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The Coupling Analysis of Innovation Input-Innovation Output-Innovation Environment—The Case of China

Hang Li*, Sangwook Kim**

*Doctor Student, Dept. of East-Asia Studies, Paichai University, Daejeon, Korea
**Professor, Dept. of China Trade and Commerce, Paichai University, Daejeon, Korea

[Abstract]

In the digital age, innovation is at the heart of information technology development. This paper explores the differences of regional innovation capabilities from within the innovation system from a new perspective. By applying the coupling coordination degree model, the coupling coordination degree analysis is conducted for the three systems of innovation (innovation input, innovation output, and innovation environment) in 31 provinces, municipalities, and autonomous regions of China. The results show that: the overall level of coupling coordination degree in China is low, and the number of provinces in good coordination and quality coordination is low number, but they are all distributed in the eastern economically developed regions, showing a high correlation between regional innovation and regional economic development. The overall trend of China's innovation coordination is on the rise. The research results of this paper can provide a new perspective for the evaluation of innovation capability, and also provide an important impact of innovation on promoting the development of ICT industry.

▸ **Key words**: China, Coupling Analysis, Coupling Coordination Degree, Innovation Output, Innovation Input, Innovation Environment

[요 약]

디지털 시대에 혁신은 정보기술발전의 핵심이다. 본문은 혁신 시스템 내 지역혁신능력의 차이를 새로운 관점에서 분석하고 있다. 본 연구는 커플링조정모델을 이용하여 중국의 31개 성, 시, 자치구의 혁신시스템(혁신투입, 혁신산출, 혁신환경)에 대해 커플링 정도를 비교 분석하고 있다. 분석 결과는 두 가지로 요약할 수 있다. 첫째, 중국의 전반적인 커플링 조정 수준은 낮다. 그리고 양호한 커플링과 높은 수준의 커플링 단계에 있는 지역의 수는 많지 않다. 둘째, 커플링의 전반적인 추세는 상승하고 있으나, 상대적으로 양호한 커플링 단계에 있는 지역은 대부분이 지역경제발전 수준이 높은 동부 연해안 지역에 분포되어 있다. 본문의 연구 결과는 혁신 능력 평가에 대한 새로운 관점을 제공할 수 있으며, ICT 산업의 발전을 촉진하는 데 혁신이 중요한 영향을 미칠 수 있음을 강조하고 있다.

▸ **주제어**: 중국, 커플링분석, 커플링조정도, 혁신산출, 혁신투입, 혁신환경

• First Author: Hang Li, Corresponding Author: Sangwook Kim
*Hang Li (1247587664@qq.com), Dept. of East-Asia Studies, Paichai University
**Sangwook Kim (jinxiangyu@pcu.ac.kr), Dept. of China Trade and Commerce, Paichai University
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I. Introduction

In the digital age, where information technology and industry are converging, innovation is at the core. This paper examines the impact of coordinated development within innovation on regional innovation capacity. It is also of great practical importance to enhance the competitiveness of the ICT industry and improve the technological development of the Internet.

Currently, academic analysis within innovation systems has focused on the impact of innovation input on the innovation environment. Some studies examine the impact on innovation capacity in terms of innovation input, R&D investment is one of the key factors affecting innovation capacity[2][3]. Furman et al.(2002) using various OECD countries finds that R&D investment alone can explain the differences in innovation capacity across countries[4]. de Rassenfosse & van Pottelsberghe de la Potterie(2009) finds that policy and education determines the relationship between R&D and patent output[5]. Some scholars have studied the aspect of innovation input to innovation output and found that there are three cases. First, R&D input has a positive relationship to output. Pakes & Griliches(1980) found that the elasticity of effect of both was about 0.6 when they studied patent and R&D data of 121 companies in the United States[6]. R&D investment has a positive impact relationship on innovation output, thus improving the core competitiveness of the company[7][8][9][10]. Second, innovation inputs hurt output, however, Bergström (2000) in his study of Swedish firms came to a different conclusion that government subsidies have a positive effect only in the first year, and all subsequent ones bring a negative effect[11]. Srinivasan & Lilien(2009) found that increased R&D investment during the recession not only does not have any beneficial effect on the profitability of service firms but also makes e-commerce firms less profitable[12]. Li, Yulong & Cui, Zihan(2021) used extended decoupling score to verify the relationship between innovation input and innovation outputs, demonstrating the existence of decoupling in the vast majority of regions[13]. Bound et al.(1982) found that as R&D investment increases, the number of patents obtained decreases[14]. Ben & Wang(2011) found that inadequate or excessive innovation input can lead to inefficient innovation output[15]. Third, another part of the study concludes that there is no significant relationship between the two. Bönte (2004) studying German manufacturing, finds that input under government subsidies does not affect firm production[16]. It can be observed that there is uncertainty in the relationship between both R&D and innovation output[17].

