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Mix and Match: Preferred 'Mix of Open Innovation Modes' for Solving Innovation Problems

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Abstract

Open innovation is not a fad but a phenomenon. Manifold large firms have adopted different open innovation modes for coordinating open innovation projects, ranging from partnerships to open innovation platforms. However, open innovation managers require a deeper understanding of how to successfully choose the 'right' mode for a particular open innovation project. Each project has its own problem attributes that influence which open innovation modes to choose. This study explores the preferred open innovation modes for a particular open innovation project based on a sample of 104 open innovation projects collected from large firms in the US and Europe. Our results clearly indicate the attributes of innovation problem (complexity and hiddenness of required knowledge) trigger the adoption of open innovation modes.

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Abstract: *Open innovation is not a fad but a phenomenon. Manifold large firms have adopted different open innovation modes for coordinating open innovation projects, ranging from partnerships to open innovation platforms. However, open innovation managers require a deeper understanding of how to successfully choose the 'right' mode for a particular open innovation project. Each project has its own problem attributes that influence which open innovation modes to choose. This study explores the preferred open innovation modes for a particular open innovation project based on a sample of 104 open innovation projects collected from large firms in the US and Europe. Our results clearly indicate the attributes of innovation problem (complexity and hiddenness of required knowledge) trigger the adoption of open innovation modes.*

Keywords: Open Innovation, Open Innovation Modes, Problem Solving, Problem Complexity, Hiddenness of Knowledge

Open innovation is becoming increasingly pervasive among large firms (Chesbrough & Brunswicker, 2014). Firms invest in open innovation and tap into the know-how of customers, suppliers, competitors, universities but also start-ups, end-users, or even citizens in order to improve their ability to solve various kinds of innovation problems, simple ones but also more complex ones (e.g., Chesbrough & Brunswicker, 2014; Chesbrough, 2003; Dahlander & Gann, 2010; Jarvenpaa & Välikangas, 2014; Laursen & Salter, 2006; Salter, Criscuolo, & Ter Wal, 2014; West & Bogers, 2014; West, Salter, Vanhaverbeke, & Chesbrough, 2014). There is evidence that greater openness allows firms to solve such problems in a more effective and efficient way, ultimately leading to a greater innovation performance at the firm level (e.g., Foss, Laursen, & Pedersen, 2011; Laursen & Salter, 2006). While the argument that greater openness may potentially lead to higher innovation performance convinces managers to engage in open innovation, it does not provide an answer to the right open innovation 'mode'.

Indeed, open innovation comes in various modes. Alliances, licensing agreements, innovation contests, or innovation crowdsourcing are examples of modes proposed by existing literature for managing an open innovation project (Felin & Zenger, 2014; Jarvenpaa & Välikangas, 2014; Malhotra & Majchrzak, 2014; Morgan & Wang, 2010). In the lights of the variety of modes, a manager's key question has shifted from open versus closed innovation towards the right 'mode' of open innovation (Felin & Zenger, 2014; Pisano & Verganti, 2008). This study aims to provide managers with an answer to this question. It is motivated by existing work that reports the variety of open innovation modes that firms choose. Some firms prefer to use their traditional partnership relationships to explore a new technology (Keil, Maula, Schildt, & Zahra, 2008), or opt for licensing agreement (Dechenaux, Thursby, & Thursby, 2011), do others experiment with more 'open' modes such as innovation contests or firm-sponsored communities (Malhotra & Majchrzak, 2014). The latter often link to larger number of external sources including complete 'strangers' (Bahemia & Squire, 2010; Chesbrough, 2012).

Most of the existing advices on selection of right open innovation modes take a firm-level perspective. Some studies suggest that particular firm level and industry level characteristics, such as firm size or environmental uncertainty, are critical contingencies for the effectiveness of particular open innovation modes (van de Vrande, Vanhaverbeke, & Duysters, 2009). However, advice drawn from such studies can mislead the managers' choice as micro level factors, such as the particular problem that a firm want to solve it constitutes the effectiveness of a particular mode (Felin & Zenger, 2014). For example, ill-structured and complex problems, in which the solution depends upon a large number of highly interdependent factors, regularly need very extensive

dialogue and knowledge exchange to ensure sufficient understanding of the problem (Nickerson & Zenger, 2004; Pisano, 2006). For such complex problems, those open innovation 'modes' that support knowledge exchange and dialogue may lead to greater project outcomes. Usually managers would opt for traditional partnerships, in which trusted knowledge exchange is possible (Felin & Zenger, 2014). At the same time, we learn that a large firm-sponsored community of external partners, if properly managed, can also solve more ill-structured and complex problems and allow firms to access hidden and unexpected ideas that the internal project team has not been aware of at the beginning of the project (Malhotra & Majchrzak, 2014). In contrast, simple and well-described open innovation 'tasks' usually require little knowledge sharing and integration (Macher, 2006). Thus, existing work would suggest that firms should engage in licensing agreement or competitive innovation contests as those create strong incentive effects but do not support knowledge sharing and integration (Malhotra & Majchrzak, 2014; Pisano, 2006).

Departing from these preliminary and fragmented discussions, we argue that a more integrated and nuanced advice on the optimal relationship between micro-level project attributes and different open innovation 'modes' alternative is needed. Each of open innovation modes has its advantage and disadvantages to support knowledge sharing and access to wide range of external partners. Further, we argue that the current discussions often take a too simplified view. They often assume that firms only choose one particular mode for one particular problem. In reality firms use a 'mix' of different open innovation modes to successfully solve an innovation problem. For example, in our study we learned that firms like the family-owned manufacturer of machinery and electronics, the Bosch group based in Germany, mixes different 'modes'. First, they search for a new partner with the help of an open innovation intermediary. Afterwards, they engaged in a partnership with a selected partner for realizing a proof-of-concept.

