be intuitively seen from Figure 3 that Wuhu City has higher scores on the two principal components, indicating that Wuhu City has done better in science and technology financial innovation investment and intellectual property protection, as well as R&D investment and financial structure, while Bozhou, Fuyang and Suzhou cities have lower scores on both principal components, indicating that they need to focus on strengthening innovation investment, intellectual property protection and R&D investment in the development of science and technology finance, while Hefei has a higher score on the first principal component (innovation and intellectual property index) and higher scores on the second principal component (R& D input and financial structure index) may be due to the fact that Hefei is doing much better than R&D input in terms of financial input and outcome output. Therefore, as a provincial capital, Hefei should increase investment in scientific and technological innovation.

3.3. Cluster analysis

As shown in Figure 4, each city is divided into five categories according to the Duda-Hart criterion, among which, the first echelon is Hefei, as the provincial capital, is the political, economic and cultural center of Anhui Province, attracting a large number of science and technology enterprises and financial institutions, and the development level of science and technology finance is in the leading position in the province. The second echelon is Wuhu City, as one of the important cities in Anhui Province, Wuhu City has a relatively complete industrial chain and a good industrial development environment, attracting a large number of science and technology enterprises and financial institutions to settle in, and its level of science and technology financial development is second only to Hefei, far ahead of other cities; The cities

in the third echelon include Ma'anshan, Chuzhou, Xuancheng and Tongling, although these cities have a certain economic foundation and the level of science and technology financial development is at the provincial average; The fourth echelon of cities includes Huangshan City, Bengbu City and Chizhou City, the development level of science and technology finance is relatively backward, these cities are relatively lagging behind in economic development and science and technology finance, and need to increase policy support and investment to improve the development level of science and technology finance; The fifth echelon includes Huaibei City, Lu'an City, Fuyang City, Bozhou City, Anqing City, Suzhou City and Huainan City, which are relatively weak in the economic layout of Anhui Province, with a poor financial environment and insufficient R&D investment, and a poor level of development of science and technology finance.

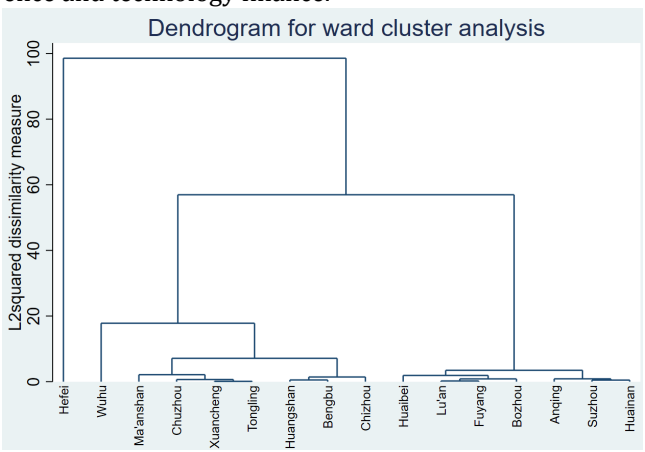

Fig.4 Cluster analysis of the development level of science and technology finance in cities in Anhui Province

4. Conclusions and Recommendations

4.1. Conclusions

In this paper, descriptive statistical analysis, principal component analysis and cluster analysis were carried out on eight indicators affecting the development level of science and technology finance in Anhui Province, and the overall description, comprehensive evaluation, ranking and classification of the development of science and technology finance in Anhui Province were obtained. In the principal component analysis, two principal components were extracted, and the cumulative variance contribution rate was 80.4%, and according to the scores of each principal component on each index, the first principal component was named the innovation and intellectual property index, and the second principal component was named the R&D input and financial structure index, and the scoring model was established. In the comprehensive evaluation, Hefei, Wuhu and Ma'anshan have high comprehensive scores, while Bozhou, Huainan and Suzhou have low comprehensive scores, and the development level of science and technology finance is relatively backward. In

the cluster analysis, the 16 prefecture-level cities in Anhui Province were divided into five categories, the first was Hefei, the second was Wuhu, the third was Ma'anshan, Chuzhou, Xuancheng and Tongling, the fourth was Huangshan, Bengbu and Chizhou, and the fifth was Huaibei, Lu'an, Fuyang, Bozhou, Anqing, Suzhou and Huainan.

4.2. Recommendations

4.2.1 Increase R&D investment and promote scientific and technological innovation

First of all, increase investment in scientific and technological innovation research and development, especially for Hefei, as the provincial capital, should give full play to the leading role, and at the same time, increase financial support for the fourth and fifth echelon cities; Second, the government should establish and improve innovation incentive policies, improve preferential tax policies such as additional deduction of R&D expenses, and encourage enterprises to increase R&D investment; In addition, local universities should actively explore the path of basic research and technological innovation cooperation with scientific research institutions and high-tech enterprises; Finally, it is also necessary to pay attention to the protection of scientific research achievements, establish a sound intellectual property trading market, promote the transformation and application of intellectual property rights, improve the level of application, protection and application of intellectual property rights, and provide a strong guarantee for scientific and technological innovation..

4.2.2 Optimize the financial structure and improve the efficiency of financial services

First of all, it is necessary to continuously promote the reform and opening up of the financial market, attract more financial institutions and fintech companies to enter Anhui Province, and enhance the competitiveness of the financial market. At the same time, the government can strengthen financial supervision, standardize the operation of financial institutions, and encourage financial institutions to better provide financing support for technology enterprises. In addition, it can also strengthen the application of financial technology, promote the digitalization and intelligence of financial services, improve the efficiency of financial services, reduce financing costs, and benefit more technology enterprises.

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