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Exploring the Relationship between Open Innovation and Innovation Performance in Big Data Environment: The Moderating Effects of Innovation Expropriability

Abstract: - In the era of big data, the industry environment is complex and volatile, and enterprises need to innovate their business models by creating innovative value networks and reconstructing transaction systems to avoid being eroded in the process of global economic transformation. The traditional closed innovation processes are no longer deemed suitable for advancing firm innovation. Instead, open innovation has become a pivotal strategic choice in the quest to foster innovative developments. This study builds upon the paradox of open innovation (OI) in the age of big data, and introduces the innovation expropriability theory. Utilizing survey data from high-tech industrial park firms in the Yangtze River Delta region of China, it empirically examines the influence of open innovation on firm innovation performance (FIP). Furthermore, it explores the independent and joint moderating effects of rival absorptive capacity (RAC) and appropriability regimes (ARs). The findings reveal that OI significantly improves FIP. The effect of OI on FIP is positively moderated by ARs, while the independent moderating effect of RAC is not significant. However, a joint moderating effect is observed between RAC and ARs. Further investigation reveals that the moderating role of RAC depends on the presence of ARs, indicating a matching relationship between RAC and ARs. This research holds significant implications for firms in implementing open innovation strategies and ensuring effective intellectual property protection to enhance innovation performance in the era of big data.

Keywords: Big Data, Open Innovation, Innovation Expropriability, Rival Absorptive Capacity, Appropriability Regimes, Innovation Performance.

I. INTRODUCTION

As the booming advancement of the Internet and big data technology, the total amount of data has shown explosive growth, and its volume has reached the level of PB/EB [1]. In the meantime, the security risks of firm innovation and production factors such as data, information and knowledge are increasing day by day [2]. Knowledge leakage, information trafficking and other enterprise data security incidents occur frequently, which bring serious hidden dangers to enterprise business secrets and innovation revenue [3].

Amidst intensifying industry competition, increasing technological complexity, accelerated knowledge iteration, and shortened product lifecycles, firms have broken away from the traditional closed innovation paradigm and shifted towards the flexible and adaptable approach of open innovation to navigate the rapidly changing external innovation landscape [4]. However, there remains a contrasting perspective on whether OI can effectively enhance FIP, giving rise to the "open innovation paradox". On one hand, the "organizational openness" perspective argues that OI facilitates the interaction, integration, and collaboration of innovation elements among firms. By engaging in extensive cross-organizational cooperation, firms can acquire valuable external resources and knowledge, thereby contributing to improved FIP. On the other hand, the "spillover prevention" view contends that while building open innovation networks with external stakeholders across organizational boundaries, firms need to exhibit or share their technological knowledge, which increases the risk of product information leakage and core knowledge exposure, potentially hampering FIP [5]. Moreover, empirical studies conducted by scholars both domestically and internationally have generated diverse results on the relationship between OI and FIP. Some scholars have found a positive correlation [6], while others have uncovered negative or inverted U-shaped relationships [7].

The "open innovation paradox" can be summarized as a contradiction between knowledge sharing and protection, specifically referring to the plight that firms face in disclosing some knowledge to exchange with partners while also needing to protect their knowledge from unauthorized theft. Considering the risks of innovation

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uncertainty, knowledge leakage, and opportunism associated with OI, the ability to effectively protect the fairness and rationality of the process of value creation and acquisition becomes a key factor influencing the benefits of OI. The introduction of the theory of expropriability sheds light on addressing the inconsistency in the findings mentioned above. Expropriability refers to the ability of competitors to access and utilize a firm's innovative knowledge [8]. It is influenced by two factors: the risk of knowledge spillover induced by competitor imitation and learning, as well as the knowledge protection barriers formed by the firm through the establishment of mechanisms to prevent knowledge leakage, namely, rival absorptive capacity and appropriability regimes [8, 9]. RAC acts as a key factor in defining the competitor's ability to absorb exogenous knowledge for self-innovation [9]. It is a gauge of competitors' ability to mine innovation from OI networks, which can easily trigger imitation and detrimental knowledge spillover. ARs, by granting firms exclusive rights over their knowledge and setting knowledge protection barriers, can restrict free-riding behavior by imitators. This not only promotes the commercialization of innovative technological achievements but also has a positive impact on knowledge spillover and RAC in an OI environment. Therefore, under different levels of RAC and ARs, OI may have varying effects on FIP. Existing research lacks an exploration of the boundary conditions that influence the relationship as stated above from the standpoint of expropriability.

