Journal of Combinatorial Mathematics and Combinatorial Computing, 118: 3–17
DOI:10.61091/jcmcc118-01
http://www.combinatorialpress.com/jcmcc
Received 20 June 2023, Accepted 10 December 2023, Published 25 December 2023

Combinatorial Press

Article

Evaluation of Individual Innovation and Entrepreneurship Effect Based on Linear Space Model and Grey Correlation

Xiaohao Ning[1,*]

[1] College of Computer Science and Engineering, Jishou University, Zhangjiajie 422700, Hunan, China.

* **Correspondence:** 122812040@qq.com.

Abstract: This paper analyzed the components of the connotation of innovation ability, then constructs a linear spatial model of innovation and entrepreneurship ability, proposes a multi-objective function model of the utilization efficiency and allocation efficiency of education resources, and uses the grey correlation algorithm The experimental simulation and model solution are carried out. The simulation results show that, through the optimization, the utilization efficiency and allocation efficiency of the educational resources for innovation and entrepreneurship for all are increased by 18.72% and 20.98% respectively, and tend to be in equilibrium, which can achieve the optimization of educational resources allocation. Among all people, the correlation value with ideal entrepreneurship is 0.3177, achieving the most excellent innovation and entrepreneurship education.

Keywords: Linear spatial model, Grey correlation, Resource allocation, Multi-objective optimization, Innovation and entrepreneurship

---

1. Introduction

The continuous impact of the information age, the environment of universal entrepreneurship in the new era has become more complex, and the paths of universal entrepreneurship have become richer and more diverse, which makes the selectivity of entrepreneurial paths of all people in contemporary higher education institutions more diverse, but with it, the risks of entrepreneurship are constantly rising [1, 2]. The improvement of the entrepreneurial ability of all people in higher education institutions will be directly reflected in the success rate of entrepreneurship, which can obviously alleviate the current employment difficulties of university graduates in higher education institutions, and can also build a stronger self-confidence in employment and entrepreneurship for university graduates, bringing them a broader space for development, so it is particularly important for all people to choose a suitable entrepreneurial path, which will make entrepreneurial activities become twice as successful with half the effort [3].

Under the reality that big data technology is constantly influencing all areas of society, big data analysis technology brings many advantages to the entrepreneurial path of all people in higher education institutions. Big data technology has clearly enhanced the richness of entrepreneurial thinking of contemporary university graduates in higher education institutions, allowing students' entrepreneurial thinking to stand in the perspective of strategic development, and entrepreneurial thinking to be more long-term developmental rather than purely immediate interests [4]. Simply put, big data analysis

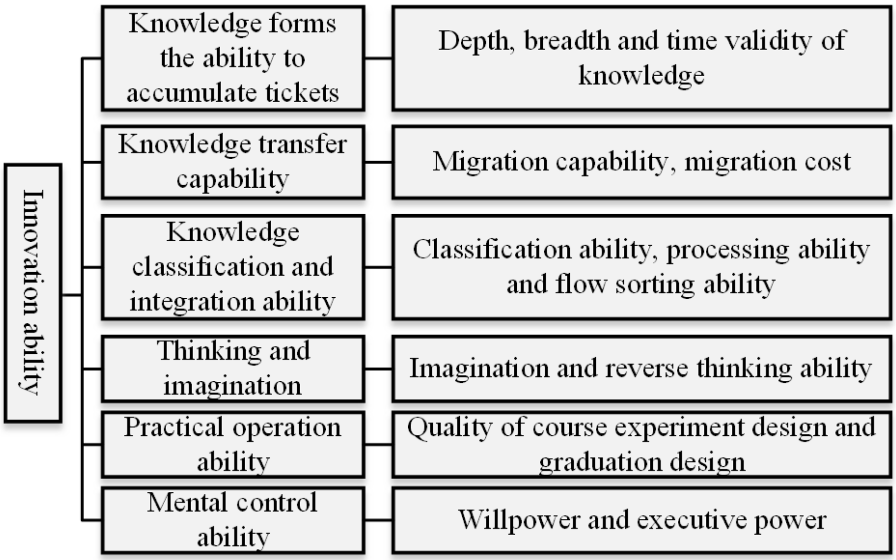

Figure 1. Elements of Innovation Capability

makes the entrepreneurial direction of all people broader and the entrepreneurial path more diversified in character. It is possible to find out the specific entrepreneurial thinking of a certain industry at a certain stage based on the detailed analysis and calculation of big data, which has positive significance for all people to find the right time and way to start a business [5].

The continuous use of big data technology has also brought entrepreneurial thinking closer to "internet technology" and "digital technology", allowing the entire population to complete a comprehensive analysis of entrepreneurial paths based on the vast amount of data resources, helping the entire population to achieve their employment goals and entrepreneurial aspirations on the basis of ensuring the feasibility of entrepreneurial paths and their development potential, thereby driving the overall development of the entire market economy [6].

2. Model of the Components of Innovation and Entrepreneurship

2.1. Innovation Ability

The elements of innovation ability should include innovation consciousness, innovation thinking, innovation personality, and the accumulation of relevant knowledge, knowledge foundation. The basic components of innovative ability are summary here as the accumulation of knowledge, the ability to transfer knowledge, the ability to classify and integrate knowledge, the ability to think and imagine, the ability to operate in practice and the ability to control mentally (willpower and executive power) [7]. The linear space is described as follows: R6 knowledge formation and accumulation, knowledge transfer ability, knowledge classification and integration management ability, thinking and imagination, practical operation ability, and mental control ability), which is a 6-dimensional linear vector space, and it is necessary to test whether each dimension is independent of the other [8]. For the basic components of innovation ability assumed in Figure 1, a scale can be designed to measure the ability to accumulate knowledge (depth, breadth and temporal validity of knowledge), the ability to transfer knowledge (transfer ability, transfer cost), the ability to classify and integrate knowledge and manage it (knowledge classification ability, management ability, deductive reasoning ability), the ability to think and imagine (imagination, reverse thinking ability), the ability to operate in practice (course The students were asked to answer a certain number of multiple-choice questions in each of the six areas (quality of experimental design, quality of graduation design), and the scores of these areas were counted by asking the students to answer the questions [9].

