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Technology Complexity and Open Organization: Foreign Innovation Projects in the Biopharmaceutical Sector in China

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Abstract

High-technology enterprises are increasingly developing their technological advantages in foreign countries. In doing so, they need to make the decision whether to organize the R and D activity inside the organization or outside through alliance. The perceived assumption suggests that technological complexity dictates the internal organization of the R and D activity. However, emerging evidence suggests that technological complexity induces external alliance for the transformation of the organizational knowledge to new product. We test this proposition that there is a positive correlation between technological complexity and the external alliance of the firm. The hypotheses find support that complexities of (i) Scale, (ii) Scope, (iii) Intra-clusters and (iv)Inter-cluster of the patent claims predict external alliance. However, the odds of the external alliance are not in a linear manner. Rather, the odds of these predictors are high, low and high again. The article discusses theoretical and practical implications.

Keywords: Transformation of technology; Complexity of patent claims; Alliance for clinical trials; Innovation projects in China; New product development

Introduction

High technology organizations are increasingly facing survival and growth challenges. Whereas the investment in R and D projects is increasing; the development of the new product is decreasing in the biopharmaceutical sector [1]. The pressure for the productivity and emerging opportunities from changing institutions as well as from the advent of enabling information and communication technologies are pushing firms to manage their R and D projects efficiently and effectively around the world. In doing so, high technology firms are attempting to avail opportunities in foreign countries that are not available at in the home market. Thus, the arising need for and opportunities from the changing environment have disturbed two established assumptions in the organizational literature.

The first perceived assumption is that high-technology organizations prefer home countries for their innovation projects (R and D) [2]. However, the evidence increasingly shows that knowledge organizations are increasingly locating their innovation activities in the other industrialized economies [3,4]. A further challenge to the perceived assumption is that firms from industrialized economies are locating their R and D projects in emerging economies [5]. Thus, the international location of the high technology R and D is not limited to the developed countries.

The second perceived assumption is that high technology firms prefer the transformation of vertical technology inside the organization. One reason for the internalized innovation activity is the preference for low transaction cost inside the organization compared to the outside. The other reason for this assumption is the high risk of the pilferage of the technology outside the firm. Accordingly, the firm prefers to manage its innovation projects inside its boundaries Williamson [6], In particular, technological complexity tends to incur a high external transaction cost and risk of external pilferage. Therefore, technological complexity should predict the internalization of the innovation projects of the high technology firm [7].

However, this widely perceived assumption considers the transaction cost but ignores the potential value from the external alliance [8]. The emerging evidence suggests that organizations are increasingly forming external alliances for positive outcomes [9]. Instead of focusing on the transaction cost, the knowledge enterprise needs to focus on the value creation through the alliance. Without a sustainable alliance with external resource owners, the firm cannot access private resources of its partners. Therefore, the international location does not constraint the external collaboration for the strategic purpose of technology transfer [10].

Firstly, the external alliance can reduce technical and institutional uncertainty in R and D projects [11]. Secondly, the external alliance offers complementary values in the transformation of the complex technology [12]. Thirdly, open innovation provides conducive conditions for the inter-partner technological appraisal [13]. Fourthly, open innovation captures dynamics of the industrial value chain Hellman [14,15], and in doing so, it can reduce the knowledge theft by locking-in the potential rival. Thus, an external alliance is more likely than the internalized innovation products of complex technologies [16-18].

Despite these developments in the literature, there exists an empirical void. No systematic study has established a systematic link between the technological complexity in patent structures and external alliance for the transformation of knowledge to products in the foreign market. Our exploratory study aims to make some progress in

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this direction. The main purpose of this study is to understand whether an increase in the technological complexity in the codified knowledge predicts an increase in the external alliance by foreign firms in China.

We support the idea that organizations in the biopharmaceutical sector prefer strategic alliance in a foreign market for their innovation projects when they face challenge for the transformation of the complex technology [19,20]. Thus, the empirical question is whether technological complexity correlates with the external alliance in clinical trials as innovation projects.