Based on the above analysis, our paper examines the link between OI and FIP by introducing the binary analysis framework of the theory of expropriability. It examines the independent and combined moderating effects of RAC and ARs on the relationship between OI and FIP. The key contributions are as follows: (1) Analyzing and testing the fundamental relationship between OI and FIP, providing more empirical support for the existing theoretical disagreements; (2) Analyzing and testing the independent moderating effects of RAC and ARs on the relationship between OI and FIP, helping to clarify the boundary conditions that influence the impact of OI on FIP; (3) Analyzing and testing the combined moderating effects of RAC and ARs on the link between OI and FIP, revealing the complexity of the moderating effects of expropriability in the context of OI. This also provides guidance for firms to adjust their OI strategies according to the level of expropriability.

II. THEORETICAL AND HYPOTHESES

A. Expropriability and its Matching Scenarios

RAC and ARs collectively contribute to the expropriability of innovation for a firm [8, 9]. These two factors exhibit different matching relationships, as shown in Table 1 below. (1) When high rival absorptive capacity is coupled with high appropriability regimes, the firm faces a moderate level of expropriability, effectively restricting imitative behavior by competitors. (2) When low rival absorptive capacity is coupled with low appropriability regimes, the firm also faces a moderate level of expropriability, as the weak absorptive capacity of competitors renders their imitative behavior ineffective. (3) When low rival absorptive capacity is coupled with high appropriability regimes, the firm encounters weak expropriability, making it difficult for competitor imitative behavior to pose a threat. (4) When high rival absorptive capacity is coupled with low appropriability regimes, the firm faces strong expropriability, making it easy for competitors to engage in imitative behavior.

Table 1: Matching Scenarsios of Rival Absorptive Capacity and Appropriability Regimes

		Rival absorptive capacity	
		Low	High
Appropriability regimes	High	Low rival absorptive capacity-high appropriability regimes (weak expropriability)	High rival absorptive capacity - high appropriability regimes (moderate level of expropriability)
	Low	Low rival absorptive capacity-low appropriability regimes (moderate level of expropriability)	High rival absorptive capacity - low appropriability regimes (strong expropriability)

B. Research Hypotheses

1) OI and FIP

The relationship between OI and FIP has been widely explored by scholars, but a consensus has not yet been reached. Most studies suggest a positive linear relationship between OI and FIP [10]. However, some scholars argue that the relationship is not purely positive, as excessive openness may result in a dependency on external resources, undermining the firm's inclination towards innovation. Considering that the overall level of openness in Chinese firms is not high and the negative effects of excessive openness have not yet emerged [11], we believes that OI can enhance FIP. Firstly, OI practices facilitate the exploration of external knowledge and the integration of internal and external innovation resources, thus compensating for internal knowledge deficiencies and avoiding

the “familiarity trap” or “core rigidity” caused by overreliance on internal knowledge [12]. Secondly, OI promotes interactive learning between firms and external partners, facilitating the full realization of collaborative synergies in cross-organizational cooperation, iterative upgrading of the company's knowledge base and knowledge management system, and ultimately leading to cost-saving in technological innovation and improved product development efficiency. Thirdly, open innovation expands the opportunities for firms to benefit from their innovation outcomes, allowing for enhanced innovation performance through various forms of externalization, such as technology licensing, franchising, and patent sales [13]. Given these considerations, we propose the following hypothesis:

H1: Open innovation positively impacts firm innovation performance.