Serial number	Element dimension	Connotation Evaluation score
1	Relationship Competency	Ability to establish and maintain interaction between individuals, individuals and organizations
2	Innovative creativity	Innovatively solve various problems in the process of entrepreneurship
3	Entrepreneurial perseverance	The ability to persist without giving up in the face of difficulties and setbacks in entrepreneurship
4	Grasp the opportunity	Ability to identify, evaluate and capture market opportunities through various methods
5	Motivation of entrepreneurship	Expectation and pursuit of entrepreneurial lifestyle and its achievements
6	Resource integration	Ability to integrate human, financial, material and technical resources inside and outside the organization
7	Practical learning ability	The ability to continuously learn the knowledge and skills required for entrepreneurship

Table 1. Dimensions of Entrepreneurial Ability Components

2.2. Analysis of the Components of Entrepreneurial Competencies

For the connotation of entrepreneurial competencies, a more scientific and systematic expression of the connotation of entrepreneurial competencies was given by combining case studies and questionnaires, the seven dimensions of relational competence, innovation and creativity, entrepreneurial perseverance, opportunity grasping, etc. to express the composition of entrepreneurial competencies for all [10]. The calculation of its elemental components can be designed with a certain number of multiple-choice questions, and by asking students to answer the questions to count their scores in these dimensions, and then convert the scores into relative probabilities to measure the weighting relationship of each component, and then test their correlation by factor analysis [11]. (See Table 1)

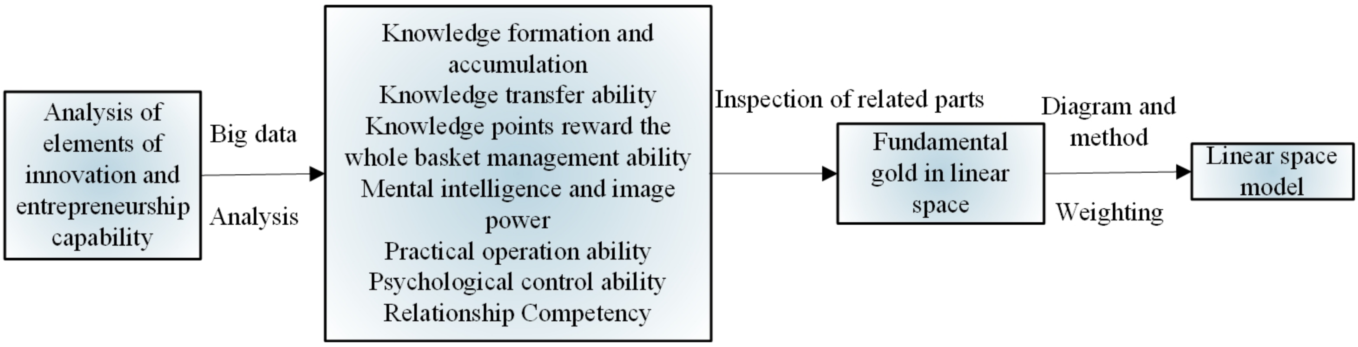

Figure 2. Structure of Linear Space Model of Innovation and Entrepreneurship Capability

3. Linear Space Model Construction

3.1. Determination of Weights of Basis Vectors

Assuming that our previous hypothesis is valid, we can obtain R6 knowledge formation accumulation, knowledge transfer ability, knowledge classification and integration management ability, thinking imagination, practical operation ability, and mental control ability) a set of innovative ability base vectors [12]. Similarly, T^7 (Relational Competence, Opportunity Grasp, Innovation and Creativity, Resource Integration, Entrepreneurial Motivation, Entrepreneurial Perseverance, and Learning by Doing) can be obtained as another set of basis vectors. Finally, the coefficients of these two sets of basis vectors and the weights of the components of innovation and entrepreneurship can be determined [13]. How to determine the weights? Take innovation capability as an example: let there be m attributes for the evaluation of the innovation and entrepreneurship capability of all people. i.e. $c_1, c_2, ..., c_m$ takes this part of the attributes as the basis for determining the weights. The weight refers to the degree of influence of an indicator factor on the innovation and entrepreneurship of all people. The size of the weight is usually positively correlated with the degree of influence, with weights ranging from 0 to 1, and the sum of the weights of the evaluation factors being 1.

3.2. Spatial Model of Innovation Capabilities

After determining the constituents of innovation and entrepreneurship, the correlation and independence of each basic constituent are tested, the similarity of the 2 base vectors and the correlation detection of each vector metric are carried out, and then the base vectors of the linear space of unified innovation ability are constructed, and then the weights of each base vector are determined by the topologic theory, from which the linear space model of innovation and entrepreneurship ability can be constructed $C = (\xi_1, \xi_2, ..., \xi_n)$, $n \leq 11$, ξ_1. Here n is the linear space dimension (see Figure 2).

3.3. Evaluation Model

As the linear space of innovation capability is abstract, it is not easy to observe and measure, therefore, it is necessary to transform this abstract value into an observed quantity. The ability to accumulate knowledge can be observed in terms of the depth and breadth of knowledge and its temporal validity [14]; the ability to transfer knowledge can be measured in terms of the ability to transfer knowledge and the cost of transfer; the ability to classify, integrate and manage knowledge can be measured in terms of the ability to classify knowledge, the ability to manage and the ability to reason deductively; the ability to think and imagine can be observed in terms of the ability to imagine and the ability to think in reverse [15]; the ability to operate in practice can be calculated in terms of the quality of the course Mental control can be measured by observing willpower and executive ability [16]; relational competence can be measured by actively keeping in touch with new friends and establishing friendships with strangers [17]; opportunity grasp can be measured by trying to assess the feasibility of business opportunities and finding ways to assess the value of some business opportunities [18]. Statistical measurement, etc. [17]. To do this, two tasks are required: first, constructing a mapping between the basis vectors in linear space and the observable measures; and constructing a scale for the observable measures. Next, statistical calculations are made and the evaluation model is derived, i.e. $C = (\xi_1, \xi_2, ..., \xi_n) \rightarrow (f_1(\psi)_1, f_2(\psi)_2, ..., f_n(\psi)_n)$ where $f$is the mapping function relationship and ψ is the observable measure.

3.4. Construction of a Model for the Optimal Enhancement of Individual Innovation and Entrepreneurship for all People

Since the calculated value of $C = (f_1(\psi)_1, f_2(\psi)_2, ..., f_n(\psi)_n)$ reflects $C = (\xi_1, \xi_2, ..., \xi_n)$, the magnitude of the vector base of the linear space in which innovation and entrepreneurship are expressed.

Step 1: we can start by measuring the linear spatial vector value of the innovative entrepreneurial ability of a known successful person and use this value as a reference standard value.