Theory and Hypotheses

Innovation

The concept of innovation tends to vary across context. Even Schumpter [21], offers five types of innovation: (i) new products, (ii) new methods of production, (iii) new markets, (iv) new chains of input, and (v) new industrial structures. The OECD adds the sixth dimension, which refers to the external relation of the organization [22]. These definitions constitute two main interrelated concepts: product innovation and organizational innovation. Product innovation, for our purpose, refers to the new pharmaceutical drug. The process of a new drug development requires the transformation of codified knowledge to embodied, which hinges upon the organizational tacit knowledge necessary for a successful and smooth organizational coordination. In other words, the clinical trial process, which is a transformation of patented knowledge to drugs and medical technologies, is a consequence as well as an antecedent of organizational explicit knowledge (contents), tacit knowledge (organizational learning), and embodied knowledge (technological products). Hence, the interaction of these types of knowledge with the industrial system constitutes the broader concept of technology in the innovation project.

Clinical trials

A clinical trial is an R and D activity for a new product development in the biopharmaceutical industry, which refers to an innovation project in the industry Azoulay [23], typically a clinical trial involves four phases. Phase-I engages a small number of volunteers for the safety test. Phase-II engages a large number of volunteers for the effectiveness and safety of the drug. Phase-III further expands the scale and scope of effectiveness and safety. Phase-IV takes place after the feedback from the market of the commercialized drug and upon the instruction of the FDA.

Almost every clinical trial involves multiple types of tacit knowledge from various organizations in different contexts. For instance, universities, regulatory institutions, financiers, experts, volunteers and ethical organizations take part in various ways across time and space of the clinical trial process. In the setting China, additional actors and organizations get involved in the foreign innovation project. The government, patent owners, volunteers and hospitals are some of the additions to the complexity of the foreign clinical trial. The product innovation heavily depends on the innovative organizational structures. Naturally, the clinical trial may reflect complexity in the project different from those in the home country of the sponsor.

Open organization

An open organization refers to the external alliance for an innovation project of the firm, and the external alliance enables the firm access to external resources [24]. Especially, the flow of knowledge between organizations in the industrial setting is essential for any of the above types of innovation. Since the transformation of knowledge into a new product does not occur in a vacuum, it requires a deliberated decision of the management to consider how, when and where to organize such complex activities. Earlier theorists favored a closed organization to improve economic efficiencies of the process [25]. Because R and D spending is increasing and productivity is decreasing in the biopharmaceutical sector [1,26], the contemporary view favour an open innovation that increases the firm's value by increasing its knowledge resources and potential of the drug output [9]. The extant literature indicates that the external alliance for the vertical transformation of technology provides a better chance for the survival and growth of the firm [27]. The advantage for this open organization can span to foreign locations [28], Therefore, the firm's next challenge after the internationalization decision is to decide whether to allay or acquire [29].

High technology firms prefer alliance to the internalization through acquisition good reasons. One merit of the external alliance is its role in the integration of internal and external knowledge and resources for a better value of the firm [30,31]. The interaction with the outside actors fosters a better level of organizational co- evolution with the environment, which can reduce the inertial risk [27]. The second merit of the external alliance is that external alliance can prevent the pilferage of its critical knowledge to the market by forming an alliance with the current and potential competitors. Thus, contrary to the perceived assumption, the external alliance can manage technological complexity better than the internal mode [32,33].

Technological complexity

Technological complexity refers to the number of components and their inter relationships in a system [34]. Two types of systems interact to form a technological system: a technical system such as patents and an institutional system such as organizations, industries, and national economies. Although they interact in the innovation project, our explicit concern, in the current context, is the knowledge system in patents.

According to this definition of technological complexity, a patent is a system of knowledge comprising multiple claims and their interactions. The patent contains a structure of codified knowledge that represents the potential industrial product [18]. This codified knowledge varies in the level of complexity before and after the transformation of knowledge due to the interaction of the tacit input to the explicit outcome [35]. Thus, the transformation of the knowledge in the patent occurs at two stages: before and after.

The former case, the tacit knowledge gets transformation into explicit and codified knowledge in patents. The firm transforms its tacit knowledge into codified knowledge in patents through a long process prior knowledge in the industry [36]. The complexity of the patented knowledge is likely to mirror the magnitude of the tacit knowledge of the organization. Therefore, the complexity of the codified knowledge varies across patent systems at this stage of the transformation because of the variegated tacit knowledge of the organization [35].