To enrich our understanding of the preferred 'mix of open innovation modes" for a particular innovation problem, this study is focused on the relationship between the 'types' of innovation problems that companies want to solve, and the appropriate open innovation modes. *In short, our focus is on answering the question: What is the preferred mix of open innovation modes to solve a particular innovation problem?* To answer to this question, we draw upon a sample of 104 open innovation projects in large firms in the US and Europe collected in a global open innovation survey in 2014 and 2015.

1 Types of Open Innovation Projects: A Problem-Solving Perspective

Consistent with previous studies, we consider two main attributes of innovation problem (Felin & Zenger, 2014; Macher, 2006; Nickerson & Zenger, 2004) including problem complexity and hiddenness of required knowledge in the current study. Complex problem is comprised of a large number of highly interdependent tasks, elements, and knowledge sets which make complex problem less decomposable (Fernandes & Simon, 1999). The hiddenness of knowledge is defined in terms of the degree to which the sources or locations of knowledge deemed relevant are known for firms and project teams, or available with practical amounts of search (Felin & Zenger, 2014; Fernandes & Simon, 1999). Sometime, external partners who have the relevant knowledge for solving firms' innovation problem are unknown to the firms and project teams. It creates many difficulties to solve problems since firms do not know about the location of the relevant knowledge. As a result, they are not able to make contract or start collaboration with external partners to access their relevant knowledge for solving problem. Instead, they need to inform external partners about their problem to find the relevant knowledge. We also need to think about the interaction between problem complexity and the hiddenness of required knowledge (Felin & Zenger, 2014). In the current study, we propose four distinct types of open innovation projects based on two attributes of innovation problem as showed in Figure 1[1]. 1) Type 1: Open innovation projects that tend to solve simple (decomposable) and well described problem and at the same time the location of relevant knowledge is known for firms and project teams. 2) Type 2: Open innovation projects that tend to solve simple (decomposable) and well described problem but external sources having the relevant knowledge are not known for firms and project teams. 3) Type 3: Open innovation projects that should solve complex (non-decomposable) problem and at the same time internal project team is aware of the location of relevant knowledge. 4) Type 4: Open innovation projects that involve in solving complex (non-decomposable) problem and external sources having the relevant knowledge are unknown for firms and project teams.

[1] We will empirically explore these 4 types from our data as well (see section 4).

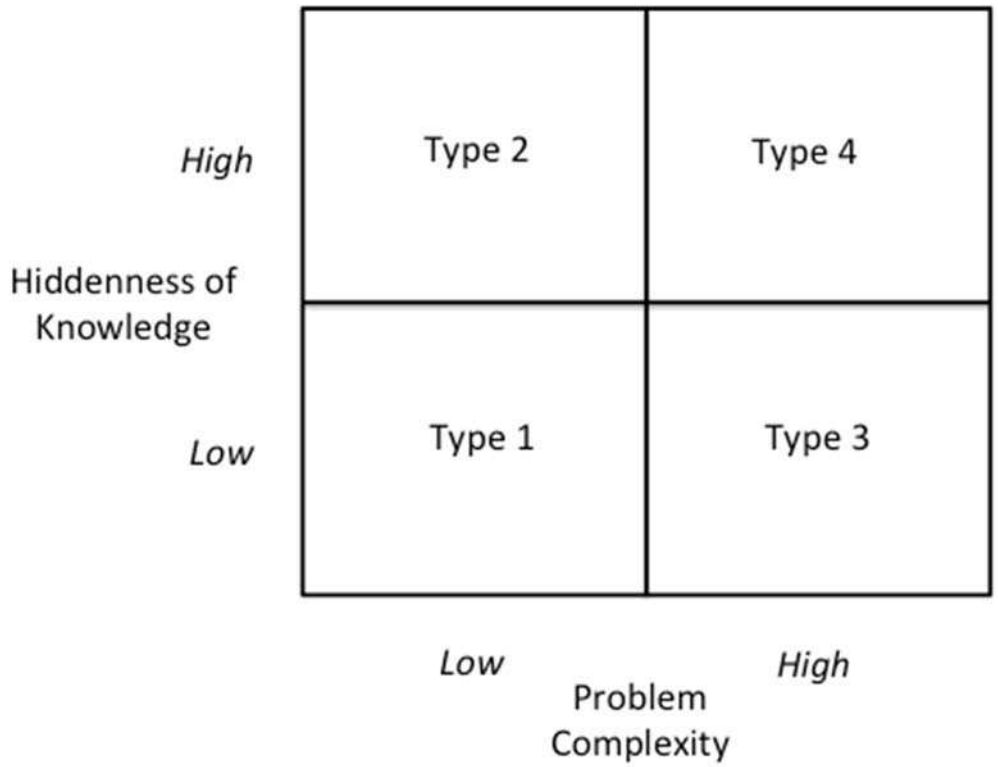

Figure 1: Four Types of Open Innovation Projects Based on Problem Attributes

Following Nickerson and Zenger (2004) and Felin and Zenger (2014), different types of problem require different search approaches. This also affects the 'right' choice of a particular open innovation mode. They differentiate between two different search approaches: 1) directional (is also called trial and error search) which is a type of search guided only by feedback or experience from prior trials; and 2) theory-driven (is also called cognitive search) which is a type of search by which involved partners in problem solving cognitively evaluate the probable results of solutions rather than using only feedback after solutions are made (Nickerson and Zenger, 2004). They state "[theory driven/cognitive] search is necessary when problems are complex" whereas "directional search is warranted when problems are decomposable [not complex]" (Nickerson and Zenger, 2004: 621). A theory-driven search implies that firms find and synthesize different knowledge areas relevant to problems to shape a search theory and a cognitive map as a basis for the evaluation of the likely consequences of solution selections (Felin & Zenger, 2014; Macher, 2006; Nickerson & Zenger, 2004). Extensive knowledge sharing is necessary in a theory driven search to ensure that all firms involved have access to and are aware of all relevant knowledge areas that pertain to a certain problem (Felin & Zenger, 2014). To support such knowledge sharing, open innovation modes that facilitate the knowledge sharing among involved partners are more advisable than modes that do not support knowledge sharing. In contrast, solving simple problem by directional search requires little

knowledge sharing between firms and external partners as the external partners can work on the problem independently (Macher, 2006). Triggering external partners to solve simple problems may be simply a matter of incentives rather than knowledge sharing. Thus, managers need to focus on open innovation modes that motivate external partners to engage in an independent problem solving process.