Step 2: compare the difference or variance value of the base vector between a certain sex measure and the standard value and identify the corresponding basic components.

$$\xi_{iK} = \frac{\min_i \min_k |X_{ok} - X_{ik}| + \rho \max_i \max_k |X_{ak} - X_{ik}|}{|X_{ok} - X_{ik}| + \rho \max_i \max_k |X_{ok} - X_{ik}|} (\text{i} = 1, 2, \ldots, m : k = 1, 2, ..., n).$$

Step 3: Targeted enhancement of the identified basic components of innovation and entrepreneurship capacity E $= (\Delta_1, \Delta_2, ..., \Delta_i) (\Delta > \Delta_0, \text{i} < \text{n}, \Delta_0$Is threshold).

4. Grey Correlation Degree Algorithm

Based on the formula for calculating the grey correlation coefficient

$$\begin{cases} \xi_{iK} = \frac{\min_i \min_k |X_{ok} - X_{ik}| + \rho \max_i \max_k |X_{ak} - X_{ik}|}{|X_{ok} - X_{ik}| + \rho \max_i \max_k |X_{ok} - X_{ik}|}, \\ \xi_{iK} (i = 1, 2, ..., 6; k = 1, 2, ..., 11). \end{cases} \quad (1)$$

Calculate the correlation coefficient $\xi_{iK} (i = 1, 2, ..., 6; k = 1, 2, ..., 11)$ between each indicator and the corresponding correlation coefficient in the reference series, forming a matrix ξ_{iK} .

4.1. Calculating the Correlation

From Table 1, it is possible to know the weights of the different indicators at each level, i.e. $W_{AB}, W_{B1C}, W_{B2C}, W_{B3C}, W_{B4C}, W_{B5C}$ Using the formula: $R = (r_i)_{1\times m} = (r_1, r_2, ..., r_m)$ the degree of correlation of the indicators at each level is calculated.

$$\begin{cases} R_{BI} = W_{B1C} \times E^T_{BIC} = (0.0077, 0.0148, 0.0212, 0.0125, 0.0609, 0.0764, 0.0793, 0.0152); \\ R_{B2} = W_{B2C} \times E^T_{B2C} = (0.0049, 0.0114, 0.0153, 0.0073, 0.0386, 0.0222, 0.0575, 0.0103\ ); \\ R_{B3} = W_{B3C} \times E^T_{B3C} = (0.0084, 0.0168, 0.0140, 0.0116, 0.0471, 0.0695, 0.1100, 0.0166\ ); \\ R_{BA} = W_{BAC} \times E^{T}{}_{BAC} = (0.0396, 0.0546, 0.0534, 0.0607, 0.5058, 0.2044, 0.3583, 0.0602\ ); \\ R_{BS} = W_{B5C} \times E^T_{BSC} = (0.0125, 0.0264, 0.0260, 0.0165, 0.1308, 0.0545, 0.1026, 0.0206\ ). \end{cases} \quad (2)$$

In the above equation $E_{B1C}, E_{B2C}, E_{B3C}, E_{B4C}, E_{B5C}$ is the matrix consisting of the corresponding data in the table of correlation coefficient values, respectively. The final correlation for the target layer - indicator R is calculated as

$$\begin{aligned} R_A &= (r_1, r_2, r_3, r_4, r_4) \\ &= W_{AB} (R_{Bb} R_{B2}, R_{B3}, R_{BA}, R_{BS}) (0.0262, 0.0389, 0.0388, 0.0397, 0.3177, 0.1408, 0.2411, 0.0411). \end{aligned}$$

	First-level indicators	Secondary indicators	weight	School A	School B	School C	School D	School E	School F	School G	School H
Evaluation index system of innovation and entrepreneurship education for college students	Innovation and entrepreneurship courses and activities	Number of innovation and entrepreneurship courses	0.02	60.01	69.62	71.82	67.82	74.71	72.40	76.95	68.92
		Innovation and entrepreneurship course content	0.02	61.17	70.78	73.67	68.45	70.55	74.09	76.55	69.67
		Innovation and entrepreneurship lecture	0.03	61.78	69.22	70.78	68.34	72.91	75.16	76.17	68.95
		Innovation and entrepreneurship activities	0.05	64.13	70.02	72.35	68.77	74.71	76.23	75.54	70.05
	Innovation and entrepreneurship education conditions	Teachers of innovation and entrepreneurship education	0.02	67.02	72.68	76.35	71.88	76.49	76.21	77.32	73.07
		Innovation and entrepreneurship education system	0.03	61.72	72.68	76.55	72.87	76.44	75.69	76.93	72.75
		Innovation and entrepreneurship books	0.02	68.83	72.68	76.67	70.45	76.49	75.69	76.93	72.45
		Construction of innovation and entrepreneurship sites and facilities	0.02	66.48	71.56	68.72	69.82	75.89	75.12	78.09	72.42
		Innovation and entrepreneurship atmosphere	0.02	64.72	72.33	73.18	69.35	74.72	75.16	76.56	72.32
	Innovation and entrepreneurship education channels	Access to education information	0.04	64.77	70.38	69.49	68.02	74.13	73.52	77.32	71.49
		Convenience of access to education services	0.05	64.12	70.39	70.02	68.45	75.96	75.65	76.19	70.95
		Feedback on demand channels for innovation and entrepreneurship education	0.05	65.32	71.56	60.49	67.89	74.72	75.69	75.78	70.45
	Self-innovation and entrepreneurship	Establishment of innovation and entrepreneurship awareness	0.15	60.01	65.38	67.62	67.08	75.56	71.36	73.85	65.49
		Evaluation on the mastery of innovation and entrepreneurship knowledge	0.08	53.54	60.02	58.42	60.14	66.25	68.14	68.07	62.65
		Evaluation of innovation and entrepreneurship ability	0.12	64.13	71.95	72.12	69.12	77.08	73.52	73.07	62.65
		Tendency evaluation of innovation and entrepreneurship choice	0.16	65.89	65.16	64.49	68.41	76.49	72.47	68.02	63.52
		Self-innovation and entrepreneurship achievements evaluation	0.10	53.54	60.02	58.45	60.12	68.25	76.45	72.41	74.22
	Achievements of innovation and entrepreneurship education in colleges and universities	Theoretical innovation of innovation and entrepreneurship education in colleges and universities	0.04	64.12	71.93	72.12	69.11	77.05	73.32	75.02	62.45
		Innovation and entrepreneurship education in colleges and universities Practice innovation	0.02	66.49	71.55	71.59	69.22	78.25	74.61	75.02	71.49
		Innovation and entrepreneurship education and management innovation in colleges and universities	0.04	64.72	74.25	71.51	69.12	77.05	74.02	76.94	71.59
		Achievements of innovation and entrepreneurship education in colleges and universities	0.05	68.272.455	72.35	73.41	69.82	76.45	76.49	76.44	72.22

Table 2. Quality Evaluation Index System and Satisfaction Data

Based on the magnitude of the correlations in R_A, the order of correlations for the quality of innovation and entrepreneurship education for all of the eight institutions can be determined as follows: $E > G > F > H > D > B > C > A$.

