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Open Innovation Networks and the Role of Intermediaries: An Agent-Based Simulation

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Abstract

This paper builds an agent-based simulation model that illustrates the dynamics of an Open Innovation (OI) network of firms in search of a technological development partnership. The model simulates an environment populated by innovation seekers and innovation providers. Each of these agents (firms) has half of the final product and has to decide whether to develop the rest internally or seek a partner that developed the other half of the product. Moreover, this paper explores the effects on the innovation network dynamics of the presence of intermediaries that act as brokers between innovation seekers and innovation providers. The results suggest that innovation providers are on average better off when they establish partnerships, especially when their number is limited and intermediaries are present in the market. The model shows that the presence of intermediaries makes the market more efficient by lowering costs of all firms in the network, whether they use an intermediary or not.

1 Introduction

In the last 15 years, the landscape of innovation has changed radically: technology evolves faster than ever and companies are faced with a continuously increasing amount of uncertainty. In the current competitive environment, constant innovation seems to be at the same time indispensable and extremely expensive to attain. Therefore, many firms are experimenting with a variety of ways to increase their ability to innovate by creating synergies between their internal processes and external knowledge sources. To this end, many organizations started employing a set of practices that have been synthesized by Henry Chesbrough (Chesbrough, 2003c; Chesbrough et al, 2006) with the expression *Open Innovation* (OI), defined as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively” (Chesbrough et al, 2006, p.1). The transformations that these practices are collectively generating imply, Chesbrough argues, a paradigm shift in the way the problem of innovation is perceived and managed both by organizations and by end users (Chesbrough, 2003c; Kuhn, 1970). This shift is becoming more visible as several environmental factors make it increasingly difficult for companies to rely solely on internal innovation sources and to protect their intellectual property. On the one hand, increased workers’ mobility, exposure to security breaches, and

uncertainty of intellectual property regulations across countries make it more difficult for innovative firms to contain their knowledge within organizational boundaries for extended periods of time. On the other hand, new technologies and increased communication capabilities dramatically increase the availability of unused ideas that can find a profitable way to market. Thus, for many companies in highly innovative markets the switch to an OI strategy is a necessity rather than a choice.

Recognizing the relevance of this phenomenon, many scholars examined several different aspects of open innovation and the body of research is growing constantly (Chesbrough et al, 2006; West and Gallagher, 2006). Gianiodis et al (2010) offered a comprehensive literature on the subject, centered around a classification of different strategies that firms can employ in the networks of firms arising from OI practices. Some firms act as *innovation seekers* and take the role of technology buyers, building their competitive strategy around the search of innovative solutions outside of their boundaries. For example, several software companies devolve some of their employees to participate full time in the open source community; similarly, many pharmaceutical companies procure new technologies by acquiring smaller companies which developed them (Dahlander and Wallin, 2006; Higgins and Rodriguez, 2006).

On the opposite side of the spectrum, we find firms that act as *innovation providers* and focus their efforts in offering an innovative concept or solution to other companies. Many high tech firms are born around a single innovative idea or technology, but do not have the infrastructure to embed it in a product and to bring it to market. Such companies need to establish partnerships to create appropriate channels to commercialize their technologies. Alternatively they can sell or license their innovations to technology seekers (Christensen et al, 2005). Some firms, termed *open innovators*, act both as innovation takers and providers. These firms thrive on the continuous exchange of knowledge through their boundaries, and proactively stimulate inflows and outflows of innovative ideas with their environment.

The creation of a thriving market for innovations created the ideal space for the development of firms that facilitate exchanges by lowering transaction costs between seekers and providers. Such *innovation intermediaries* act as innovation brokers, by having on one side the innovation seeker and on the other a pool of innovation providers with the capabilities to solve the seekers' problems (Saur-Amaral and Amaral, 2010; Terwiesch and Xu, 2008). The peculiarity of these companies is that they are a genuine new product of the open innovation phenomenon, and they could not exist without other kinds of players in the open innovation network. Although some companies are starting to get a strong presence in the market for innovation (e.g. Innocentive, Yet2.com, Nine Sigma), innovation scholars have yet to develop a systematic theory of their effects on technology markets and how their presence changes the behavior of firms involved in Open Innovation. This paper contributes to filling this literature gap by developing a simulation model of an open innovation network, which can be used to explore the behavior of the agents involved under different circumstances.

The paper is organized as follows. The next Section provides a literature review and the theoretical background for the development of the simulation model. Section 3 presents the development and implementation of the model, while Section 4 discusses the output analysis and its implications. Finally, Section 5 provides some conclusions and directions for future research.