When the location of relevant knowledge for solving problem is unknown at the beginning of project, it is very difficult to identify the right knowledge required to solve the problem. When innovation problems require novel solutions and access to hidden knowledge, an appropriate search strategy should support access to a wide diversity of knowledge sources. They therefore need to adopt a search strategy that invites and motivates a large number of external partners to increase the potential to access to hidden knowledge (Afuah & Tucci, 2012). In contrast, when firms know the relevant knowledge, search simply becomes a matter of incentives for those partners that have the relevant knowledge to engage in the process of problem solving.

2 Open Innovation Modes for Solving Innovation Problems

To solve innovation problems with open innovation, firms have a variety of choices to coordinate or govern the problem solving process – we refer to them as open innovation modes. Such open innovation modes do not include traditional 'closed' forms for governing innovation such as authority-based hierarchy (Chesbrough, 2003). Examples of such open innovation modes are alliance partnerships and joint ventures (Keil et al., 2008), open innovation platforms, contests, or open innovation communities (Afuah & Tucci, 2012; Kathan, Hutter, Füller, & Hautz, 2015; Malhotra & Majchrzak, 2014), the use of open innovation intermediaries (Bahemia & Squire, 2010; Bakici, Almirall, & Wareham, 2010; Howells, 2006), or licensing contracts (Arora & Fosfuri, 2003; Li-Ying & Wang, 2014).

In this study, we build upon Felin and Zenger (2014), and focus on distinct archetypes of open innovation modes: 1) markets/contracts, 2) partnerships, 3) open innovation platforms, and 4) firm's open innovation communities. There are distinct in terms of three dimensions of governance: 1) the communication channels used to interact with the external partners to support knowledge sharing, 2) the types of incentives to motivate the external partners to engage in problem solving process, and 3) and the firm's ability to control the right to own or use the technology and knowledge to appropriate value from problem solving process (Felin & Zenger, 2014; Nickerson & Zenger, 2004). For example, relative to both markets/contracts and open innovation platforms, both partnerships and firm's open innovation communities can create strong communication channels

among partners that can support extensive knowledge sharing between them. While these open innovation modes might not be exhaustive, they represent core archetypes of open innovation modes, which can be further decomposed in subcategories. In the following, we briefly describe each open innovation mode and discuss them along the three dimensions of governance, communication channels, incentives, and control over IP.

Markets/Contracts: When making use of markets and contractual modes of open innovation, firms access and acquire externally developed technologies and solutions that are owned by external partners (Dahlander & Gann, 2010). Those external partners make the knowledge available for the particular problem to be solved in the project via transactional arrangements like licensing contracts or research contracts for developing a specific solution for firms. In a transactional relationship, the external partner appropriates immediate value from their know-how. As they have control over the actual intellectual assets through legal property rights, creates an incentive to provide access to their knowledge, and also further invest in the development of it so that it meets the particular requirements of the firm (Aghion & Tirole, 1994). Compared to partnerships and open innovation communities (which will be discussed later), this transactional mode implies little communication between the project team and the external partner. Thus, it does not support knowledge sharing and exchange. The main underlying mechanism for the success of market-based mode is the successful 'match' of internal problems with "those external parties that possess solutions that often already solved in the form of extant products or services" (Felin & Zenger, 2014: 920). The capability to identify external partners with relevant knowledge and technologies to solve the problem is related to the awareness of firms about potential solution providers.

Partnerships: Through partnership based open innovation mode, firms opt for more openly exchange knowledge and information with known potential external partners to jointly solve the problem (e.g., strategic innovation alliance or innovation consortium). In partnerships, the allocation of control rights over existing and emerging technologies and knowledge can be determined based on a negotiation between firms and external partners (Leiponen, 2008). Negotiable allocation of control rights motivates external partners to intensively engage in interaction with firms to develop a new technologies and solutions to solve firms' problem. External partners can ensure effective value appropriation coming from joint solution development due to negotiable control rights in partnerships supporting trusted knowledge sharing. Moreover, partnerships create richer communication channels between firms and their external partners supporting extensive knowledge sharing and exchange between them (Ness, 2009; White, 2005). Awareness of relevant external partners having sufficient relevant knowledge and capabilities for

solving firms' problem is critical for engaging in partnership based open innovation mode (Felin & Zenger, 2014).

Open Innovation Platforms: Through open innovation platforms, firms tend to solve their problems via a large set of external sources that may have relevant knowledge, technologies, or completed solutions for solving firms' problem (Malhotra & Majchrzak, 2014; Morgan & Wang, 2010). Open innovation platforms are often supported by information technology for broadcasting firms' problem for a wider set of external sources. Control rights over solutions developed by external sources usually belong to firms and it is specified at the beginning when firms broadcast their problems through open innovation platforms. As a result, property rights related to solutions developed in open innovation platforms cannot create incentives for external sources to engage in solution development. Firms should compensate external partners who develop most valuable solutions by prizes and payment to motivate them to participate in problem solving process. Firms have a broad communication channel with a wide range of external partners in open innovation platforms but this communication channel is not deep enough to support extensive knowledge sharing between firms and external partners (Felin & Zenger, 2014). This mode of open innovation creates a good opportunity for firms to find unknown relevant external sources with required knowledge and technologies for solving firms' problem but has limited support for extensive knowledge exchange.