5. Analysis of Empirical Results

5.1. Entrepreneurship in Higher Education

Among the 8 colleges and universities surveyed, the highest value of association with the ideal college and university is E for all, with a value of 0.3177. E for all has the most excellent college and university innovation and entrepreneurship education; college G (association of 0.2411), college F (association of 0.1408) and college H (association of 0.0411) belong to the second level. The correlation degree of these four universities is significantly higher than that of the four undergraduate institutions, namely, university D (correlation degree of 0.0397), university B (correlation degree of 0.0389), university C (correlation degree of 0.0388) and university A (correlation degree of 0.0262), all of which belong to the third level, (see Table 2).

5.2. Coupled and Coordinated Pattern

A comprehensive evaluation of the level of innovation and entrepreneurship in each province was conducted using the TOPSIS model based on the entropy value method, and the results are shown in Figure 3 Figure 4 and Table 3. From Figure 3, it can be seen that: ① from 2006 to 2018, the national average innovation and entrepreneurship level shows a continuous increasing trend, and the two time series characteristics show an obvious positive correlation; ② the national regional innovation level shows a linear increasing trend, but the regional entrepreneurship level shows an obvious three-stage characteristic, the entrepreneurship development level from 2006 to 2013 shows a slow increasing trend, from 2014 to 2017 shows a rapid increasing, and a slowing trend from 2017 to 2018 [17] [18]. In recent years, China's innovation performance and efficiency, the number of innovation clusters and their competitiveness, the number and scale of entrepreneurial enterprises, and the performance and competitiveness of entrepreneurship have all been at the forefront of the international arena [19].

As can be seen from Table 3 and Figure 4, there are large differences in regional innovation and entrepreneurship levels in China, with economically developed regions having higher levels of innovation and entrepreneurship. From the perspective of the three major zones, the regional innovation and entrepreneurship levels in the east, central and western regions have all continued to improve. From a chronological perspective, the eastern region has the highest average innovation and entrepreneurship levels and is higher than the national average; followed by the central and western regions, both of which are lower than the national average. From a provincial perspective, the regions with the highest national innovation levels in 2006 were Beijing, Guangdong and Jiangsu, and the lowest regions were Hainan, Xinjiang and Tibet; by 2018 the regions with the highest innovation levels were Guangdong, Beijing and Jiangsu, and the lowest regions were Hainan, Qinghai and Tibet [20]. Meanwhile, the regions with the highest levels of entrepreneurship nationwide in 2006 were Guangdong, Beijing and Jiangsu, and the lowest regions were Gansu, Hainan and Tibet; by 2018 the regions with the highest levels of entrepreneurship were Guangdong, Beijing and Shanghai, and the lowest regions were Ningxia, Qinghai and Tibet [21]. Overall, innovation and entrepreneurship are mainly concentrated in developed regions such as Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta regions, while less developed regions in the west are relatively underdeveloped. China's vast territory and the uneven economic development of various regions have led to an imbalance in the allocation of factor resources and differences in the level of regional innovation and entrepreneurship, which will further exacerbate the imbalance in regional economic development and form the Matthew effect of regional innovation and entrepreneurship differences [22].