2 Literature Review

2.1 Open Innovation

The theoretical construct of Open Innovation (OI) was first conceptualized by Chesbrough (2003c) as a way to denote a change in how research and development (R&D) practices were habitually conducted in a variety of industries. The traditional paradigm of innovation in the industrial era was epitomized by large research facilities established by major industrial companies (such as Xerox PARC or AT&T Bell Labs). The role of these R&D units was to generate a large amount of innovative technologies, only a small number of which was successfully commercialized by the parent company. This approach to innovation was based on the premise that the same organization took care of the whole process of innovation and development, from idea generation to research to commercialization (Chesbrough, 2003c, p. XX). This meant that a large number of innovations never reached the market, generating a substantial loss of efficiency in the innovation process. Conversely, the absence of an innovation market meant that the solution to a firm's technological problem could be lying in the closed-off archives of another company.

Things started to change in the decades around the turn of the century, as many conditions that enabled companies to pay a high price to develop their own technologies started to deteriorate. First, the costs of maintaining large R&D departments increased because of higher costs for highly skilled labor and because the nature of research itself changed, requiring more expensive technologies (Chesbrough, 2003c). Moreover, innovation cycles are constantly shortening, significantly reducing the payoffs of new technologies while at the same time requiring larger investments to keep up with the increased pace (Fine, 1998). At the same time, it became more and more difficult to retain a company's research personnel. The trend towards mobility of skilled labor means that companies have to provide more attractive hiring and retention packages and that, when they lose a researcher, they face the risk of their knowledge being transferred to a competitor (de Vrande et al, 2006). Simultaneously, the expansion of venture capital market gave small companies with innovative ideas the possibility to develop and license out their technologies, while at the same time providing a possible outlet for unused ideas in large R&D centers (Bray and Lee, 2000).

Taken together, these factors led to a change in how companies approached technology development and commercialization. Companies in search of innovative solutions started to look outside their boundaries to universities, start-ups, and even their customers (Bray and Lee, 2000; Hippel, 2005; Perkmann and Walsh, 2007); and companies in possession of unused technologies started to consider licensing them out in the open market as well as through the creation of spin-offs and joint ventures (Chesbrough, 2003b; Hansen et al, 2005). This new, open innovation strategy changed the way firms and researchers considered the issues relating to innovation and intellectual property management.

As pointed out by Huizingh (2011), several practices of OI are not unique to this time in history or to the modern corporation. Indeed, even the most closed-off organization engaged to some degree in practices aimed at acquiring external knowledge or leveraging internal unused resources. In the modern industrial era, spin-offs, mergers, and acquisitions have been some of the most commonly employed strategies. Even further back, several productive sectors have, throughout history, benefited from the creation of communities that served the

function of diffusing technological advances (Carbonara, 2004). However, the pervasiveness of such practices in recent times is unprecedented. The forces of globalization and the lowering of communication costs have effectively created a global market for innovations, which allowed firms to incorporate Open Innovation practices systemically in their operating strategy to an extent that was not previously possible.

2.2 Strategic Roles in Innovation Networks

Companies that systematically engage in open practices as a way to shape their innovation strategy are said to employ an open innovation strategy, defined as “a business model that is designed to purposefully allow and facilitate knowledge and technology transfers across organizational boundaries.” (Gianiodis et al, 2010, p. 554). That is, such firms make the permeability of their organizational boundaries part of their overall strategy, rather than a one-time solution to a problem. With the increase in open-source software and user innovation communities, open innovation as the default mode of operation is becoming increasingly commonplace, originating a web of relationships revolving around innovation markets and exchanges (West and Gallagher, 2006; Gianiodis et al, 2010).

Firms that participate in open innovation networks can assume different roles, based on the types of knowledge flows that they decide to put at the center of their business model (Cowan et al, 2007). Gianiodis et al (2010) have proposed that firms in an open innovation network can assume the roles of Innovation Seeker, Innovation Provider, Open Innovator, or Intermediary. An innovation seeker is a firm that looks for technological solutions to its innovation problems outside its boundaries (instead of relying on an internal development effort). Innovation providers are companies that possess a technology or the ability to develop an innovative solution to a problem and are willing to offer it in the open market. Open innovators are companies that act as both seekers and providers, such as the the large technology giants of the 20th century, who had a significant amount of unused patents as they had unsolved problems (Chesbrough, 2003a). Finally, innovation intermediaries are a category of companies that emerged in order to facilitate the exchanges among seekers and providers and that act as a technology broker as well as a facilitator between the interested parties (Howells, 2006; Fleming and Waguespack, 2007). Formally, an innovation intermediary is defined as “an organization or body that acts as an agent or broker on any aspect of the innovation process between two or more parties.” (Howells, 2006, p. 720).