The term coupling originally comes from physics and mainly refers to the phenomenon of two or more systems that are interdependent, interact and promote each other. Coupled coordination allows a better measure of the synergy between systems and is widely used. Li, Min & Wang, Lei(2017) studied the degree of coupling and coordination of circular economy and green finance[18]. It can be seen that scholars have little research on the coupling relationship within the innovation system. In summary, from the existing studies, there are many academic studies on innovation. However, most scholars have looked at the relationship between innovation performance and innovation output from the perspective of R&D input. Most of them are further dominated by linear relationships, with less research on the internal coupling of innovation systems and a lack of nonlinear analysis for comprehensive evaluation. This paper argues that regional innovation is a coupled and coordinated relationship that includes an innovation input-output-environment and has interactions. Therefore, this paper analyzes the coordination within 31 provinces, cities, and autonomous regions in China by constructing the index system of innovation three systems and using the coupling coordination degree model, which can provide a new research perspective for improving the innovation capacity of regions.

II. Innovative three-system coupling mechanism

The innovation system is a complex and multi-layered dynamic system, and the different elements that make up the system have a mutually reinforcing and constraining effect on each other. The innovation system can be divided into three subsystems: innovation input, innovation output, and innovation environment[1]. Among them, innovation input includes human resources and financial investment, innovation output includes papers and turnover, innovation environment includes elements such as social environment and government support.

The coupled coordination of regional innovation input, innovation output, and innovation environment refers to the existence of interrelationship among the three subsystems and their constituent elements, which influence and constrain each other. The innovation elements in the regional innovation system form an orderly movement, the innovation resources are efficiently utilized, and then the innovation output is increased and continuously transformed into an innovation environment with the joint action of other elements to promote the rapid development of the regional economy. The improvement of the innovation environment attracts more innovative talents and stimulates the innovation output, constituting a dynamic linkage of the three. On the one hand, the innovation environment provides a financial and technological guarantee for independent innovation, which promotes the superposition effect of innovation capacity. On the other hand, it also promotes innovation subjects to attract new knowledge, technology, talents, and other innovation resources from other regions, which advances the further improvement of regional innovation capacity. The regional innovation system generates synergistic effects under the continuous action of the three subsystems, and the whole system develops orderly. and innovation capacity is improved continuously in the end.

Coupling is derived from physics, and analyzing its relationship can be a good solution to the developmental obstacles between systems. And the coupling coordination degree is the degree of coordination between different systems in the development process[19][21][22][18].

III. Research Methodology and Data Sources

1. Method of calculating the weights

The entropy method can avoid subjective factors, and its weight calculation is based on the actual observation of data and objective data[21], so this paper selects the entropy method in determining the index weights, and the specific calculation formula is as follow. Calculate the sample standard value P_{ij}, entropy value e_j, and utility value d_j for the jth indicator.

$$P_{ij} = \frac{X_{ij}}{\sum_{i}^{m} X_{ij}} \tag{1}$$

$$e_j = -\frac{1}{\ln m} \sum_{i}^{m} P_{ij} \ln P_{ij} \tag{2}$$

$$d_j = 1 - e_j \tag{3}$$

The weight W_j of the jth indicator.