2) Independent moderating effect of RAC

Based on the “diamond model” proposed by Schumpeter, not only competing firms but also various organizations such as suppliers and users are considered potential “rivals”. RAC can influence FIP in the context of OI in two ways. On one hand, the capability-based view suggests that rival absorptive capacity provides firms with knowledge about local competitors’ resources, actual and potential competitive threats, and enhances firms’ competitive awareness and capabilities [14]. This encourages firms to effectively utilize external innovation resources, adapt to turbulent and complex business environments, continuous development of new products and services, and improve their innovation performance. On the other hand, transaction cost theory argues that rival absorptive capacity may result in the loss of core assets such as products, processes, and customers to rival firms [15], leading to a loss of innovation leadership. Firms may be defeated by rival companies in the competition for learning, thereby facing significant risks of losing innovation knowledge, information, and achievements, hindering the improvement of FIP in the OI context. Considering that the current innovation protection environment in China is not yet perfect, while RAC might have both positive and negative moderating effects on the relationship between OI and FIP, the positive innovation incentive effect is smaller than the negative innovation imitation effect. Therefore, rival absorptive capacity is expected to exhibit an overall negative moderating effect. Given these considerations, we propose the following hypothesis:

H2: RAC negatively moderates the relationship between OI and FIP.

3) Independent moderating effect of the ARs

With the changing business environment, scholars have found that ARs is not only an exogenous variable influenced by the industry environment but also an endogenous variable through which firms change and shape their own strategic activities and business behaviors, exhibiting strong subjectivity and agency [16]. The theory of profiting from innovation suggests that in the process of open innovation, there are inevitable risks such as knowledge leakage and opportunism, and firms need the appropriability regimes to protect against the erosion of innovation benefits by external stakeholders. When the appropriability regimes are strong, a high level of protection can reduce the risks of knowledge spillover and opportunism in the open innovation environment, effectively stimulate firm innovation motivation, and promote the increase in innovation benefits. Furthermore, a high level of protection can ensure that firms enjoy the fruits of their innovation, safeguarding their innovation interests. Finally, a high level of protection facilitates the formation of a fair and trustworthy network environment [17], enhancing firm innovation motivation within the open innovation network. Conversely, when the appropriability regimes are weak, a low level of protection cannot prevent malicious knowledge spillover and opportunistic behavior within the open innovation network, hindering the formation of a fair and trustworthy environment, and consequently impeding the improvement of FIP in the OI context. Given these considerations, we propose the following hypothesis:

H3: ARs positively moderates the relationship between OI and FIP.

4) Joint moderating effect of RAC and ARs

RAC and the ARs together constitute the firm’s innovation expropriability, which determines the firm’s ability to utilize external knowledge for innovation [8, 9]. Therefore, there exists a joint moderating effect of RAC and ARs on the relationship between OI and FIP. As mentioned earlier, RAC has both a positive innovation incentive effect and a negative innovation imitation effect on the relationship between OI and FIP, while the ARs facilitates the firm in realizing the positive innovation incentive effect of RAC and mitigating the innovation imitation effect. When the ARs are strong, the firm sets up knowledge protection barriers and increases the difficulty of knowledge imitation, thereby restricting the rival firms' ability to acquire and utilize knowledge and mitigating the detrimental effects of RAC. Conversely, when the ARs are weak, the firm’s knowledge protection capability is insufficient, making it easier for rival firms to imitate knowledge at a lower cost, thus ineffective in limiting the adverse impact of RAC on FIP [18]. Hence, compared to firms with weaker appropriability regimes, firms with stronger

appropriability regimes not only realize the innovation incentive effect of rival absorptive capacity but also avoid the innovation imitation effect, thereby being more likely to achieve higher FIP. Given these considerations, we propose the following hypothesis:

H4: RAC and ARs have a joint moderating effect on the relationship between OI and FIP.

The following conceptual model is proposed based on the above analysis (Figure 1).

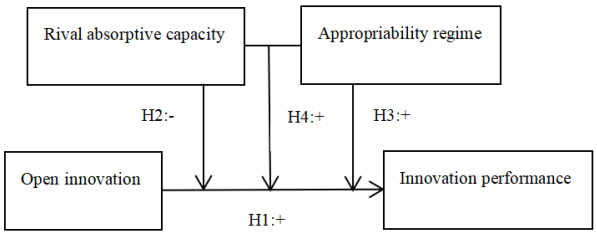

Figure 1: Conceptual Model

III. RESEARCH METHODOLOGY

A. *Data Source*

This study selected high-tech industrial park firms in the Yangtze River Delta region of China as the research subjects, primarily due to their strong innovativeness and high willingness to openness. The measurement of research variables in this article drew upon well-established scales from top domestic and international journals, and underwent a standard translation-backtranslation process considering contextual factors from previous foreign research. Various sources, including relevant government departments, industry associations, and alumni networks of academic institutions, MBA students, and EMBA students from academic institutions, were utilized to collect firm directories and contact information. Thirty firms were randomly selected to participate in pre-survey activities, and based on the results, questionnaire items were further refined. The formal survey began in October 2022 and concluded in February 2023. Sample selection followed the following criteria: (1) firms regularly engage in both inward and outward open innovation activities; (2) firms have more than 50 employees. CEOs, CTOs, and other executives who possess a deep understanding of the firm's innovation activities were invited to participate in the survey, and active participation was encouraged through the provision of research reports and other means. We distributed 400 questionnaires and obtained 297 valid questionnaires, with a validity rate of 74.3%.