In the latter case, the transformation of knowledge occurs from the explicit knowledge codified in patents to embodied knowledge in products. This stage in the transformation starts with the explicit knowledge and ends with the embodied knowledge in physical products [37]. In this transformation from the codified knowledge to physical products, the organization needs to combine its tacit and explicit knowledge in subtle ways [38]. For instance, the transformation of a patent into a pharmaceutical drug requires the combination of tacit, explicit and embodied knowledge. Since explicit and tacit knowledge exists internally and externally, their interaction identifies with

the notion of knowledge complexity. In other words, the level of complexity of the patent depends on explicit and tacit knowledge, mediated by embodied knowledge and industrial conditions.

The transformation of complex knowledge depends on the change in the organizational structure from the closed to open form Ring [39], since the external alliance of the enterprise represents the open organization, we propose that the complexity in the patented knowledge can lead to the inter-organizational alliance.

Hypotheses

Patents contain multiple layers of claims that differentiate their levels of knowledge complexity in Bessen [40,41], Based on a review of patent claims through a deconstruction process, the literature alludes to four types of patent structures: patent scale, scope, intra-clusters and inter-clusters. Figure below depicts four types of patents and their levels of complexity.

Complexity of scale

The notion of scale refers to the number of claims depicted shown in Figure 1A. We expect that the patent scale can induce the need for an external alliance. Each claim represents some concepts that highlight the relevance and importance of the innovation. In social sciences, theorists suggest that the sheer number of components of a system can increase the level of complexity in the system [42].

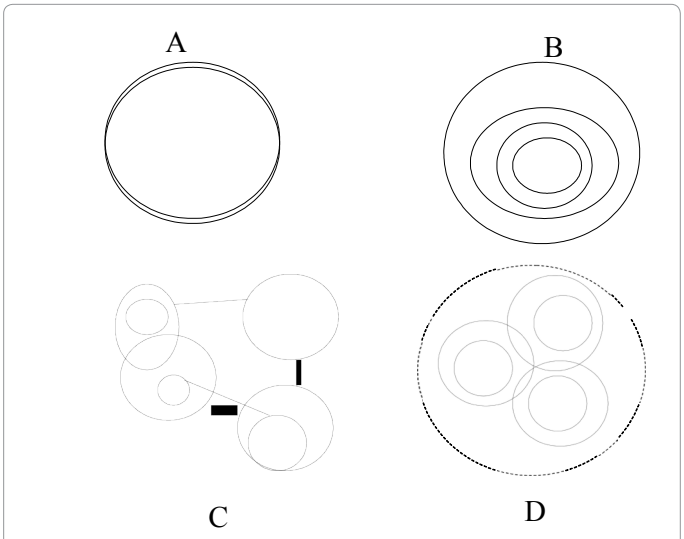
For instance, cancer is a targeted disease in the clinical trial project. We find that a typical cancer-patent has about 35.7 claims. These claims capture inputs, techniques, future possibilities, and probabilities. The reasoning behind the number of claims is that it provides exclusivity to the owner in about 36 different ways. The patent scale may capture the core technology and overlap neigh bouring technologies, tools, methods or targets. For instance, a patent issued in 2006 to a German biopharmaceutical organization has 1376 claim, which includes multiple dimensions. The transformation of knowledge from of these claims to new drugs requires complementary resources from outsiders. A review suggests that the pharmaceutical firm requires about 50 patents from external organizations to engage in the transformation of codified knowledge to new products in the clinical trial process [43].

Multiple organizations may own at least a part of the patent. The firm needs to acquire their consent. Similarly, the firm needs external investment, technical expertise, managerial knowledge and institutional approval. This view provides a straightforward positive link between the number of patent claims and external alliance.

Hypothesis 1: Complexity of the patent scale will positively correlate with open organization for the clinical trial development.

Complexity of scope

The scope of patent claims refers to the wide application of technologies in the patent claims. Whereas the patent scale suggests that multiple claims capture one innovation, the patent scope suggests that multiple innovations follow one claim. Hence, the difference between the scale and scope is of many-to-one and one-to-many respectively. Figure 1B shows in the structure of the patent claims forming a loop. The loop encircles subclasses of patent claims. A typical claim makes a ring within in another claim in a coiled-like structure. The coil structure has several potential properties. Firstly, the coil structure captures characteristics of the scale and scope. Secondly, the scope tends to include incremental applications that extend to new applications. Thirdly, the incremental innovation may capture a process, product, methodology or a combination of all. Patent owners keep appending patent claims to protect their patents and products in the pipeline.