$$W_j = \frac{d_j}{\sum_{j=1}^{p} d_j} \tag{4}$$

2. Linear weighting method

After determining the index weights with the entropy weight method in the previous subsection, the evaluation model of the comprehensive level of the three systems of regional innovation is constructed. Its calculation formula is (5)[22].

$$U_i = \sum_{j=1}^{n} W_j P_{ij} \tag{5}$$

Where, U_i is the integrated level of development of the i system. W_j is the weight of j indicators. P_{ij} is the standardized value of each indicator.

3. Coupling coordination degree model

In this paper, innovation input, innovation output, and innovation environment are regarded as three systems, which interact and influence each other. Based on the coupling theory, it can then be defined as the coupling of innovation input, innovation output, and innovation environment. The calculation formula is as follows[18].

$$C = 3 \times \left[\frac{U_1 \times U_2 \times U_3}{(U_1 + U_2 + U_3)^3} \right]^{\frac{1}{3}} \tag{6}$$

Where C is the coupling degree value, the value range is [0,1], the larger the value of C, the stronger the interaction between the system. U_1, U_2, U_3 are the composite scores of innovation input, innovation output, and innovation environment systems respectively.

C can only discern the degree of interaction between systems. It cannot reflect the degree of harmony and consistency between systems. In this paper, we introduce the coupling coordination degree model.

$$D = \sqrt{C \times T} \tag{7}$$

$$T = \beta 1 U_1 + \beta 2 U_2 + \beta 3 U_3 \tag{8}$$

Where T is the combined level of innovation input, innovation output, and innovation environment. β1 is the weight of innovation input. β2 is the weight of innovation output. β3 is the weight of innovation environment. In this paper, we consider that innovation input, innovation output, and innovation environment are equal important, so β1=β2=β3, taking a value of 1/3. According to the previous literature Zhang Huili et al. (2018), the coupling coordination degree criteria are divided as shown in the table1[19].

Table 1. Classification of coupling coordination degree types

Coupling coordination	Degree of coupling coordination	
0<D≤0.3	1	Severe disorders
0.3<D≤0.5	2	On the verge of disorder
0.5<D≤0.7	3	Primary coordination
0.7<D≤0.9	4	Good coordination
0.9<D≤1.0	5	Quality coordination

IV. Empirical Analysis

4.1 Indicator system and study area

Citing the innovation indicator system of Li & Kim (2022) and related data, this paper calculates the composite score and coupling analysis of innovation input (U1), innovation output (U2), innovation output (U3) in 31 provinces, cities, and autonomous regions of China through the coupling coordination degree model[1].

4.2 Overall description of the composite score of each subsystem

In terms of investment, the region with the highest innovation input score in 2006 is Beijing, the region with the highest innovation input score in 2013 is Guangdong, and the region with the highest innovation input score in 2020 is still Guangdong. Guangdong has had a high growth rate of innovation input over the three years, and the regions with the smallest innovation input scores over the three years are Qinghai and Xizang. In terms of growth, the provinces with the fastest growth in Innovation input during the three years are Guangdong and Jiangsu.

In terms of innovation output, the top ranking in the three years is still Beijing, Zhejiang, Guangdong, and Jiangsu. Although Beijing's innovation input has been gradually declining over the three years, Beijing, as the capital of China, has long developed a stable system of innovation output generation, having experienced the key economic development of China's reform and opening up over the decades. The fluctuating states