In this survey, the focus was primarily on small and medium-sized firms, with 39.1% of them having a workforce of 50-100 people, 37.0% with 100-500 employees, 13.5% with 500-1,000 employees, and 10.4% with over 1,000 employees. Regarding the age of the firms, 36.4% fell within the 2-5 year range, 34.0% within 5-10 years, 20.5% within 10-20 years, and 9.1% had been in operation for more than 20 years. With respect to their nature, surveyed firms consisted of 35.0% state-owned firms, 15.2% joint ventures (with Chinese control), and 49.8% private firms.

B. *Variable Measurement*

All items in this research survey were measured using a Likert 5-point scale, with 1 indicating "completely inconsistent" and 5 indicating "completely consistent", where higher scores imply a better fit with the actual situation of the firm.

1) Dependent variable

Firm Innovation Performance (FIP): According to the research of Hsu and Fang [19] and Alegre and Chiva [20], the overall measurement of firm innovation performance combines four indicators: better product quality achieved through technology adoption compared to competitors, improved production flexibility through technology transformation compared to competitors, customer recognition obtained through new product development, and the average patent growth rate over the past three years.

2) Independent variables

Open Innovation (OI): Based on the scale developed by Hung et al. [21], five items were designed to measure OI from the dimensions of inbound and outbound OI.

3) Moderating variables

Rival Absorptive Capacity (RAC): Based on the studies of Zahra and George [22] and Jansen et al. [23], four items were designed to measure rival firms' investment in acquiring external new knowledge, as well as the identification, perception, acquisition, and assimilation of external knowledge.

Appropriability Regimes (ARs): According to Hurmelinna-Laukkanen et al. [24], four items were designed to measure appropriability regimes, including formal regimes such as patents and trademarks, and informal regimes such as secrecy agreements.

4) Control variables

Drawing from the findings of Zhang and Li [25], this study considered firm age (AGE), firm size (SIZE), cooperation years (LENGTH), and industry type (INDUSTRY) as the primary control variables.

IV. Empirical Results and Analysis

A. Homogeneity Bias Test

Following the recommendations of Podsakoff et al. [26], some items in the questionnaire were reverse-coded, and questionnaires with obvious contradictory answers were eliminated during the data cleaning process. Exploratory factor analysis was conducted using the Harman single-factor method, which included all items. The results revealed that, without rotation, four common factors emerged, with the first factor explaining 37.6% of the total variance. This indicates that there was no homogeneity bias in this study.

B. Reliability and Validity Test

First, reliability analysis was conducted for the variables of OI, RAC, ARs, and FIP. The results, as shown in Table 2, were evaluated using the heterogeneity index, and the Cronbach's α coefficients for the four variables and the overall scale were 0.886, 0.910, 0.899, 0.901, and 0.855, respectively. All coefficients exceeded 0.70, indicating high reliability of the questionnaire used in this survey.

All items measured in this study were taken from well-established expert research and were refined based on the results of a pre-survey to ensure content validity. Additionally, the results of the KMO test and Bartlett's test of sphericity demonstrated that the overall KMO value and cumulative variance explained exceeded 70.0%, indicating high convergent validity of the questionnaire as a whole.