Firm's Own Open Innovation Communities: Through open innovation communities, firms tend to develop innovation communities, including diverse set of external partners, hosted by them for the specific aim of accessing to a wide range of external sources to solve their problems (Dahlander & Piezunka, 2014). Control rights over developed solutions and technologies are usually retained by the firms that sponsor the community (Felin & Zenger, 2014). As a result, there is no incentive for external partners to participate in problem solving perspective from an IP perspective. However, there are a range of other motives and incentives at work such as prizes, reputation and social status, enjoyment, and also altruism (Fuller, 2010). With respect to control over IP, there are multiple opportunities for controlling the use of IP, including 'informal' mechanism like social norms and rules (Fauchart & Von Hippel, 2008) that guide the community in how to protect and share knowledge. Open innovation communities create a strong communication channels between involved actors which can support extensive knowledge sharing not just between the internal project team and the external partners but also among the diverse group of external participants. Further, if properly managed, the community can also support intensive knowledge sharing and knowledge integration (Malhotra & Majchrzak, 2014). Moreover, it can provide firm with access to diverse

relevant knowledgeable external partners and also hidden knowledge which can support cooperative knowledge sharing.

To sum up, compared to both markets/contracts and open innovation platforms, both partnerships and firm's open innovation communities can create strong and stable communication channels between involved partners supporting collaborative and extensive knowledge exchange between them. Relative to open innovation platforms, protection of shared knowledge is strong in partnerships and firm's open innovation communities that support trusted knowledge sharing. Open innovation platforms and communities provide firms with a wider range of external and hidden sources supporting to solve those problems face with hidden and unknown required knowledge compared to partnerships and contractual mode. As it is clear, each of open innovation modes has its advantage and disadvantages to support knowledge sharing and access to a wide range of external partners. To effectively solve the problem, firms can apply a mix of open innovation modes to complement them to avoid their disadvantages based on problem's needs. For example, due to moderate incentives of open innovation platforms for external sources to engage in problem solving, firms can complement it by adopting partnership or contract based mode after finding a potential provider. As a result, a mix of open innovation modes can be applied by firms for problem solving. A summary of comparative analysis of four distinct open innovation modes based on three dimensions of governance is indicated in Table 1.

Table 1: Comparative Analysis of Open Innovation Modes and Their Association with Two Attributes of Innovation Problem

	Markets/Contracts	**Partnerships**	**Open Innovation Platforms**	**Firm's Open Innovation Communities**
Communication channels	Limited	Strong	Limited but wide	Strong and wide
Incentives	High incentives	High incentives	Moderate incentives	Low incentives
Control rights over technology and knowledge (IP)	Owned by external partners	Negotiable between firm and external partners	Owned by firm	Usually owned by firm
Knowledge Sharing	Limited	Strong	Limited	Strong
Access to wide range of external partners	Limited	Limited	Strong	Strong

Complex problem	0	+	0	+
Hidden required knowledge	0	0	+	+

As mentioned earlier, each type of problem needs different search strategies for finding appropriate solutions. Different search strategies require different types of open innovation modes to support effective solutions search. In the next section, we want to explore that what is the preferred mix of open innovation modes for solving a specific problem.

3 About the Research: Design, Data, and Method

To gather a complete understanding of the interplay between the micro-level open innovation project attributes and the preferred 'mix of open innovation modes' choice, and to ensure well-founded conclusion, we combined a survey study with illustrative case studies approach.

3.1 Survey Study

First, we drawn upon a survey database of 104 open innovation projects in large firms in Europe and the United States collected as a global open innovation executive survey in 2014 and 2015. Our sample includes large stock market listed firms with annual revenues of more than $250 million and more than 1000 employees. The survey was sent to senior executives (e.g., Chief Executive Officers, Chief Technology Officers, R&D Director, Open Innovation Manager, etc.) as primary contacts at the firm headquarters. They were asked to select an open innovation project that they have completed within the last two years. To make sure they selected an open innovation project, we provided them with a definition of open innovation[2] at the beginning of the survey. This survey includes a comprehensive set of measures at the project level for different problem attributes and different types of open innovation modes that improves upon previous survey-based researches on open innovation. Therefore, our empirical study significantly advances existing survey-based empirical examinations of open innovation modes, which are mostly concerned with firm level variables (Beers & Zand, 2014; Faems, Van Looy, & Debackere, 2005; Laursen & Salter, 2006; Laursen & Salter, 2014).

Perceptual measures are applied to operationalize the constructs based on their definition in this study. We measured the complexity of problem by two items: 1) the project involved a large

[2] Open innovation implies that your organization makes *purposive* use of external know-how and capabilities and/or external paths to market, as your organization looks to accelerate internal innovation, and expand the markets for external use of internal innovation, respectively.

number of highly interdependent tasks (they could not be completed independently), and 2) new tasks and interdependencies between them emerged unexpectedly and the hiddenness of required knowledge by "we were able to identify the know-how required to solve the problem before we started interacting with external sources[3]". We asked respondents to describe the project on a seven-point Likert scale based on these items where 1 refers to "strongly disagree" and 7 refers to "strongly agree". Respondents were also asked to select the open innovation modes applied by the project team during problem solving. We also asked respondents to indicate whether the project was successful or not[4].