Table 2. Score and coupling coordination degree of each innovation subsystem

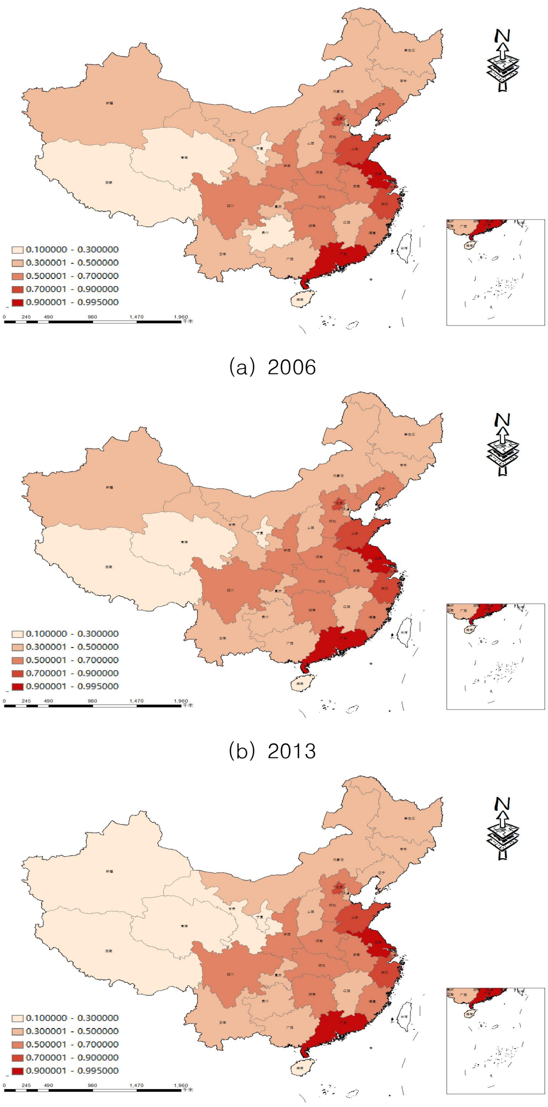
	2006					2013					2020				
Region	U1	U2	U3	D	Type	U1	U2	U3	D	Type	U1	U2	U3	D	Type
Beijing	0.614	0.573	0.418	0.881	4	0.566	0.561	0.420	0.818	4	0.491	0.585	0.422	0.766	4
Tianjin	0.413	0.428	0.337	0.485	2	0.437	0.424	0.337	0.488	2	0.373	0.439	0.332	0.410	2
Hebei	0.451	0.441	0.337	0.542	3	0.458	0.433	0.336	0.522	3	0.421	0.463	0.344	0.515	3
Shanxi	0.415	0.404	0.333	0.438	2	0.420	0.401	0.317	0.403	2	0.373	0.427	0.319	0.373	2
Inner Mongoria	0.382	0.392	0.316	0.342	2	0.396	0.393	0.326	0.362	2	0.357	0.416	0.327	0.333	2
Liaoning	0.476	0.471	0.366	0.639	3	0.468	0.450	0.356	0.577	3	0.391	0.464	0.338	0.476	3
Jilin	0.404	0.411	0.320	0.421	2	0.406	0.408	0.318	0.404	2	0.363	0.429	0.317	0.358	2
Heilongjiang	0.430	0.432	0.327	0.495	2	0.418	0.421	0.317	0.438	2	0.367	0.431	0.308	0.350	2
Shanghai	0.537	0.536	0.413	0.797	4	0.508	0.495	0.401	0.702	4	0.435	0.527	0.407	0.656	3
Jiangsu	0.600	0.600	0.469	0.935	5	0.660	0.652	0.486	0.987	5	0.563	0.650	0.478	0.903	5
Zhejiang	0.530	0.592	0.479	0.885	4	0.536	0.583	0.461	0.841	4	0.489	0.592	0.466	0.800	4
Anhui	0.424	0.428	0.344	0.505	3	0.469	0.452	0.354	0.578	3	0.435	0.470	0.370	0.566	3
Fujian	0.420	0.437	0.362	0.534	3	0.438	0.443	0.381	0.557	3	0.404	0.471	0.408	0.562	3
Jiangxi	0.418	0.408	0.315	0.420	2	0.425	0.410	0.323	0.436	2	0.405	0.445	0.341	0.472	2
Shandong	0.550	0.532	0.440	0.824	4	0.584	0.521	0.450	0.815	4	0.495	0.556	0.426	0.749	4
Henan	0.479	0.475	0.361	0.639	3	0.504	0.463	0.373	0.638	3	0.468	0.496	0.383	0.635	3
Hubei	0.469	0.472	0.349	0.613	3	0.485	0.473	0.365	0.628	3	0.439	0.509	0.368	0.609	3
Hunan	0.439	0.451	0.338	0.546	3	0.459	0.445	0.345	0.550	3	0.428	0.485	0.366	0.573	3
Guangdong	0.622	0.638	0.497	0.995	5	0.674	0.629	0.469	0.968	5	0.626	0.720	0.495	0.995	5
Guangxi	0.398	0.406	0.320	0.402	2	0.415	0.402	0.319	0.402	2	0.384	0.425	0.331	0.399	2
Hainan	0.353	0.376	0.292	0.173	1	0.366	0.378	0.290	0.205	1	0.340	0.397	0.299	0.203	1
Chongqing	0.395	0.419	0.314	0.410	2	0.413	0.421	0.320	0.436	2	0.387	0.449	0.332	0.444	2
Sichuan	0.481	0.467	0.342	0.605	3	0.492	0.461	0.350	0.603	3	0.456	0.498	0.366	0.612	3
Guizhou	0.378	0.388	0.296	0.278	1	0.394	0.398	0.300	0.336	2	0.376	0.422	0.314	0.361	2
Yunnan	0.392	0.401	0.309	0.365	2	0.408	0.399	0.308	0.373	2	0.382	0.426	0.321	0.386	2
Xizang	0.348	0.370	0.287	0.100	1	0.354	0.373	0.278	0.100	1	0.332	0.389	0.288	0.100	1
Shanxi	0.452	0.437	0.325	0.516	3	0.462	0.439	0.343	0.542	3	0.407	0.482	0.352	0.533	3
Gansu	0.381	0.394	0.304	0.322	2	0.390	0.395	0.298	0.320	2	0.358	0.412	0.303	0.292	1
Qinghai	0.350	0.373	0.290	0.140	1	0.357	0.373	0.285	0.144	1	0.333	0.392	0.291	0.134	1
Ningxia	0.355	0.378	0.291	0.184	1	0.360	0.376	0.291	0.181	1	0.337	0.395	0.296	0.180	1
Xinjiang	0.377	0.391	0.310	0.322	2	0.388	0.386	0.307	0.308	2	0.357	0.403	0.308	0.277	1