Table 2: Reliability and Validity Test Results

Measurement items	Reliability coefficient	KMO	Factor explanatory power
Open Innovation	0.886	0.860	71.22%
Rival Absorptive Capacity	0.910	0.830	78.50%
Appropriability Regimes	0.899	0.818	75.67%
Firm innovation performance	0.901	0.827	78.81%
The overall reliability coefficient of the sample data: 0.855; KMO value: 0.895; the factor explanatory power: 75.91%			

C. Exploratory Factor Analysis

Exploratory factor analysis was performed for the variables of open innovation, rival absorptive capacity, appropriability regimes, and firm innovation performance. The results revealed that the communalities of the measurement items for the four latent variables exceeded the threshold of 0.6, and the factor analysis met the statistical requirements (see Table 3). Additionally, considering the results from Table 2, the dimension of open innovation accounted for an accumulated variance of 71.22%, rival absorptive capacity accounted for 78.50%, appropriability regimes accounted for 75.67%, and firm innovation performance accounted for 78.81%. Moreover, each variable of open innovation, rival absorptive capacity, appropriability regimes, and firm innovation performance yielded a distinct factor.

D. Descriptive Statistics

Table 4 presents the mean, standard deviation, and correlation coefficients for open innovation, rival absorptive capacity, appropriability regimes, and firm innovation performance. There is a significant positive correlation between OI and FIP ($r=0.49$, $p<0.001$), providing initial support for H1, which suggests that open innovation fosters improvements in firm innovation performance. RAC shows a significant negative correlation with FIP ($r=-0.33$, $p<0.001$). There is a significant positive link between ARs and FIP ($r=0.52$, $p<0.001$). RAC also exhibits a significant negative correlation with the appropriability regimes ($r=-0.16$, $p<0.05$). The highest correlation coefficient among the variables in Table 4 is 0.52 (less than 0.70), indicating that multicollinearity issues in this model can be ruled out.

Table 3: Exploratory Factor Analysis

Latent variables	Measurement items	Component matrix	Communality
Open Innovation	Our firm frequently acquires valuable knowledge from external sources.	0.767	0.611
	Our firm establishes close connections and engages in collaborative innovation with external entities.	0.832	0.676
	Our firm actively seeks better knowledge from external sources	0.846	0.755
	Our firm proactively disseminates knowledge to the outside world.	0.881	0.783
	Our firm frequently collaborates with external entities in developing new technologies.	0.855	0.736
Rival Absorptive Capacity	Our competitors invest heavily in acquiring new knowledge.	0.910	0.832
	Our competitors are able to quickly identify and acquire the knowledge they need.	0.921	0.856
	As soon as new knowledge emerges in the industry, our competitors strive to acquire it.	0.867	0.771
	Our competitors can easily grasp the knowledge they obtain.	0.832	0.694
Appropriability Regimes	Patent or copyright applications.	0.842	0.711
	Trademark registration.	0.903	0.813
	Signing confidentiality agreements.	0.861	0.742
	Preventing the loss of key technical personnel by increasing salaries and other means.	0.871	0.761
Firm innovation performance	Obtained better product quality compared to competitors through technology importation.	0.865	0.753
	Obtained better production flexibility compared to competitors through technological transformation.	0.897	0.801
	Customer recognition obtained through new product development.	0.901	0.807
	Average annual growth rate of patents over the past three years.	0.894	0.792

Table 4: Correlation Coefficient Matrix

Variables	1	2	3	4	5	6	7	8
AGE	1							
SIZE	-0.03	1						
LENGTH	0.12*	0.09	1					
INDUSTRY	0.05	0.05	-0.10	1				
OI	-0.01	0.08	0.31***	0.01	1			
RAC	-0.17**	0.06	-0.38***	0.13*	-0.07	1		
ARs	0.13*	-0.11	0.36***	-0.04	0.46***	-0.16*	1	
FIP	0.14*	0.05	0.51***	0.00	0.49***	-0.33***	0.52***	1
Mean	2.70	2.68	2.52	0.49	2.57	2.66	2.41	3.03
S.D.	0.86	0.83	0.90	0.50	0.77	0.66	0.60	0.67

Note: *** $p<0.001$，** $p<0.01$，* $p<0.05$.

E. Regression Results

1) Direct effect testing

Hierarchical regression analysis was conducted to examine the research hypotheses. The results are presented in Table 5. Model 1 serves as the baseline, and Model 2 includes the addition of open innovation, resulting in a significant improvement in model fit. The regression coefficient for open innovation is 0.34, which is significant at $p<0.001$, indicating a positive and significant impact of open innovation on firm innovation performance. This finding further confirms hypothesis H1.