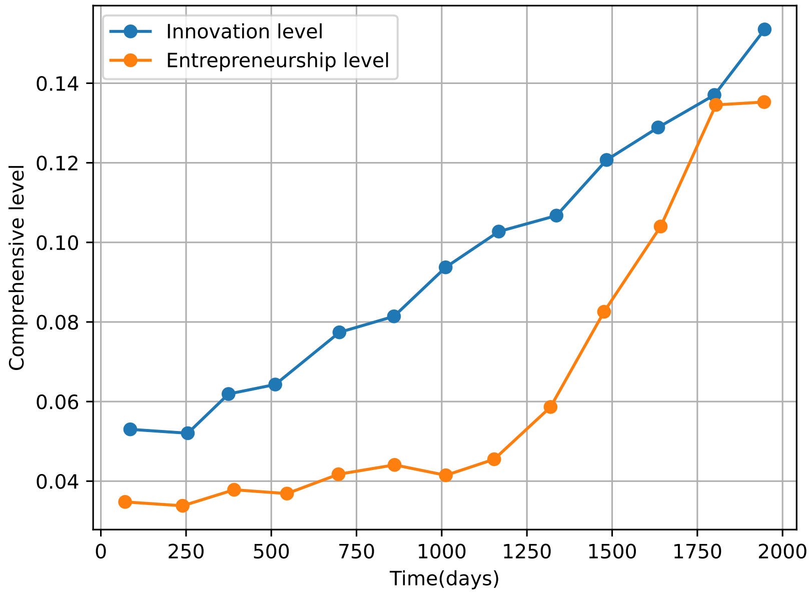

Figure 3. Regional Average Level of Innovation and Entrepreneurship

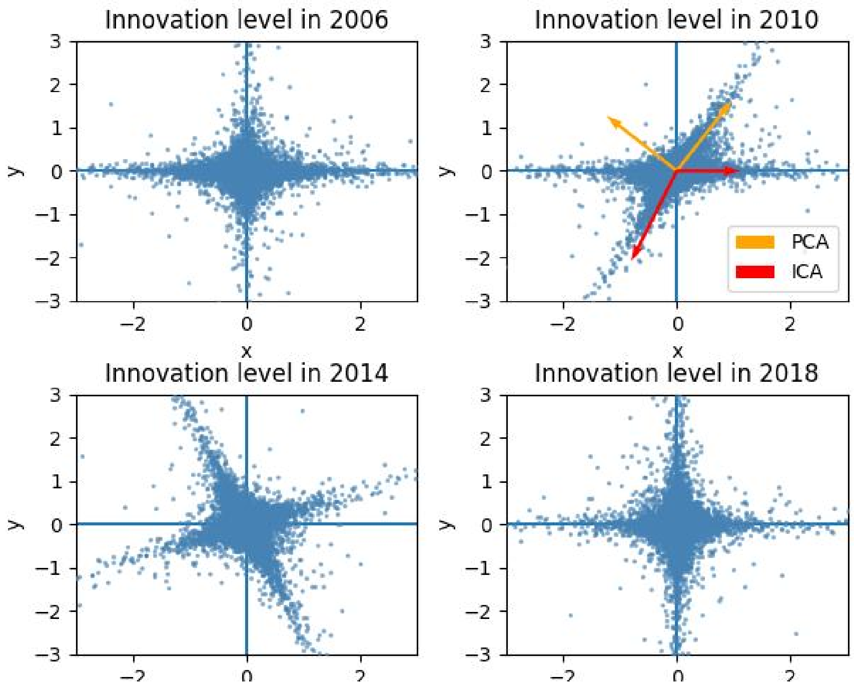

Figure 4. Regional Innovation and Entrepreneurship Level Pattern

Zone	Region	Regional innovation water				Regional entrepreneurship water			
		2006	2010	2014	2018	2006	2010	2014	2018
Eastern region	Beijing	0.1638	0.2577	0.4166	0.5726	0.0936	0.1205	0.2974	0.5324
	Tianjin	0.0456	0.0552	0.0902	0.1297	0.0314	0.037	0.0788	0.1805
	Hebei	0.0378	0.0506	0.074	0.1095	0.0287	0.0274	0.0445	0.1532
	Liaoning	0.0574	0.0806	0.0974	0.1185	0.0406	0.0469	0.0521	0.0897
	Shanghai	0.0885	0.1335	0.1674	0.2685	0.0702	0.1112	0.1865	0.414
	Jiangsu	0.1128	0.2488	0.3567	0.4877	0.0882	0.128	0.1649	0.3185
	Zhejiang	0.0935	0.1855	0.2697	0.26	0.0489	0.1026	0.0871	0.2287
	Fujian	0.034	0.0526	0.0838	0.1497	0.0405	0.049	0.057	0.1045
	Shandong	0.0722	0.128	0.1926	0.28	0.0487	0.1024	000874	0.2289
	Guangdong	0.1482	0.2612	0.3637	0.6398	0.1145	0.1648	0.2435	0.578
	Hainan	0.0187	0.0328	0.0297	0.0196	0.0138	0.0132	0.0147	0.0278
	Mean value	0.0796	0.1352	0.1947	0.2865	0.0572	0.0789	0.1214	0.2598
Central region	Shanxi	0.0365	0.0367	0.0442	0.0512	0.0245	0.0244	0.0207	0.0302
	Jilin	0.0378	0.0445	0.0507	0.0689	0.0205	0.0226	0.0202	0.0306
	Heilongjiang	0.0421	0.0569	0.0601	0.0668	0.023	0.03	0.0228	0.0915
	Anhui	0.0349	0.0557	0.0986	0.1496	0.028	0.0246	0.0335	0.088
	Jiangxi	0.0281	0.0377	0.0487	0.0933	0.0239	0.0236	0.0285	0.0529
	Henan	0.0448	0.0635	0.098	0.1398	0.0248	0.0279	0.0485	0.1518
	Hubei	0.0596	0.0828	0.1294	0.2165	0.0268	0.0338	0.0686	0.1935
	Hunan	0.0418	0.0625	0.0877	0.1214	0.0	258	0.0223	0.0299
	Mean value	0.0407	0.0549	0.0772	0.1147	0.0249	0.0252	0.0342	0.0908
Western region	Inner Mongolia	0.0187	0.0237	0.0295	0.0304	0.0172	0.0155	0.0174	0.0253
	Guangxi	0.0265	0.0339	0.0454	0.054	0.0198	0.0166	0.0238	0.0572
	Chongqing	0.0247	0.0386	0.0582	0.0936	0.0248	0.0312	0.0496	0.01602
	Sichuan	0.0545	0.785	0.1128	0.2047	0.0249	0.0316	0.0495	0.1600
	Guizhou	0.0212	0.0244	0.0306	0.0478	0.0162	0.0135	0.0216	0.0346
	Yunnan	0.0336	0.0336	0.0426	0.0541	0.015	0.0163	0.0238	0.0385
	Tibet	0.0087	0.0144	0.0423	0.0102	0.0135	0.0139	0.0055	0.0093
	Shaanxi	0.0596	0.0698	0.1175	0.1779	0.0205	0.0338	0.0306	0.0879
	Gansu	0.0384	0.032	0.0356	0.0412	0.0156	0.0129	0.0145	0.0198
	Qinghai	0.0268	0.0188	0.0217	0.0166	0.015	0.0096	0.0084	0.0112
	Ningxia	0.0158	0.0063	0.0205	0.0177	0.0169	0.0113	0.0127	0.0223
	Xinjiang	0.0296	0.0178	0.0258	0.0296	0.0154	0.0126	0.0128	0.0225
	Mean value	0.0502	0.0326	0.0487	0.0649	0.0183	0.0177	0.0212	0.0479
Mean value		0.0268	0.0748	0.1078	0.1563	0.0338	0.0415	0.0598	0.1341

Table 3. Regional Innovation and Entrepreneurship Level

5.3. Evaluation of coupling coordination degree

According to the regional innovation and entrepreneurship coupling coordination degree evaluation model, the results of the regional innovation and entrepreneurship coupling coordination degree were calculated (Table 4 and Figure 5). From Table 4 and Figure 5, it can be seen that the coupling coordination degree of innovation and entrepreneurship in all provinces and regions of the country as a whole has increased to a greater extent, but there are obvious differences between different regions. From the perspective of coupling coordination and ranking, the coupling coordination of innovation and entrepreneurship levels in the country's provinces shows a more obvious east-west difference, from 2006 to 2018, the coupling coordination and its ranking in Beijing, Shanghai, Jiangsu, Zhejiang and Guangdong are consistently higher, while Tibet, Qinghai and Ningxia are consistently lower; from the perspective of growth rate, it also shows a pattern of "high in the east and low in the west "From 2006 to 2018, Hubei and Sichuan provinces had the fastest growth rates, with average annual growth rates greater than 1, followed by Guangdong, Beijing, Henan, Zhejiang, Shanghai, Shandong, Tianjin, Jiangsu, Hebei, Chongqing, Anhui, Shanxi and Fujian, whose growth rates were greater than the national average; in addition, Qinghai, Ningxia, Tibet and other regions had The growth rate of coupling coordination is negative and has an overall decreasing trend from 2006 to 2018 [23].