of innovation inputs and innovation outputs in Jiangsu and Guangdong remain the same. It can be seen that these two regions have consistent input-output coordination. In terms of growth, the provinces with the fastest growth in innovation output during the three years include Guangdong and Anhui.

In terms of the innovation environment, Guangdong and Jiangsu, and Zhejiang have maintained their leading positions during the three years, while Beijing is not in the leading position, which again shows that Beijing's innovation output has developed and matured. In terms of growth, the provinces with the fastest-growing innovation environment in the three years were Sichuan, Guizhou, Shaanxi, and Fujian.

4.3 Overall coupling coordination degree results and analysis

Looking at three different points in time, 2006, 2013, and 2020, the changes in the graph are more obvious. Among them, from 2006 to 2013, the change in Guizhou Province is more obvious, change from severe disorders to on the verge of disorder, improving by one grade, indicating that Guizhou's innovation coordination ability is constantly improving and has greater potential for development. From 2013 to 2020, the changes in Liaoning and Xinjiang are more obvious, both lowering the coordination level by one level each. The possible reason for this is that the coupling coordination between Liaoning and Xinjiang has been decreasing since 2006, plus the outbreak of COVID-19 in 2020, which has had a greater impact on the two regions. Liaoning province was once a



(a) 2006

(b) 2013

(c) 2020

Fig. 1. Spatial differences in regional innovation coupling coordination degree in China in 2006, 2013 and 2020

major industrial province in China. With the transformation of China's economic development, the Liaoning industry is facing great challenges. Liaoning currently does not have a complete science and technology innovation industry chain and has a weak independent innovation capability. Therefore, more attention should be paid to the innovation coordination capacity of the above regions. They can be broadly classified into five categories according to the size of the D-value and the classification criteria.