A = Scale: Independent structure of main claims.
B = Scope: Coiled structure of sub-claims.
C = Intra-clusters: Interloping structure of links between main claims.
D = Inter-cluster: (multifarious) structure of links outside the patent.

Figure 1: Patent claims and structural complexity.

For instance, only 35% of the existing applications are complete at one time in the US patent office claim [44]. It implies that about 65% of the patent claims are not available in the public domain for an extended period. Therefore, new applicants may include those claims already submitted to the patent office. Then, 65% of patents claims remain overlapped [45], Moreover, the complexity of scopes further increases due to the conceptual variation in the patent of the firm and related patents in the market. These scopes can delay the patent office, which can lead to overlaps of claims [44].

Hypothesis 2: Complexity of the patent scope will positively correlate with open organization for the clinical trial development.

Complexity of intra-cluster

The intra-cluster complexity refers to the patent claims clustered around several targets in the industrial innovations. Clustered claims are instances of bundled knowledge that reflects endogenous and exogenous links [45]. The number of components and the degree of their interdependence makes the transformation of knowledge contingent upon the concurrent transformation of multiple products in the system [46], Figure 1C shows in reflects these intra-clusters patent claims. The literature shows that a biotechnology patent can include procedures, processes, methods and compositions of biological compounds [47-50]. Our estimate of the patents used in this study shows that about 25% of claims represent methods, about 21% claims represents inputs and outputs of the treatment. Even less so, about 10% and 7% claims represent the composition and therapy respectively. Thus, the ensuing increase in the methods requires additional tacit knowledge as well as other resources from outside partners [51,52].

Hypothesis 3: Complexity of the patent interloping will positively correlate with open organization for the clinical trial development.

Complexity of multifariousness

The multifarious patent structure refers to the complex interaction

between patents and their claims, internally and externally. Whereas the intra-cluster patent represents the major claims ownership of the firm and minor of the environment, the multifarious structure represents the minor ownership of the firm and major of the environment. The firm owns the minor but transforms the externally owned knowledge. Figure 1D shows in links between the nodes and links interloping within and outside the patent in multifarious ways. First, they overlap prior patents of the owner. Second, they include rival technologies. Third, they appear as a collection of sub-patents or super-patents. The inwards and outwards interaction makes the multifarious structure a highly complex system. This level of complexity has attributes of the previous levels of scales, scopes and interlopes. Therefore, it induces the open organization for the transformation of the technology for the following reasons.

First, the firm needs to cooperate with the external owners to reduce the cost of the clinical trial and complexity of the market environment in the host country. A clinical trial can cost a billion dollar [53]. Second, at a foreign location, the transformation of knowledge involves additional actors and interactions [45]. Third, multifarious patents favour radical innovation more than incremental innovation [54]. For instance, a vaccine for infectious diseases such as Ebola, MERS, SARS or any other epidemic is an external industrial phenomenon rather than an internal reason for the technological innovation. Such a radical innovation project engages multiple foreign institutions, which makes the multifarious patent even more complex. In comparison to the incremental innovation that improves the existing processes, the radical innovation demands external interaction.

The external dimension in the multifarious patent implies that the underlying tacit knowledge of the external organization needs to complement the transformation. In response to the potential complexity, the firm need to coordinate diverse technological assets, actors and activities in favour of integration [55], At the same time, the firm intends to keep its interdependence from the external actors in the field [56]. The inter-organizational form of open innovation meets the challenge and creates the balance.

Hypothesis 4: Complexity of the patent multifariousness will positively correlate with open organization for the clinical trial development

Methodlogy

Research context

The context of this study is the foreign owned innovation projects in the biopharmaceutical sector in China. Indeed, China offers a competitive cost-based advantage and has a highly qualified pool of human resources [22]. It has a well-developed infrastructure, especially well-equipped hospitals and efficient organizational conditions Zhang [57], by conforming to international institutions, China is moving up on the quality scale [58]. Therefore, the standard used in the clinical trial in China is on par with standards used in the industrialized countries. The size of the Chinese market for the pharmaceutical products is more than $68 billion. Moreover, China is the first country to develop the first Cancer Gene Therapy. These are some of the reasons that highlight why China attracts foreign firms in the sector [59].