2) Testing of independent moderating effect

Models 3 and 4 were used to examine the independent moderating effects of RAC and ARs. In Model 3, after including the interaction term of open innovation*rival absorptive capacity, the regression coefficient of the interaction term is not significant ($\beta=0.05$, $p>0.05$), thus H2 is not supported. In Model 4, after including the

interaction term of open innovation*appropriability regimes, the regression coefficient of the interaction term is significant (β=0.12, p<0.01), indicating that the ARs positively moderates the relationship between OI and FIP, thus supporting hypothesis H3.

Table 5: Regression Analysis Results

	Model 1	Model 2	Model 3	Model 4	Model 5
N	1.88***	1.33***	1.69***	2.17***	2.06***
AGE	0.08	0.09	0.07	0.06	0.02
SIZE	0.00	-0.02	-0.01	0.01	0.02
LENGTH	0.51***	0.40***	0.34***	0.34***	0.25***
INDUSTRY	0.05	0.04	0.05	0.04	0.06
OI		0.34***	0.37***	0.20***	0.20***
RAC			-0.12*		-0.12*
ARs				0.31***	0.29***
OI*RAC			0.05		0.03
OI*ARs				0.12**	0.11*
OI*RAC*ARs					0.13**
R^2	0.27	0.38	0.40	0.46	0.49
ΔR^2		0.11***	0.02***	0.06***	0.03***
F value	27.41***	35.51***	27.25***	35.29***	27.39***
VIF Max	1.04	1.15	1.95	1.42	1.96

Note: *** p＜0.001， ** p＜0.01， * p＜0.05.

To visually demonstrate the moderating effects of RAC and ARs, the sample was divided into groups by adding and subtracting one standard deviation from the mean of the moderating variables, as suggested by Aiken [27]. The regression coefficients of the grouped data were calculated to depict the moderation effect plot and conduct a slope test. The moderation effect plot (Figure 2) for rival absorptive capacity shows that there is no significant difference in the impact of OI on FIP between high and low RAC contexts, indicating that the independent moderating effect of RAC is not supported. On the other hand, the moderating effect plot (Figure 3) for the ARs demonstrates that when the level of ARs are high, the effect of OI on promoting FIP is enhanced. Conversely, when the level of ARs are low, the promoting effect is weakened. This indicates that the ARs positively moderates the relationship between OI and FIP.

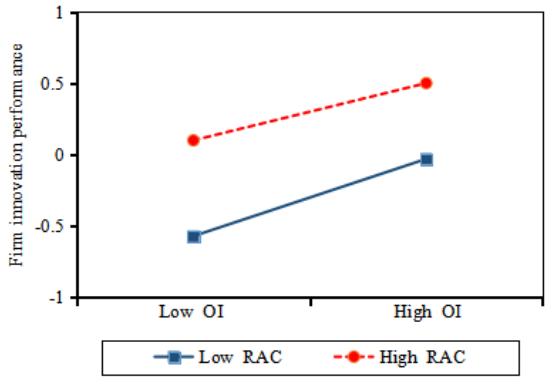

Figure 2: The Moderating Effect of RAC on the Relationship between OI and FIP

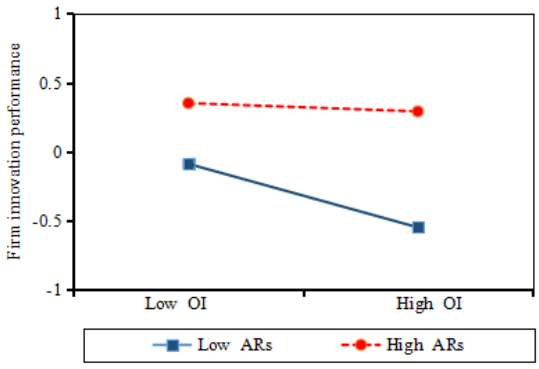

Figure 3: The Moderating Effect of the ARs on the Relationship between OI and FIP

3) Testing of joint moderating effect

The joint moderating effect of RAC and ARs on the relationship between OI and FIP was examined in Model 5. After incorporating the interaction term of OI * RAC * ARs, the regression coefficient of the interaction term was found to be significant (β=0.13, $p<0.01$). This suggests that RAC and ARs jointly moderate the relationship between OI and FIP, supporting Hypothesis 4. Exploring the joint moderating effect plot (Figure 4) of RAC and ARs, it is observed that when both RAC and ARs are high, the slope of OI in promoting FIP is most significant. This indicates the existence of a joint moderating effect between RAC and ARs.