In the context of "mass innovation, mass entrepreneurship", innovation and entrepreneurship are developing rapidly in all provinces and regions with high levels of innovation and entrepreneurship development are concentrated in areas with high levels of economic development and Urbanization, such as Beijing, the core city of Beijing-Tianjin-Hebei, Shanghai, Jiangsu and Zhejiang in the Yangtze River Delta, Guangdong, Hubei in the middle reaches of the Yangtze River and Sichuan in the Chengdu-Chongqing region. The regions with a high degree of coupling and coordination of innovation and entrepreneurship are also concentrated in these areas [24]. Regions with higher levels of economic development have richer and higher quality innovation and entrepreneurship resources, as well as a higher business environment, and are therefore more conducive to the coupled and coordinated development of regional innovation and entrepreneurship [25, 26].

5.4. Spatial autocorrelation analysis

In order to better reflect the spatial characteristics of the coordination degree of coupling innovation and entrepreneurship in the province, spatial autocorrelation analysis is introduced here. The global Moran's I was first used to examine the spatial autocorrelation of the degree of coupling and coordination of innovation and entrepreneurship in the whole region, and then the local Moran's I was used to examine the spatial correlation characteristics of the local degree of coupling and coordination of innovation and entrepreneurship (Figure 6, Table 5). As shown in Table 5, the spatial autocorrelation of innovation and entrepreneurship was high in 31 provinces and cities across China, and the Moran's I index showed a fluctuating increasing trend from 2006 to 2018, and passed the 1% significance level test in all years except 2006. It can be seen that China's regional innovation and entrepreneurship has a more obvious spatial dependence characteristic.

The results of the local Moran's I index test are shown in Table 5, with the high agglomeration areas mainly in the economically developed coastal regions and the low-low agglomeration mainly in the less developed regions in the northwest. From 2006 to 2018, the high agglomeration area expanded significantly, forming a contiguous region of high coupling of innovation and entrepreneurship in the east-central region; Sichuan joined to the high-low agglomeration area in 2018, i.e. the level of coupled and coordinated development of innovation and entrepreneurship in Sichuan is high, but the coupling coordination of the surrounding areas is low; the low-high agglomeration area was Hebei, Anhui and Fujian in 2006, but all three regions withdrew by 2018. And Jiangxi joined, combined with the clustering results of the high agglomeration area, it can be seen that under the role of spatial spillover, the peripheral regions of the high agglomeration area have continuously improved the coordination of innovation and entrepreneurship coupling, and then gradually joined the core area

Zone	Region	2006	Stage	2010	Stage	2014	Stage	2018	Stage	Growth rate
Eastern region	Beijing	0.3523	IV	0.4195	III	0.5932	III	0.7433	II	0.0926
	Tianjin	0.1946	V	0.2114	IV	0.2902	IV	0.3914	IV	0.0846
	Hebei	0.1820	V	0.1936	V	0.2381	IV	0.3598	IV	0.0812
	Liaoning	0.2199	IV	0.2472	IV	0.2672	IV	0.3216	IV	0.0386
	Shanghai	0.2814	IV	0.3496	IV	0.4204	III	0.5766	III	0.0877
	Jiangsu	0.3162	IV	0.4231	III	0.4923	III	0.5515	II	0.0825
	Zhejiang	0.2689	IV	0.2241	IV	0.4102	III	0.3532	III	0.0878
	Fujian	0.1912	V	0.1449	IV	0.2653	IV	0.4985	IV	0.0705
	Shandong	0.2437	IV	0.3042	IV	0.3600	IV	0.7765	III	0.0874
	Guangdong	0.3608	IV	0.1726	III	0.5452	III	0.1518	II	0.0962
	Hainan	0.1268	V	0.1781	V	0.1445	V	0.4869	V	0.0166
	Mean value	0.2489	IV	0.1835	IV	0.3662	IV	0.2281	III	0.0752
Central region	Shanxi	0.1722	V	0.1922	V	0.1736	V	0.2142	IV	0.0274
	Jilin	0.1674	V	0.1725	V	0.1798	V	0.2798	IV	0.0236
	Heilongjiang	0.1746	V	0.2047	V	0.1921	V	0.3366	IV	0.0502
	Anhui	0.1608	V	0.2302	V	0.2402	IV	0.2648	IV	0.0741
	Jiangxi	0.1825	V	0.1928	V	0.1932	V	0.3815		0.0539
	Henan	0.2000	V	0.1908	IV	0.2614	IV	0.4522	IV	0.0906
	Hubei	0.1816	IV	0.2304	IV	0.3069	IV	0.3078	III	0.1052
	Hunan	0.1772	V	0.1926	V	0.2258	IV	0.3082	IV	0.0907
	Mean value	0.1336	V	0.1912	V	0.2214	IV	0.3085	IV	0.0582
Western region	Inner Mongolia	0.1332	V	0.1378	V	0.1496	V	0.1672	V	0.0208
	Guangxi	0.1512	V	0.1539	V	0.1812	V	0.2349	V	0.0462
	Chongqing	0.1585	V	0.1802	V	0.2086	IV	0.3062	IV	0.0778
	Sichuan	0.1911	V	0.2228	IV	0.2733	IV	0.4255	III	0.1023
	Guizhou	0.1359	V	0.1356	V	0.1612	V	0.2014	IV	0.0401
	Yunnan	0.1523	V	0.1524	V	0.1778	V	0.2136	IV	0.0337
	Tibet	0.1039	V	0.1185	V	0.1225	V	0.0982	V	-0.0215
	Shaanxi	0.1877	V	0.2201	IV	0.2455	IV	0.3536	IV	-0.0108
	Gansu	0.1425	V	0.1412	V	0.1502	V	0.1698	V	0.0736
	Qinghai	0.1572	V	0.1154	V	0.1163	V	0.1163	V	0.0159
	Ningxia	0.452	V	0.0910	V	0.1277	V	0.1165	V	-0.0215
	Xinjiang	0.1258	V	0.1218	V	0.1349	V	0.1264	V	-0.0108
	Mean value	0.1488	V	0.1493	V	0.1706	V	0.2144	IV	0.0225
Mean value		0.1915	V	0.2148	IV	0.2533	IV	0.3356	IV	0.0328