(1) Quality coordination area: Guangdong, Jiangsu

The table 2 shows that the overall trend of the region is innovation output (U2) > innovation input (U1) > innovation environment (U3), which is the innovation output type. According to evaluation of China's regional innovation capacity in 2021, Guangdong Province has ranked first for five consecutive years[20]. Guangdong Province has benefited from the reform and opening-up policy, and its overall economic development has also led to the development of innovation. Although Guangdong's innovation environment(U3) is located in the top 31 regions in China, the innovation output (U2) index is higher compared to Guangdong Province itself, which is because Guangdong Province has formed a fairly mature innovation output system with a strong output transformation capability.

(2) Good coordination area: Beijing, Shanghai, Zhejiang and Shandong

The relationship between these provinces excluding the 2020 regional innovation subsystem is largely innovation input(U1) > innovation output (U2) > innovation environment(U3), which shows that the development of innovation output in these four provinces in 2006 in 2013 is relatively lagging compared to innovation input, and the transformation of innovation input to innovation output is less efficient. By 2020 all four provinces have regional innovation output(U2) > innovation input(U1) > innovation environment(U3), indicating that their ability to transform innovation output has risen in recent years. The common feature of these regions is that they have developed economic bases, which provides strong support for the development of innovation. As a result of China's reform and opening policy, the eastern coastal regions represented by the Yangtze River Delta and the Pearl River Delta have not only attracted a large amount of foreign investment and a large inflow of innovative resources, effectively promoting innovation development, but it also clearly distinguishes itself from other regions in terms of its innovative dynamism.

(3) Primary coordination area : Hebei, Liaoning, Anhui, Fujian, Henan, Hubei, Hunan, Sichuan, Shanxi

Sichuan has been increasing the role of innovation input to innovation output, but the coordination of innovation is low because of the poor transformation of innovation output results, which affects the overall coordination of innovation development. Provinces and cities on the verge of dislocation have high room for innovation improvement, so the state should focus on strengthening innovation input and innovation environment in these provinces, which has a strong impact on improving China's overall innovation capacity.

(4) On the verge of disorder area : Tianjin, Shanxi, Inner Mongolia, Jilin, Heilongjiang, Jiangxi, Guangxi, Chongqing, Yunnan, Gansu, Xinjiang

Most provinces have a downward trend in innovation output (U2) > innovation input (U1) > innovation environment (U3) in both 2006 and 2013, and a possible reason for the downward trend in innovation output in 2020 is the shock of the COVID-19 and the decline in output in 2020. Provinces that are themselves on the verge of dislocation are less coordinated, and most also have a weaker industrial development base, which COVID-19 exacerbates by reducing the efficiency of innovation inputs to innovation outputs. Due to the high number of provinces with severe dislocations, there is also greater variation within them. They are therefore the provinces with more potential for leapfrogging development.

(5) Severe disorders area : other remaining provinces

In most of these regions, the relationship between the regional innovation subsystems is one of innovation output (U2) > innovation input (U1) > innovation environment (U3). Because of their geographical location, these regions have a low level of economic development and a weak industrial development base, which does not provide a sufficient economic base for innovation development, resulting in a lag in innovation investment and a low level of overall coordination. It is easy to see that, despite being in a region of serious dislocation, innovation output continues to outstrip innovation input, which shows that these provinces and cities have greater potential for development.

V. Conclusion

China's overall innovation system is at a low to medium level of coordinated development and is still far from a high level of coordinated coupling. This is consistent with the fact that China's overall innovation capacity is at the lower to middle level, and indirectly justifies this study[1]. The coupling coordination of all provinces, municipalities, and autonomous regions has decreased in 2020 by the impact of COVID-19, but the coupling coordination of most of the regions in the middle and low coordination development has been optimized from the data of 2006 to 2013, which can be seen that the imbalance of regional innovation development in China is gradually improving, and the overall show a better trend of regional innovation capacity improvement.