Sample and data

There were 781 clinical trials sponsored by foreign organizations in China by the end of 2012. Most of these sponsors come from the OECD countries. About 58% clinical trials occur inside the organization, and about 42% occur in an open organization. We obtained the data from the NIH (National Institute of Health) and formal press releases of the sponsor. We also used OSIRIS and Factiva sources for the data on the industrial enterprises.

We meticulously coded the data in a backward process. In every clinical trial project, we identified the industrial application of the new product in the purpose. Then we linked the purpose to the patent. After identifying the main patent and its sponsor, we examined the internal structure of the patent. The examination of the patent structure in our methodology resembles a reverse engineering process. This tedious process revealed insightful and informative patterns of variegated patent structures [40]. In the biotechnology sector, the method and compounds exist together in the patent [60], Thus, the structure affects the transformation of knowledge to products.

Prior literature suggests that the process of a new product development in clinical trials is a highly time-consuming process [53]. The process becomes lengthier in the transformation of an international patent into biotechnology product. Moreover, as the number of patents is increasing in the world, the distance between the patented technology and its transformation into a new product is increasing [61,62]. Hence, the identification of these structural attributes helped the development of the relevant variables.

Variables

Dependent variable: The dependent variable is whether the technology transfer from the patent to a new product uses the open innovation or closed innovation. The open innovation mode represents the external organizational alliance (1), and the closed innovation represents internalized innovation projects (0). Thus, the dependent variable is a binary measure.

Independent variables: There are four main independent variables. The first independent variable counts the number of patent claims. It refers to the patent scale. The scale consists of the count of multiple claims that have wrapped the focal technology. The second independent variable is the ordinal

variable, from a low level to a high in terms of the complexity of the patent. These claims in the scope may or may not represent the same function in the patent. They represent sub-claims in the patent. Thus, every next level is high on the ordinal scale.

The third variable represents intra-clusters of patent claims. These are links between main claims associated with the main function of the patent. This variable is also an ordinal variable, representing a low to high level of complexity in the intra-patent clusters. The fourth variable represents inter-cluster or links between sub-claims in the patent. A patent can have multiple functional clusters and their claims. Some of the peripheral functions that are not part of the main claim can span to external technologies and functions. Hence, the multifarious patent has highest external links of claims and level of complexity.

Control variables: The first control is the size of the sponsor of the clinical trials. The size reflects the number of employees. Larger companies differ from smaller enterprises in resources and capabilities in the handling of the complexity of the social system [63,64]. The second variable is a dummy, representing European firms (OECD). The third variable is a dummy representing American firms (the USA and Canada). The third dummy is the default category (Japanese). National institutions shape organizational technology and patents; therefore, these controls account for the national institutional variation.

The remaining nine dummies represent years, from 2004 to 2012. A small number of clinical trials represent the pre-2004 period in China. The foreign entry in China for clinical trials had not taken off before 2004. Therefore, we use the pre-2004 clinical trials as the default category (0).

Results

Table 1 shows in the summary and inter-variable correlation. The correlations are less than 50%, except in the relationship between European firms and the number of cities (55%). It seems that European firms tend to conduct their clinical trials inside the firm more than they do with others. Thus, European firms are less open to collaborative activities.

Table 2 shows in VIF values in social sciences, if the value of VIF is less than 10, it is acceptable [65]. If it crosses this threshold, it violates the assumption of multicollinearity. The VIF value in our article is within the acceptable range. The VIF of European firms is slightly high. Either the organization has a broader scope of knowledge in the patent, or it is carefully organizing its patent in complex ways. The VIF does not exceed the critical limit of 10.

Table 3 shows in results from logit regression Model 1 is a base-model. Models 2 to 5 show the results from the addition of individual variables. Model 5 is the final model, and the estimated odds in the last column correspond to Model 5. The coefficients of the four types of patent structures are significant. However, the size of the odds is not in t order. The patent scale has the odd of 1.6, and the patent scope and intra-cluster have the odds of 1.4. The multifarious patent has the odds of 2.5. In this order on a scale, the four measures form an inverted-U shape curve.