Table 4. Regional Innovation and Entrepreneurship System Coupling Coordination

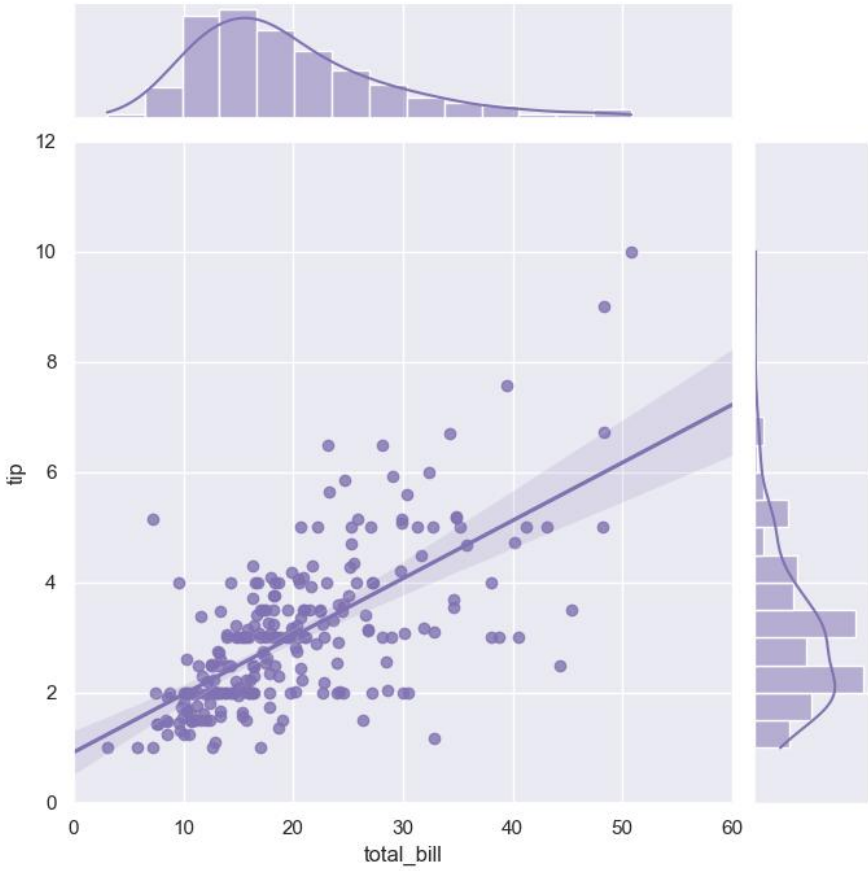

Figure 5. Coordination Pattern of Regional Innovation and Entrepreneurship Coupling

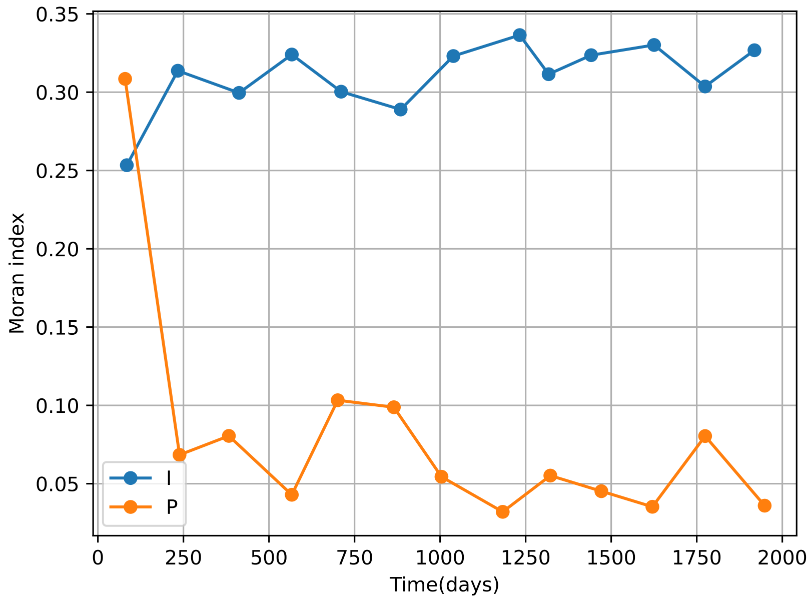

Figure 6. Global Moran's I Index of the Coordination Degree of Innovation and Entrepreneurship Coupling

Cluster type	2006 year	2018 year
H-H	Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang	Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Anhui, Henan, Hunan
H-L	Nothing	Sichuan
L-H	Hebei, Anhui, Fujian	Jiangxi
L-L	Sichuan, Qinghai, Xinjiang	Sichuan, Qinghai, Xinjiang
Not significant	Other regions	Other regions

Table 5. Local Moran's I Index Clustering Results of the Coordination Degree of Innovation and Entrepreneurship Coupling

High School	Resource utilization efficiency			High School	Resource utilization efficiency		
	Before experiment	After optimization	Lifting rate/%		Before experiment	After optimization	Lifting rate/%
C_1	0.705	1.057	0.497	C7	1.009	1.036	0.026
C_2	0.994	1.028	0.033	C_8	0.798	1.045	0.308
C_3	0.747	1.085	0.449	C_9	0.936	1.031	0.101
C_4	0.970	1.063	0.094	C_{10}	1.027	1.046	0.018
C_5	1.019	1.057	0.037	C_{11}	0.694	1.073	0.543
C_6	0.871	1.027	0.178	C_{12}	0.856	1.066	0.244

Table 6. Resource Utilization Efficiency

of the high agglomeration area; the low-low agglomeration area is mainly located in the western region of Qinghai, Xinjiang and other peripheral areas, which is also a relatively lagging area in the development of innovation and entrepreneurship in China. In addition to the above regions, from 2006 to 2018, the local Moran's I index test results for Guangdong Province, which has a high level of innovation and entrepreneurship, are not significant, probably because the regions with high innovation and entrepreneurship development in Guangdong Province are mainly concentrated in the Pearl River Delta region, the spillover effects across provincial administrative units are not significant, and there is no significant local spatial autocorrelation due to the varying levels of innovation and entrepreneurship coupling coordination in the surrounding regions.

5.5. Resource Utilization Efficiency

In order to verify whether the model improves the utilization efficiency of resources, the optimal solution 1 is taken as an example to analyze the experimental results. According to Equation (2), calculate the resource utilization efficiency of all the people before and after the experiment. The data obtained are shown in Table 6. For C1, C3, C8 and C11 with low resource utilization efficiency, the resource utilization efficiency increased from 0.705, 0.747, 0.798and 0.694 before optimization to 1.057, 1.085, 1.045 and 1.073 respectively, with an increase rate of 49.7%, 44.9%, 30.8% and 54.3%.See Table 6.