The insignificant single moderating effect of RAC suggests that the relationship between OI and FIP is contingent upon the presence of ARs. Further investigation revealed a match between RAC and ARs. When RAC is high and combined with a high level of ARs, it leads to the greatest improvement in FIP under OI conditions (Regression Line 1 VS Regression Line 2). This may be attributed to the effective limitation of knowledge leakage and imitation threats induced by high RAC through the presence of the ARs, which minimizes the risk of innovation imitation. Additionally, the presence of high RAC acts as a motivation for continuous development of new products and services, driving sustained innovation within the organization. The presence of a high level of ARs effectively controls the negative effects of RAC in terms of innovation imitation, while also promoting positive innovation incentives, thereby enhancing FIP. On the other hand, when there is a match between low RAC and low levels of ARs, it leads to a greater improvement in FIP under OI conditions (Regression Line 4 VS Regression Line 3). This is because low RAC hinders the acquisition, absorption, and assimilation of innovation knowledge within the organization, while the low level of ARs limits the organization's ability to protect innovation knowledge from external spillovers. Consequently, competitors with weak absorptive capacity are unable to acquire the organization's innovation knowledge. Moreover, although the organization's ARs are weak, it is sufficient to protect the benefits of innovation while avoiding unnecessary resource consumption. Therefore, when there is consistency between RAC and ARs, imitation and absorption by competitors do not pose a threat to the organization's innovation capabilities, thus facilitating the realization of innovative benefits.

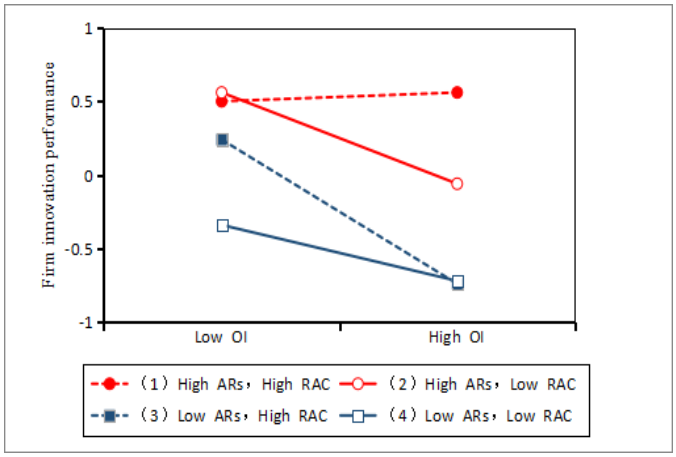

Figure 4: The Joint Moderating Effect of RAC and ARs on the Relationship between OI and FIP

V. DISCUSSION

A. Theoretical Contributions

Big data has changed the mode of enterprise innovation network, and innovation expropriability can improve the risk management ability of enterprise innovation under big data from the aspects of theory, technology and method. The research on the integration of enterprise innovation network and innovation expropriability under big data is of great significance. Based on the fundamental relationship between OI and FIP, this study integrated the theory of innovation expropriability and proposed an analysis framework for OI knowledge management to elucidate the relationship between OI and FIP under different conditions of innovation expropriability. The study yielded the following valuable findings:

First, OI positively affects FIP. Although open innovation is regarded as an important antecedent variable affecting firm innovation, the relevant theories and empirical studies have not reached a consensus. Some scholars, based on the idea of knowledge spillover and knowledge sharing, argue for a positive relationship between the two. On the other hand, some scholars, based on the notion of knowledge spillover inducing technological imitation, argue for a negative or inverted U-shaped relationship, suggesting that excessive openness amplifies the risks of knowledge leakage and opportunistic behavior. In this study, through empirical testing on companies in the

Yangtze River Delta region, it is found that open innovation significantly and positively influences firm innovation performance, providing further support for the research views of Chesbrough & KARsdon [28]. This could be attributed to the emphasis placed by firms in the Yangtze River Delta region on cultivating absorptive capacity, thereby enhancing their ability to identify and transform external knowledge. The negative effects associated with excessive openness have yet to manifest in this region.