In a separate analysis, we used the number of partners in the alliance as the dependent variable; therefore, we used the Poisson regression. The results also confirm a positive and significant ($p< 0.05$) coefficients for four structural predictors. Therefore, it suffices to include the focal results from the binary dependent variable to support the point. The discussion provides some insights based on the binary dependent variable.

Discussion

We posed the question whether knowledge complexity predicts the organizational alliance for the vertical transformation of the patented knowledge. The prior literature suggests that an external alliance provides an advantage to the firm. The focus of prior literature remains on the outcome of the open organization.

The current study focuses on the antecedents of the open organization. From the perspective of technological complexity of the patented knowledge, the main proposition is that an external alliance becomes inevitable for the vertical transformation of knowledge in the biopharmaceutical sector. We developed and tested four hypotheses related to the level of complexity in the codified knowledge. These propositions comprise (a) scale, (b) scope, (c) intra-clusters, and inter-clusters (multifarious). We find positive correlations between the four types of structures (predictors) and inter-organizational alliance.

However, contrary to our anticipation to find the gradual increase in the size of the coefficients of the four types, the result shows inverted U-shaped patterns of the odds. We anticipated that the odds would be in this order: multifarious > intra-cluster > scope > scale. The results show that the odds of multifarious claims are 1.6 times greater than the odds of scales, and the odds of scale are about 1.1 times greater than the odds of scopes and intra-clusters systems of patents. Thus, the odds decrease from the scale (1.6) to scope and intra- cluster (1.4), and then they increase towards multifarious (2.5) structure.

We draw two inferences from this observation. Firstly, the scale and multifarious patents induce the externalization of the innovation project more than the scale and intra- clusters. Secondly, the multifarious patents, which tend to interact with the environment more than the internal patent, generate a higher level of externalization than the scale patents. In other words, the high control of the firm on the scale patents and low control of the firm on multifarious patents reflect a dilemma.

Variables	Mean	S. Dev.	Min	Max	1	2	3	4	5	6	7
Alliance (open innovation)	0.33	0.47	0	1	1						
North American firms in China	0.3	0.46	0	1	-0.02	1					
European firm in China	0.58	0.49	0	1	-0.11***	-0.78	1				
Log size (employees) of the firm	10.86	0.81	6.4	11.7	0.01	-0.02	0.26	1			
Patent scale of claims	4.99	0.76	1	6	0.08*	-0.12***	0.24***	0.17***	1		
Scope of patent sub-claims	1.42	0.38	0	1.79	0.19***	-0.18***	0.20***	0.02	0.24***	1	
Intra-cluster loops of claims	0.29	0.57	0	2.94	0.27***	0.18***	-0.20***	0.23***	0.05	0.18***	1
Inter-cluster (multifarious) claims	5.95	0.58	0	6.39	-0.11***	-0.24***	0.55***	0.08*	0.38***	0.29***	-0.22***

N= 781, ***p< 0.001, **p< 0.01, *p< 0.05, †p< 0.1

Table 1: Summary and inter-variable correlations.

Variable	VIF
European firms in China	7.08
North American firms in China	5.82
Size of the firm in terms of employees	1.62
Patent scale of claims	1.60
Scope of patent sub-claims	1.31
Intra-cluster loops of claims	1.27
Inter-cluster (multifarious) claims	1.19
Mean VIF	2.84

Table 2: Variance inflation factor.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Odds
Constant	2.99(0.9)***	-1.13(1.2)	-0.25(1.2)	0.02(1.2)	-7.50(2.5)**	
North American	-0.17(0.34)	0.12(.35)	0.11(.36)	0.17(.36)	-1.25(0.65)†	0.5
European	-0.63(.35)†	-0.49(.36)	-0.73(.37)*	-0.49(.19)	-2.64(0.8)***	0.2
Firm Size	-0.32(.09)***	-0.41(.10)***	-0.35(.10)***	-0.42(0.11)***	0.15(0.28)	1.4
Patent scale of claims		0.99(.20)***	0.67(.19)***	0.68(.19)***	0.78(.25)***	1.6
Scope of patent sub-claims			0.00(0.00)***	0.00(0.00)***	0.00(0.00)***	1.4
Intra-cluster loops of claims				0.01(.00)***	0.01(.00)***	1.4
Inter-cluster (multifarious) claims					0.10(.03)***	2.5
Years binary variables	Entered	Entered	Entered	Entered	Entered	Entered
-Log Likelihood	462.6	416	400	394.8	268.3	
Chi-Square	34***	58.9***	93***	102***	93***	
Pseudo R-Square	0.04	0.07	0.1	0.11	0.15	
Degree of freedom	3	4	5	6	7	