6. Conclusion

Innovation and entrepreneurship education is a new development direction of higher education reform, which is related to the cultivation of talents and the quality of higher education. The optimal allocation of resources for innovation and entrepreneurship education for all is not only related to the development of the whole population itself and the cultivation of regional talents, but also to the improvement of the scientific use of national higher education resources. The simulation results demonstrate that efficiency of the use of resources for all people increased from 0.694 to 1.009 to 1.027 to 1.085, an average increase of 18.72%, and tended to be in a balanced state.

Funding

This work was supported by the National Natural Science Foundation of China (72161011).

Conflict of interest

The authors declare no conflict of interests.

References

1. Tian, X. and Xu, J., 2022. Do place-based policies promote local innovation and entrepreneurship?. *Review of Finance, 26*(3), pp.595-635.
2. Zhu, M.X., Kim, I.J. and An, Z.Q., 2021. Optimizing the Construction of Multidimensional System of Entrepreneurship Education from the Perspective of the Second Classroom. *Scientific Programming, 2021*, pp.1-7.
3. Yodchai, N., Ly, P.T.M. and Tran, L.T.T., 2022. How the creative mindset affects entrepreneurial success in the tourism sector: the mediating role of innovation capability. *International Journal of Contemporary Hospitality Management, 34*(1), pp.279-298.
4. Liu, H., Kulturel-Konak, S. and Konak, A., 2021. A measurement model of entrepreneurship education effectiveness based on methodological triangulation. *Studies in Educational Evaluation, 70*, p.100987.
5. Ogochukwu, I. J., 2021. Entrepreneurship innovation and finance. *Journal of Behavioural Economics, Finance, Entrepreneurship, Accounting and Transport, 9*(1), pp. 16-35.
6. Zhou, Q., 2021. Research on the problems and countermeasures of the cultivation of adult college students' innovation and entrepreneurship ability in the internet era. *Open Access Library Journal, 8*(7), pp.1-12.
7. Rippa, P., Landi, G., Cosimato, S., Turriziani, L. and Gheith, M., 2022. Embedding entrepreneurship in doctoral students: the impact of a T-shaped educational approach. *European Journal of Innovation Management, 25*(1), pp.249-270.
8. Khyareh, M.M. and Amini, H., 2021. Governance quality, entrepreneurship and economic growth. *Journal of Competitiveness, 13*(2), p.41.
9. McGill, P., 2021. Commentary on "Making the world a better place: achieving impact through innovation and an entrepreneurial ethos". *Tizard Learning Disability Review, 26*(3), pp.157-159.
10. Shahid, M., 2021. Review of Studies Related to Quality Entrepreneurship (ie Innovation and Internationalization) as Outcomes of Entrepreneurial Networking. *Asia Proceedings of Social Sciences, 7*(2), pp.169-174.
11. Hu, W., Hu, Y., Lyu, Y. and Chen, Y., 2021. Research on integrated innovation design education for cultivating the innovative and entrepreneurial ability of industrial design professionals. *Frontiers in Psychology, 12*, p.693216.
12. Xia, T. and Liu, X., 2021. Cultural values and innovation: the mediating role of entrepreneurial learning capacity. *Journal of International Management, 27*(1), p.100812.
13. Garousi Mokhtarzadedeh, N., Jafarpanah, I. and Zamani Babgohari, A., 2022. Knowledge management capability, entrepreneurial creativity, entrepreneurial intensity and firm performance: the mediating role of ambidexterity. *British Food Journal, 124*(7), pp.2179-2208.
14. Mostafiz, M.I., Sambasivan, M. and Goh, S.K., 2021. The performance of export manufacturing firms: roles of international entrepreneurial capability and international opportunity recognition. *International Journal of Emerging Markets, 16*(8), pp.1813-1839.
15. Xie, G.H., Wang, L.P. and Lee, B.F., 2021. Understanding the impact of social capital on entrepreneurship performance: the moderation effects of opportunity recognition and operational competency. *Frontiers in Psychology, 12*, p.687205.

16. Urban, B. and Maphumulo, M., 2022. The moderating effects of entrepreneurial orientation on technological opportunism and innovation performance. *European Journal of Innovation Management, 25*(3), pp.901-921.

17. Cunha, J., Ferreira, C., Araujo, M. and Nunes, M.L., 2022. The mediating role of entrepreneurial intention between creativity and social innovation tendency. *Social Enterprise Journal, 18*(2), pp.383-405.

18. Bachmann, J.T., Ohlies, I. and Flatten, T., 2021. Effects of entrepreneurial marketing on new ventures' exploitative and exploratory innovation: The moderating role of competitive intensity and firm size. *Industrial Marketing Management, 92*, pp.87-100.

19. Bunduchi, R., Crisan-Mitra, C., Salanta, I.I. and Crisan, E.L., 2022. Digital product innovation approaches in entrepreneurial firms-the role of entrepreneurs' cognitive frames. *Technological Forecasting and Social Change, 175*, p.121343.

20. Dabic, M., Stojcic, N., Simic, M., Potocan, V., Slavkovic, M. and Nedelko, Z., 2021. Intellectual agility and innovation in micro and small businesses: The mediating role of entrepreneurial leadership. *Journal of Business Research, 123*, pp.683-695.

21. Salisu, J.B., 2020. Entrepreneurial training effectiveness, government entrepreneurial supports and venturing of TVET students into IT related entrepreneurship-An indirect-path effects analysis. *Heliyon, 6*(11), e05504.

22. De Rosa, M., Bartoli, L., Charatsari, C. and Lioutas, E., 2020. Knowledge transfer and innovation adoption in women farmers. *British Food Journal, 123*(1), pp.317-336.

23. Jenson, I., Doyle, R. and Miles, M.P., 2020. An entrepreneurial marketing process perspective of the role of intermediaries in producing innovation outcomes. *Journal of Business Research, 112*, pp.291-299.

24. Zbierowski, P., 2020. The mystery of high performance-mediation by entrepreneurial orientation and organizational citizenship behavior. *Journal of Entrepreneurship, Management and Innovation, 16*(2), pp.67-92.

25. Qian, X., Shi, H., Ge, C., Fan, H., Zhao, X. and Liu, Y., 2020. Application research on service innovation and entrepreneurship education in university libraries and archives. *International Journal of Computational Science and Engineering, 22*(1), pp.96-106.

26. Zhou, J., Zhang, D., Ren, W. and Zhang, W., 2022. Auto color correction of underwater images utilizing depth information. *IEEE Geoscience and Remote Sensing Letters, 19*, pp.1-5.