3.2 Illustrative Case Studies

Second, we rely on three successful open innovation projects from our sample as illustrative cases to better guide open innovation leaders in their decision among different open innovation mode alternatives, given a particular problem. A semi-structured interview protocol was applied in our phone interviews (lasted between 30 and 45 minutes) with senior innovation managers between June and October 2015 for two cases[5]. All of interviews were recorded. The interviewees were asked about the innovation problem characteristics that they wanted to solve in open innovation projects, adopted open innovation modes, and the reasons for applying specific open innovation modes. We complemented the primary data by secondary sources of data which were publicly available such as press reports, company's website, etc. and also documents provided by interviewees. Then, we wrote a story for each case based on content analysis of collected data.

3.3 Method

A three-step empirical statistical analysis was conducted to explore the preferred mix of open innovation modes for a particular open innovation project. First, we classified open innovation projects that have similar problem attributes (complexity and hiddenness of required knowledge) into homogeneous clusters. Second, to find a mix of open innovation modes, open innovation projects were clustered based on open innovation modes adopted by them. Third, we examined how problem attributes relate to mix of open innovation modes.

[3] This item was used as a reverse item for measuring the hiddenness of required knowledge.
[4] We used this definition: a successful open innovation project is a project that has completed and successfully supported the company's innovation strategy and targets, while an unsuccessful did not.
[5] We only relied on secondary sources of data for one of cases.

4 Findings

4.1 A Typology of Project-level Problem Types

Our first explorative analysis was to identify distinguished clusters of open innovation projects based on their problem attributes. First, we conducted a hierarchical cluster analysis using Ward's method and the squared Euclidian distance measure. The agglomeration coefficients were checked based on the number of clusters and also we checked the dendogram. Based on the results, a four-cluster solution seemed to be appropriate. The four-cluster solution provided us with clusters that were interpretable conceptually and comparable in size. Then, K-means cluster analysis (as a non-hierarchical cluster analysis technique) was followed for the final solution based on four-cluster solution due to its robustness (Punj & Stewart, 1983). Based on Analysis of variance (ANOVA), the two attributes showed significant differences at $P < 0.001$ between four clusters. We also applied multiple two-sample T-tests to identify which clusters were significantly different. Projects in cluster 3 and 4 are significantly more complex than those in cluster 1 and 2. The required knowledge is more hidden (more unknown) for projects in cluster 2 and 4 compared to those in cluster 1 and 3. As a result, we have four distinct types of open innovation projects based on problem attributes. Table 2 shows the four clusters (four types of projects) in terms of the two problem attributes.

Table 2: Four Clusters of Open Innovation Projects based on Problem attributes

Problem Attributes	C1: Simple Problem/ Known Knowledge (n=25)	C2: Simple Problem/ Unknown Knowledge (n=13)	C3: Complex Problem/ Known Knowledge (n=36)	C4: Complex Problem/ Unknown Knowledge (n=30)	ANOVA F-value (df=3)	T-test t-value
Complexity	3.46	3.27	6.03	5.93	88.973*	3, 4 > 1, 2**
Hiddenness	2.20	5.85	2.08	5.23	139.890*	2,4 > 1,3** 2 > 4*

Note: C = Cluster; n = Number of firms in each cluster; * = $P < 0.05$; ** = $P < 0.001$

Problems of *type 1 (*24% of the open innovation projects in our sample) are relatively simple as they can be delineated from other problems and tasks. Thus, the problem can be well described, and translated into requirements, as the set of factors that influence the problem seem to be manageable. Further, the project team has clear understanding of location of relevant knowledge for solving these problems. Problems of *type 2* (12.5% of the open innovation projects in our sample) are also relatively simple in a sense that the factors that describe the problem are not particularly

interdependent. However, the location of relevant knowledge for solving them is not known and accessible for the internal stakeholders. Colloquially, companies refer to such problems as 'holy grail' problems, as they cannot identify the right solution knowledge even though they are able to describe the problem. They have tried many different approaches to tackle the problem but failed. Problems of *type 3* (34.7% of the open innovation projects in our sample) are very complex problem as they are so many different factors that influence the overall problem, and they interact in a complex way. Despite this complexity, the internal open innovation team is aware of the location of relevant knowledge for solving them. The challenge lies in tackling the complexity of the problem space. Finally, we also identify projects that represent truly 'grant challenges' (28.8% of the open innovation projects in our sample) as they are complex and at the same time the location of relevant knowledge for solving the grant problems is not known by the firm and the internal team working on this particular project.

4.2 Open Innovation Modes: From 'Single' Choice to Mixing Modes

To explore the question of how the four open innovation problem types interplay with different open innovation modes, we first answered the question whether and how firms mix different modes within a particular project. A two-step cluster analysis was conducted to explore how open innovation projects grouped together based on the open innovation modes adopted by project team to solve the problem (We applied a two-step method because we have binary variables for open innovation practices. This method can cluster categorical variables as opposed to other methods of clustering such as hierarchical and non- hierarchical cluster analysis, which require continues variables). To cluster our firms, we explored the combinations of four distinct open innovation modes: 1) markets/contracts, 2) partnership 3) open innovation platform, and 4) Firms' own open innovation community. Based on the Silhouette coefficient, the three clusters with cluster quality around 0.5 (considered as a good quality) were selected. Table 3 shows the three clusters of open innovation projects in terms of open innovation modes used for clustering.

Table 3: Three Clusters of Projects based on Open Innovation Modes

Open Innovation Modes	C1: Partnerships & Communities (n=56)	C2: Open Innovation Platforms (n=22)	C3: Markets/ Contracts (n=26)
Markets/Contracts	Yes (57.1%)	Yes (72.7%)	Yes (100%)
Partnerships	Yes (71.4%)	Yes (59.1%)	No (100%)
Open Innovation Platforms	No (100%)	Yes (100%)	No (100%)
Firm's Innovation Community	Yes (49.2%)	No (59.1%)	No (100%)

Note: C = Cluster; n = Number of firms in each cluster

We identified three different 'mixes': The first mix is labeled as *Partnerships-Community* (53.8% of the open innovation projects in our sample are represented in this mix). Projects that use this mix do mix partnerships, a community, and also contracts. However, they do not make use of open innovation platforms such as contests, crowdsourcing, or tournaments. In comparison to the other two mixes, partnerships and communities are dominating (Case #1, Table 5).