The regions with a higher degree of coupling and coordination are still the economically developed eastern regions, showing a high correlation between regional innovation and economic development. This shows the characteristic of high in the east region and low in the west region. This result is consistent with China's economic development in that the better developed regions also have relatively high innovation capacity.

The relationship between most regional innovation subsystems shows that innovation output (U2) > innovation input (U1) > innovation environment (U3), this is contrary to the results of previous studies, and this paper suggests that the possible reasons for the discrepancy are the different systems used to construct the indicators, as well as the different years of the study[22]. Indicating that the efficiency of China's innovation output is gradually improving, and therefore regions should pay more attention to the efficiency of innovation output transformation while increasing innovation input.

Due to various limitations, there are some shortcomings in this paper, which may have some influence on the evaluation results considering the availability of data. And this paper only studies the results of regional innovation coupling coordination degree in time, and does not analyze from the spatial perspective, which also has some limitations. Innovation is the core of development in the digital era, and innovation drives ICT technology toward networking, digitization, and other directions. It has an important positive impact on enhancing the competitiveness of ICT industry, improving the development of Internet technology, etc.

REFERENCES

[1] Li, Hang & Kim, Sangwook, "Comparison of Innovation Capabilities-The Case of Chinese Regions," Journal of the Korea Society of Computer and Information, Vol.27, No.9, pp.225-234, September 2022. DOI:10.9708/JKSCI.2022.27. 09.225

[2] Arrow, K. J., "The Economic Implications of Learning by Doing," The Review of Economic Studies, Vol.29, No.3, pp.155-173, Jun. 1962. DOI:10.2307/2295952

[3] Romer, P. M., "Increasing Returns and Long-Run Growth," Journal of Political Economy, Vol.94, No.5, pp.1002-1037, Oct. 1986. DOI:10.1086/261420

[4] Furman, J. L., Porter, M. E. and Stern, S., "The Determinants of National Innovative Capacity," Research Policy, Vol.31, Issue 6, pp.899-933, Aug.2002. DOI:10. 1016/s0048-7333(01)00152-4

[5] De Rassenfosse, G. & van Pottelsberghe de la Potterie, B., "A Policy Insight into the R&D-patent Relationship," Research Policy, Vol.38, Issue 5, pp.779-792, June 2009. DOI:10.1016/ j.respol.2008.12.013

[6] Pakes, A. & Griliches, Z., "Patents and R and D at the Firm Level: A First Look,", NBER Working Paper 0561, Oct. 1980. DOI:10.3386/w0561

[7] Los, B. &. Verspagen, B., "R&D Spillovers and Productivity: Evidence from U.S. Manufacturing Microdata," Empirical Economics, Vol.25, Issue 1, pp.127-148, Feb. 2000. DOI: 10. 1007/s001810050007

[8] Morikawa, M., "Information Technology and the Performance of Japanese SMEs," Small Business Economics, Vol.23, No.3, pp.171 -177, Oct. 2004. DOI: 10.1023/b:sbej.000003 2023.11566.4b

[9] Fosfuri, A. and Tribo, J., "Exploring the Antecedents of Potential Absorptive Capacity and its Impact on Innovation Performance," Omega, Vol.36, Issue 2, pp.173-187, April 2008. DOI:10.1016/ j.omega.2006.06.012

[10] Tomlinson, P. R., "Co-operative Ties and Innovation: Some New Evidence for UK Manufacturing," Research Policy, Vol.39, Issue 6, pp.762-775, July 2010. DOI: 10.1016/j.res pol.2010.02.010

[11] Bergström, F., "Capital Subsidies and the Performance of Firms," Small Business Economics, Vol.14, Issue 3, pp.183-193, May 2000. DOI:10.1023/A:1008133217594

[12] Srinivasan, R., Lilien, G. L., "R&D, Advertising and Firm Performance in Recessions," ISBM Report 3-2009, Institute for the Study of Business Markets, The Pennsylvania State University.