Furthermore, the ARs positively moderates the relationship between OI and FIP, while the moderating effect of RAC is not significant. This is mainly due to the fact that the ARs promotes the flow of knowledge within open innovation networks by setting up knowledge protection barriers, which benefits the improvement of innovation performance under OI conditions. On the other hand, rival absorptive capacity increases the potential for knowledge spillovers within OI networks, while also incentivizing continuous innovation by firms. The positive effects of innovation incentives and the negative effects of imitation incentives may offset each other, resulting in the non-significant moderating effect of rival absorptive capacity. This study utilized a binary analysis framework based on the theory of innovation expropriability to separately examine the independent moderating effects of the ARs and RAC on the relationship between OI and FIP. It not only provides a deeper analytical perspective on the open innovation paradox but also expands the boundary conditions of innovation performance within the context of OI.

Thirdly, the relationship between OI and FIP is jointly moderated by RAC and ARs. Further research has revealed that the moderating effect of RAC on the relationship between OI and FIP depends on the ARs, indicating a matching relationship between RAC and ARs. Specifically, when there is a high match between RAC and ARs, it contributes to enhancing the positive impact of OI on FIP. Conversely, when there is a low match between RAC and ARs, it further amplifies the positive impact of OI on FIP. By examining the relationship between OI and innovation performance under scenarios of matching and mismatching between RAC and ARs from the perspective of innovation expropriability, this research enriches the theoretical understanding of OI in complex contexts. It helps explain the divergent findings regarding the OI paradox and provides guidance for firms in implementing OI strategies and dynamically adjusting the level of innovation expropriability to enhance FIP.

B. Management Insights

Firstly, Chinese firms should actively engage in open innovation activities. At present, the overall openness of our country's firms is relatively low, and the negative effects of excessive openness have not yet emerged. OI has a positive impact on FIP. In light of this, Chinese firms should not only prioritize the search for external knowledge at the strategic level and cultivate their ability to search for external knowledge, but also strengthen communication and interaction with customers, research institutions, suppliers, and competitors to expand the diversity of external knowledge acquisition. Additionally, attention should be given to cultivating internal organizational culture and adjusting the organizational structure in order to shape an open organizational culture, foster a flexible organizational structure, and foster an entrepreneurial spirit of exploration.

Secondly, it is important to use appropriability tools to protect innovation benefits and limit imitation and absorption by competitors. Innovation benefits are the primary driving force for maintaining innovation vitality in firms. The threat of imitation and copying by competing firms can deepen the vicious competition between the firm and its stakeholders, leading to a state of innovation inertia and lock-in. Restricting the imitation of technological innovation by competitors can limit homogeneous competition among firms, safeguard innovation benefits, and incentivize investment in innovation activities.

Lastly, it is crucial to effectively align the rival absorptive capacity with appropriability regimes. When competitors have low absorptive capacity, the threat of innovation imitation is weak. Establishing weaker appropriability regimes not only protects the innovation performance of the firm but also reduces unnecessary resource waste, facilitating the realization of innovation benefits. On the other hand, when competitors have high absorptive capacity, the threat of innovation imitation becomes more severe. Constructing stronger appropriability regimes not only reduces the threat of innovation imitation by competitors but also achieves the incentives for innovation, thereby facilitating the realization of innovation benefits.

C. Research Limitations

The current research questionnaire targeted the Yangtze River Delta region in China. However, China's territory is vast, and there are significant differences in the innovation dynamics and openness levels of firms in different regions. In future studies, it would be beneficial to conduct large-scale empirical research in different regions and industries across China to enhance the generalizability of the findings. Furthermore, this study confirmed the moderating effect of innovation expropriability and only examined the influence of two variables, namely, appropriability regimes and rival absorptive capacity. However, there may be other factors that could

potentially moderate the main effects of this study, such as dynamic capabilities of firms, ownership types, and business models. Future research could consider exploring the potential moderating effects of these additional factors.

VI. CONCLUSIONS

In conclusion, expanding the literature on firms' innovation strategies in big data environments by combining open innovation theory and expropriation theory, our study finds that OI has a positive effect on FIP. Our study further sheds light on the the independent and joint moderating effects of RAC and ARs in affecting this relationship. We believe our study has provided a richer understanding of the relationship between OI and FIP strategy and hope that it will stimulate further research on this topic.

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