*Mix 2 is labeled as Open Innovation Platform Dominance (*21.2% of the open innovation projects in our sample are included in this mix). These are open innovation projects that apply different open innovation modes such as market and partnership based modes with the main focus on competitive open innovation platforms such as innovation contests, tournaments, and intermediaries. Community interaction and collaboration among the crowd is usually not encouraged in these projects (Case #2, Table 5).

Mix 3 is labeled as Markets/Contracts. It includes 25% of the open innovation projects in our sample. These are open innovation projects that dominated by contractual relationships (Case #3, Table 5).

4.3 What is the 'Right' Choice? The Interplay of Problem Types and Open Innovation Mixes

The most important question that needs to be answered next is: How do problem types and open innovation 'mixes' interplay? Thus, we performed a Chi-square test to statistically explore whether there is a relationship between attributes of problem (four distinct micro-level problem types) and open innovation modes (three mixes of open innovation modes). We applied the test separately for successful and unsuccessful projects to explore the preferred mix of open innovation modes for a particular innovation problem that leads to successful outcome. An overview of the results for successful projects[6] is summarized in Table 4.

[6] We did not find a significant difference in the four micro level problem types regarding adoption of open innovation practices among unsuccessful cases.

Table 4: Chi-square Test for relationship between attributes of problem and mix of open innovation modes

		Mix of Open Innovation Modes		
		Partnerships & Communities (n=32)	Open Innovation Platforms (n=14)	Markets/Contracts (n=11)
Micro-level problem types	Simple Problem/ Known Knowledge	Obs. 6, Exp. 7.9	Obs. 4, Exp. 3.4	Obs. 4, Exp. 2.7
	Simple/ Unknown Knowledge	Obs. 1, Exp. 2.8	Obs. 4, Exp. 1.2	Obs. 0, Exp. 1.0
	Complex/ Known Knowledge	Obs. 16, Exp. 12.9	Obs. 3, Exp. 5.6	Obs. 4, Exp. 4.4
	Complex/Unknown Knowledge	Obs. 9, Exp. 8.4	Obs. 3, Exp. 3.7	Obs. 3, Exp. 2.9
Chi square, df, (p-value)	11.737, df=6, (0.068)			

Note: Obs. = Observed frequency of projects; Exp: = Expected frequency of projects, n=57; df = degree of freedom

The results reveal that the preferred mix of open innovation modes is different across four different micro-level problem types. The Chi-squared test shows that the differences in adopting open innovation modes are statistically significant ($p < 0.1$) across four distinct problem types (Chi-square=11.737 with p-value=0.068). For example, our results indicate that projects characterized with relatively simple problem but hidden solution knowledge (type 2) are more frequently associated with open innovation platforms (such as contest and open innovation intermediaries). Also, differences are observable regarding application of market/contract based open innovation mode across four types of projects. Market/contract mode is preferred to solve relatively simple problems and at the same time the relevant knowledge is known for firms and project teams (type 1). But, no project of type 2 is associated with a market/contract based mode since it is simply impossible to find a potential partner to establish a licensing contract. A mix of partnerships and a firm's own open innovation community is the most commonly applied mode for solving complex problems. Figure 2 summarizes our findings regarding the relationship between problem attributes and the preferred mix of open innovation modes.