[13] Li, Yulong & Cui, Zihan , "Research on Innovational Input-Output Decoupling and Efficiency of Counties in the Yangtze River Delta," East China Economic Management, Vol.35, No.2, pp.31-38, 2021(Chinese language). DOI: 10.19629/j.cnki.34-1014/f.200917001

[14] Bound, J., Cummins, C., Griliches, Z., Hall, B. H., and Jaffe, A. B., "Who Does R&D and Who Patents?," NBER Workingpaper 0908, June 1982. DOI:10.3386/w0908

[15] Ben, Taiming & Wang, Kuanfei, "Interaction Analysis among Industrial Parks, Innovation Input, and Urban Production Efficiency," Asian Social Science, Vol.7, No.5, pp.56-71, April 2011. DOI:10.5539/ass.v7n5p56

[16] Bönte, W., "Spillovers from publicly financed Business R&D: Some Empirical Evidence from Germany," Research Policy, Vol.33, Issue 10, pp.1635-1655, December 2004. DOI:10.1016 /j.respol.2004.09.009

[17] Greco, M., Grimaldi, M. and Cricelli, L., "Hitting the Nail on the Head: Exploring the Relationship between Public Subsidies

and Open Innovation Efficiency," Technological Forecasting and Social Change, Vol.118, pp.213-225, May 2017. DOI:10.1016/j.techfore.2017.02.022

[18] Li, Min and Wang, Lei, "Research on the Coupling and Coordinated Development of Circular Economy and Green Finance in Beijing-Tianjin-Hebei Region," Journal of Industrial Technological Economics, Vol.41, No.5, pp.72-77, 2022(Chinese language). DOI: 10.3969/j.issn.1004-910X.2022. 05.009

[19] Liu, Chuanming, and Fan, Guanyu, and Wang, Chengxiang, "Spatial-temporal Evolution Characteristics of Coupling Coordination between Urbanization and Grain Production in Huaihe Eco-economic Belt," Areal Research and Development, Vol.41, No.1, pp.38-44, 2022(Chinese language). DOI: 10.3969/j.issn.1003-2363.2022.01.007

[20] China Science and Technology Development Strategy Research Group, "Evaluation of China's Regional Innovation Capacity in 2021," Scientific and Technical Documentation Press, pp.136-140, 2021(Chinese language). ISBN: 97875189 85814

[21] Wang, Fuqiang and Ying, Zhuohui and Lv, Subing and Zhao Heng, "Evaluation of coupling coordinated development characteristics of water-economy-ecology system in Beijing-Tianjin-Hebei region," Water Resources Protection, Vol.38, No.5, pp.80-86, 2022(Chinese language). DOI: 10.3880/j.issn.1004-6933.2022.05.012

[22] Shen, Hongting, and Lu, Yuqi, and Shen, Jinghong, "Spatial-Temporal Coupling of Provincial Innovation Input-Innovation Output-Innovation Performance in China," Economic Geography, Vol.37, No.6, pp.17-22, 2017(Chinese language). DOI: 10.15957/j.cnki.jjdl.2017.06.003

Authors

Hang Li received his Bachelor and Master degrees in China Tiangong University Radio and TV Editing and Paichai University Economics and Commerce Studies of North East Asia Masters in 2017 and 2020 respectively. Dr. Li is currently enrolled in Paichai University Economics and Commerce Studies of North East Asia for her Ph.D. She is interested in regional economics, innovation, and economic modeling.

Sangwook Kim received the B.S. and M.S. degrees in Economics from Kyungpook National University, Korea, in 1996, 1998 and received Ph.D. degrees in Regional Economics from Nankai University, China, in 2002. Dr. Kim joined the faculty of the Department of China Trade and Commerce at Paichai University, Daejeon, Korea, in 2008. He is interested in regional economics, urban economics, economic modelling.