Logistic regression, the dependent variable is binary (partners=1, no partner=0) N = 781, ***p< 0.001, **p< 0.01,*p< 0.05, †p<0.1

Table 3: Knowledge complexity and open innovation (vs. internalized).

We contextualize these patterns in the assumption that technological complexity engenders uncertainty, and the notion of uncertainty is opposite to the notion of managerial control. As the level of control over technological complexity increases, the level of uncertainty should decrease. However, organizations face a dilemma of uncertainty and control in the decision-making process. Should they internalize when the internal uncertainty is low Allison [49], or they should externalize when the external environmental uncertainty is high [63].

The conventional view suggests that high uncertainty leads to the internalization of innovation projects. Our evidence points to the opposite direction. We find that firms tend to increase their external alliance in the face of high uncertainty. One possible reason is that the sectoral uncertainty in the biopharmaceutical industry provides an increased level of discretion to the management of the organization, and the management has the opportunity to blame the external environment if the innovation project fails. The potential discretion enables the management making a risky investment decision in the external organizational structure. It can deflect the pressure from the management to the environment [64,65]. Thus, the level of control over technology appears to be less important than the opportunities for the external exploitation of the knowledge in the market for the new product. Therefore, the complexity-driven uncertainty supports the externalization rather than internalization in the high technology sectors.

The international dimension of the patent claims and the transformation of technology from claims to the new product further enhance the level of technological complexity in the discourse. For instance, biopharmaceutical firms are increasingly focusing on personalized medicine. The development of the personalized medicine depends on the patient's unique molecular and genetic profile to treat the gene specific disease. Personalized medicines focus on the individual patient, and the process requires a fit between the patient's genetic content (including molecular/cellular analysis for the optimal effects. The term 'personalized medicines' has diffused from its birth place of the context of genetics to everything personalized in the medical arena [42].

A comparison between China and India can explain the concept of personalized or group-specific medicines. Asthma-related innovation projects in China are more than in India, and diabetes-related innovation projects in India are more than in China. Since the population specific medicines require the interaction with the gene structure of the patient, there is a need for the proximity between the innovation project and the targeted users kaufman [66,67], Indeed, the level of complexity in the transformation is likely to increase in the process, which requires external interaction.

The study makes an incremental contribution to the theory and practice. This article offers an alternative view in a novel context. It concludes that a technologically complex project affects external organizational relations with various institutional actors Malik [68]. The simplicity and feasible nature of the framework can be helpful for the future research in a different setting in the high technology sector. For instance, information and communication technology (ICT) heavily relies on patented technology. The research in other high technology sectors can benefit from the framework with some modification. That is that science-driven technology sectors may find it relevant.

The study informs managers that strategic complexity they often seek through patent structures may compel them to form external alliances, and they end up depending on others. Firms tend to structure their patents to increase complexity to attain a higher level of autonomy in the sector. However, the increased complexity of the strategic (complex) patent increases their dependence. Second, the assumption that independence relates to low operational cost is also misplaced. If the number of patent claims correlates with the cost of the patent application, then the transformation of those claims further increases the cost when the management needs to externalize its complex knowledge in the patent. Third, at the industrial policy and institutional level, the patent complexity may favour the integration of the innovation system. In an integrated national innovation system, where the national innovation systems seek interactive learning, multifarious structures may lead to an integrated system.

There are also some limitations of this research. First, the biopharmaceutical and the clinical trial as innovation projects are different from almost all other industrial activities. The broader generalization is the first limit. Second, the study does not examine specific alliances in the context of their home countries. Third, this article uses a cross-section analysis. A longitudinal study can better explain the evolution of external cooperation. This study does not consider whether the global experience of the sponsor reflects on the decision for the alliance. Last, this study does not consider the success rate of the clinical trial in the alliance.

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