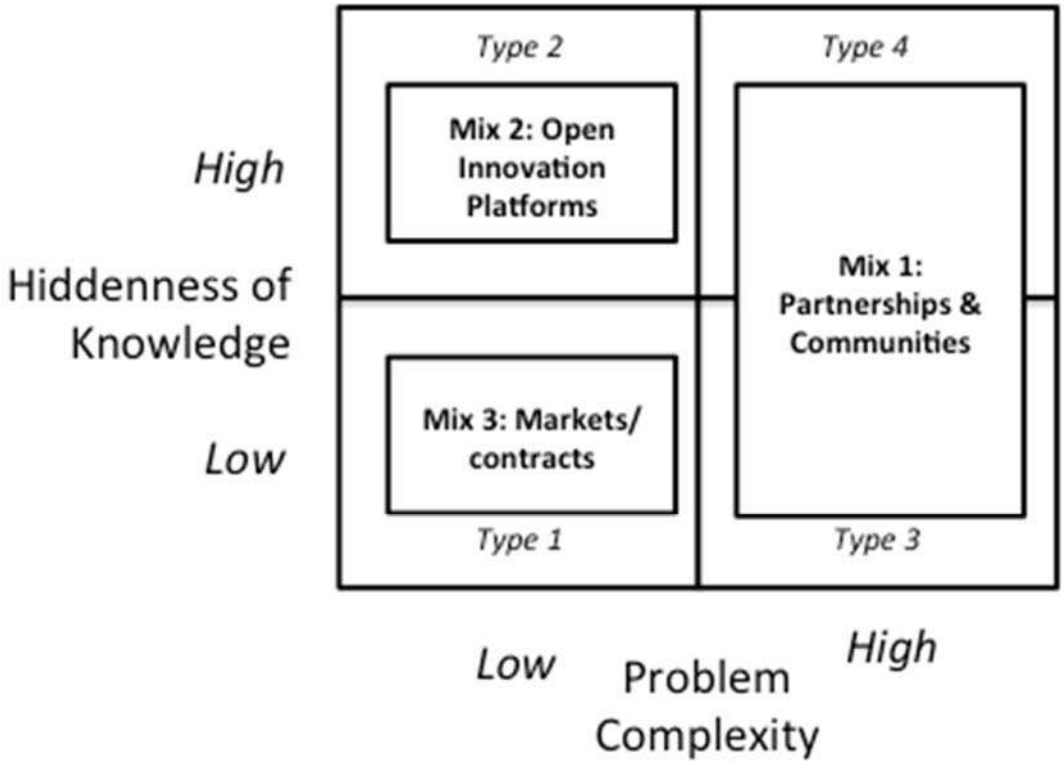

Figure 2: Four Problem Types and the preferred mix of open innovation modes

To better convey the interplay between problem types and open innovation modes to the reader, we present three cases of successful projects that are also part of our survey study. They illustrate the interplay between problem types and open innovation mix (Table 5). We selected three different projects, which made use of three different open innovation mixes. One of them makes use of mix 1, Partnership and Communities, the second makes use of open innovation platforms, and third case describes the mix 3 (contracts/markets). To illustrate the particular mix and the interplay with the particular problem type, we briefly describe the three cases.

Table 5: Summary of Three Illustrative Open Innovation Projects

Company	**Interplay of Problem Type and Open Innovation Modes**	
Evonik Industries	***Context of Project***	The objective was to develop a new technological solution for elimination of vacuum-based processes in the production of electronic devices.
	Problem Type	*Type 3: Complex Problem with Unknown Knowledge: The* technological problem related to a very uncertain and emerging technological area. Further, the potential solution knowledge was hidden, as it was not feasible to know upfront 'where' potential

		novel solution know-how could be found.
	Mix of Open Innovation Modes	*Mix 1: Partnerships and Communities:* They created a diverse community that integrates a diverse set of actors that have different perspective towards the problem, and cover a range of different technological and market-related knowledge areas. It integrated potential customers in the electronics industry, universities and research centers, and equipments suppliers.
Bosch Group	***Context of Project***	The objective was to develop a new non-electrochemical energy storage technology.
	Problem Type	*Type 2: Simple Problem with Unknown Knowledge:* The non-electrochemical technology was not totally new to the market. The interdependencies between different parts of technology that affect the success of project were well structured and understood. But, they did not know who could provide them with the most effective non-electrochemical energy storage solutions.
	Mix of Open Innovation Modes	*Mix 2: Open Innovation Platforms:* They decided to "use one of existing internet based innovation platform for crowd sourcing" to find an optimal and innovative solution. They selected the NineSigma, as an open innovation intermediary for providing technical solution, for problem broadcasting. After finding potential partners, they started to collaborate with them via partnership based mode.
Clariant	***Context of Project***	The project aimed to enrich Clariant's portfolio of ActiSorb series of catalysts and adsorbents to help their customers achieve greater efficiency for the purification of hydrocarbon feedstocks.
	Problem Type	*Type 1: Simple Problem with Known Knowledge:* Clariant knew that there was a new technology, developed by Petronas in collaboration with scientists from university, could fit their needs very well to complement ActiSorb products. They do not need to have extensive knowledge sharing with external partners to develop a new technology since Petronas[7] had already developed it.

[7] Petroliam Nasional Berhad (Petronas), Malaysian energy and petrochemical company

	Mix of Open Innovation Mode	*Mix 3: Market/Contracts:* They decided to access to externally owned technology through a contract with the external owner of technology. As a result, they entered into a licensing agreement with Petronas giving Clariant access to Petronas's HycaPure Hg technology.

Illustrative Case #1: Evonik Industries (Mix 1-Partnerships & Communities). A combination of partnership and community based modes for problem solving is applied when projects have complex problems. For example, the elimination of vacuum-based processes in the production of electronic devices is central emerging technology field. Indeed, they are essential for applications such as flexible and printable electronic devices. One of Evonik's open innovation projects was focused on this new technology. It related to a very uncertain and emerging technological area. Further, there are multiple factors that influence the process of electronic device production. Moreover, the potential solution knowledge is also hidden as there are multiple alternative approaches to the traditional semiconductor focused way of production. As Evonik industries realized that the problem was not just complex but also related to potential solution knowledge that was beyond the current knowledge of its scientists, or its existing partners. Thus, the Open Innovation team decided that new partners are needed to explore the emerging technological area. However, it is not feasible to know 'where' potential novel solution know-how could be found. Also, insights about how the technology could be used by potential customers, was essential in order to understand the particular requirements for the processes of material production process. However, such insights require deep customer insights and a deeper understanding of the customer's needs and requirements. As the technology field was very novel and uncertain, such requirements were not yet well defined, as potential application areas were not yet known. In short, the problem was not just 'complex' in a sense that there are multiple technological and market related factors are highly interdependent but also that there are large number of potential solutions - that might be even contradictory – that were not known at the start of the problem. To tackle this complex problem with an unknown number of 'hidden' solutions, Evonik decided to create a diverse community that integrates a diverse set of actors that have different perspective towards the problem, and cover a range of different technological and market-related knowledge areas for collaboration. It integrated potential customers in the electronics industry, universities and research centers, and equipments suppliers. Evonik initiated the open innovation community with the aim the support *deep-level knowledge exchange and integration* among the diverse participants through

dialogue and collaborative problem solving, in which participants integrate different perspectives and build upon the other's perspective solutions which was necessary for complex problems.

Illustrative Case #2: Bosch Group (Mix 2-Open Innovation Platforms). Projects characterized with relatively simple and well-structured problem but the location of relevant knowledge is unknown tend to apply open innovation platforms. For example, one of well-structured problems innovation projects at the Bosch Group was to develop new non-electrochemical energy storage. Developing innovative energy storage solutions to maximize the use of renewable energy while ensuring lower cost and a more reliable electricity supply is one of the main focuses of the innovation portfolio of Bosch group. The main focus of the Bosch group was on electrochemical energy storage technology and they were looking for an alternative technology for electrochemical energy storage. At that time, the non-electrochemical technology was not totally new to the market. Interviewee at Bosch said "we knew [at that point of time] that there was technological [solutions] to fulfill our [well structured] technical requirements outside of our company". As a result, they decided to "use one of existing internet platform for crowd sourcing" to find an optimal and innovative solution which was critical for them since they did not know who could provide them with the most effective non-electrochemical energy storage solutions. They selected the NineSigma, as an open innovation intermediary for providing technical solution, for problem broadcasting. They allocated sufficient time for technology specification which was essential to guide the developer's thinking and creativity. Bosch identified three partners via the NineSigma and started having direct contact and collaboration with them. Actually, Bosch first tried to find potential partners via an open innovation intermediaries and then applied partnership based collaboration with selected partners for developing a new technology since partnership mode created a great incentive for the selected external partners to collaborate with Bosch.

Illustrative Case #3: Clariant (Mix 3: Markets/Contracts). Firms tend to apply markets/contract based open innovation mode when they face with well-structured problem and they are aware of existing externally owned technology to solve the problem. For example, Clariant, a world leader specialty chemical manufacturing, wanted to complement its other ActiSorb adsorbents products to provide integrated solutions to meet the requirements of its clients for greater efficiency for the purification of hydrocarbon feedstocks[i]. They were aware of a fast and safe technology for removing mercury from natural gas developed by a team at Queen's University in collaboration with Petronas which is called "HycaPure Hg" technology[ii]. This technology was "already used at Petronas's gas processing plants a few years and it demonstrated high adsorbent capacity and stable performance", mentioned by Petronas VP of Technology and Engineering Division[iii]. Clariant knew

about the capacity and performance of the technology to complement their existing ActiSorb series of catalysts and adsorbents to "continue helping [their] customers to achieve better sustainability and greater efficiency", as said by Clariant Senior VP and Head of Business Unit Catalysts[iv]. Therefore, Clariant decided to make a licensing agreement with Petronas by which Petronas' technology can be used by Clariant to complement its portfolio of ActiSorb series adsorbents[v].

5 Managerial Implications

This study focuses on the comparative questions of open innovation modes and answering the central question of an open innovation manager: What is the right open innovation mode for my open innovation project? (Felin & Zenger, 2014). Rather than taking focusing on the question open versus closed (or inbound versus outbound), we took a more nuanced view towards the interplay between two problem attributes and the distinct mixes of open innovation modes. Indeed, we learned that in reality projects usually mix a range of open innovation modes to tackle a particular problem. We identified three archetypes of 'mixes': Partnerships-Community, Open Innovation Platform Dominance, and Market/Contracts. We empirically show that two attributes - complexity and hiddenness of required knowledge should guide the manager's choice.

Our study has three major implications for open innovation managers as follows which can provide them guidelines that support the decision for a particular mix of open innovation modes.

- Guideline #1: Carefully analyze the problem attributes of your open innovation project before deciding 'how' to engage in open innovation: Two dimensions help you to quickly position the project in the complexity/hidden matrix.
- Guideline #2: Consider 'mixing' different open innovation modes: Such combinations can also link more traditional modes like partnerships with more open modes like a firm's own open innovation community, or open innovation contest.
- Guideline #3: Open innovation managers are advised to carefully choose a mix of open innovation modes for coordinating the open innovation project that fits with the problem of the project based on empirical exploration of preferred modes. Figure 2 presents simple guidance for open innovation managers to assess which 'open innovation mode' to choose from.
    - A combination of partnerships with an open innovation community is suggested for complex problems (whether the required knowledge is known or not). They offer a firm to master 'grant' challenges that require deep knowledge exchange as well as the exploration of unknown solution knowledge through diversity.

- Open innovation platforms (contests, intermediaries, tournaments) are best combined with partnerships and markets in order to solve well-described problems with an unknown required knowledge (the holy grail problem). In such cases, firms may use the crowd to identify hidden knowledge sources and establish new partnerships. Markets or partnerships may allow the project team to develop the idea into a proof-of-concept solution.
- Market and contractual modes are recommended for relatively simple problems for which the required solution knowledge can also be easily identified.

Our guidelines put the project and the team managing the project center stage in the decision towards how to manage open innovation. Rather than providing a complex list of attributes and decision factors, a simple 2x2 matrix can guide the manager in making a decision on how to coordinate and govern a particular open innovation project. Such a decision is taking early. Neither does it require an intensive analysis, nor a lot of costs. However, it is exactly that early stage decision that will have important implications for the success of the project, and also the resources spend at a later stage.

6 Conclusions and Future Opportunities

Our paper presents a 'holistic' integrated framework for managing open innovation projects. Rather than focusing on particular type of project, or one particular type of mode, we aimed to provide managers with an integrated but nuanced view towards the right open innovation mode. While prior work on such a holistic perspective was primarily theoretical, our decision portfolio is empirically derived. Our integrated portfolio provides a range of further opportunities of research with high practical relevance. For example, within each open innovation mix, there are multiple opportunities to detail the three governance dimensions: 1) communication channels, 2) incentives, and 3) control over IP. Further, the questions of how a manager coordinates the process of knowledge protection as well as sharing within these different modes requires further investigation (Majchrzak, Jarvenpaa, & Bagherzadeh, 2015). There is much to learn, in particularly in the area of crowd-based open innovation, which subsume open innovation platforms and open innovation communities. We hope that our framework will inspire both practitioners as well as scholars to do experiment more within these different modes, and sharpen our understanding of the best way for coordinating the process of knowledge protection and knowledge sharing.

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