Although intermediaries often take on multiple roles and expand their activities beyond the simple brokerage role of connecting seekers and providers, in the present study we are interested in what Howells (2006) refers to as intermediaries that fulfill the function of “diffusion and technology transfer” (p. 716). In this capacity, intermediaries have been argued to make the market more transparent by lowering information requirements for firms. By adopting a resource based view (Barney, 1991), a number of theoretical and case studies indicated that firms benefit from the vetting of potential partners by the intermediary, reducing the uncertainty about the partners’ potential to bring resources that can lead to a competitive advantage (Hargadon and Sutton, 1997; Winch and Courtney, 2007; Lee et al, 2010; Katzy et al, 2013). Our focus on the brokerage role is supported by literature suggesting that the role of intermediaries is more important in the creation and development

phases (Janssen et al, 2014).

The implication of most of the studies is that intermediaries make markets more efficient (Tietze and Herstatt, 2009), and therefore lead to a lower cost incurred by participants in finding a suitable partner. Similarly, it can be argued that, by lowering search costs and facilitating the search for better partners, intermediaries will help in “clearing the market” more effectively, therefore resulting in higher utility for the network members, leading to the following research questions:

Research Question 1 (RQ1). Does the presence of intermediaries increase average utility for the network participants?

Research Question 2 (RQ2). Does the presence of intermediaries make the market more efficient?

Finally, although previous literature has discussed the effects of the presence of intermediaries in the market as well as their different typologies and characteristics, there is a lack of indications concerning when it is beneficial for firms in an innovation network to perform their search through an intermediary. Therefore, the last research question that this paper explores is:

Research Question 3 (RQ3). Under what conditions should an innovation seeker use an intermediary in its search?

3 Model

This paper develops a simulation of the interactions among firms involved in an innovation network using Agent Based Modeling (ABM). This modeling strategy is appropriate for the development of a theory of open innovation networks by helping in both refining the conceptualization and definition of constructs, and in developing empirically testable propositions (Davis et al, 2007; Fioretti, 2013). The dynamics of network formation are often too complex for closed-form mathematical modeling and, therefore, computational techniques such as ABM represent a valid alternative (Gilbert, 2008). In the study of Open Innovation, ABM has been used to examine the consequences of the decision to open innovate and the outcomes of engaging in flexible versus stable partnerships (Almirall and Casadesus-Masanell, 2010), but not to examine the relationships among multiple firms in a network.

3.1 Modeling Strategy

The network model described in this paper is loosely based on the concept of a “fitness landscape”, which originated in evolutionary biology (Wright, 1931; Kauffman, 1993) and has been successfully applied to the study of technological innovation (Levinthal, 1997; Kauffman et al, 2000; Almirall and Casadesus-Masanell, 2010). A fitness landscape is defined as “a multidimensional space in which each attribute (gene) of an organism is represented by a dimension of the space and a final dimension indicates the fitness level of the organism.” (Levinthal, 1997, p. 935). Each organism’s position in this landscape is characterized by

a set of genes and each of the genes can assume a specified set of values, indicating which allele is present in the agent’s genome. Each agent is therefore described by an array of N scalars $A = \{a_1, \dots, a_N\}$. Each combination of genes is associated to a specific “fitness” value, therefore associating the position in the space that a specific configuration of genes occupies to a fitness that is usually used to determine the ability of the organism to survive. If each organism possesses N genes and each gene can assume the values $\{0,1\}$ —i.e., it can be switched on or off—, the fitness landscape is constituted by 2^N combinations, each with its own fitness value. The landscapes generated by this category of models are often referred to as “rugged”, thus indicating the presence of local peaks that are likely to attract the optimization efforts of the agents (Levinthal, 1997).

This approach can be employed, with some modifications, to represent products in a product space. I follow the approach of Almirall and Casadesus-Masanell (2010) to adapting fitness landscape to the study of innovation dynamics. Each product (similarly to organisms in a fitness landscape) possesses a set of N features (analogous to genes), represented by a scalar. Each combination of features is associated to a predetermined utility level—which is analogous to fitness. The utility level represents the willingness to pay of a firm’s consumers for the product, and therefore is a representation of expected revenues. In this paper, each product possesses $N = 6$ features that can be configured in two possible ways and are represented by a binary variable. The landscape is generated by randomly assigning a utility value to each of the 2^N combinations of features; for simplicity, we assume that the utility landscape is fixed and does not change over time. The utility value is scale-free and is represented by a continuous value within the $[0, 1]$ interval. It is worthwhile noting that assigning utilities at random to each combination of features implies that the utility value of each feature is dependent on the configuration of the other $N - 1$ features in the product. In other words, the resulting utility value from changing the configuration of one feature will depend on the values of the other features.

Each product can be decomposed into two subsystems, each composed of $N/2 = 3$ features which we term α and β . The final, N -features product is therefore represented by an $\langle \alpha, \beta \rangle$ array that concatenates the features of each sub-product. In this simulation, there are two types of agents, seekers and providers, each possessing only a sub-system of the total product α or β , respectively. The product needs to be complete in order to be of any utility. The goal of each agent is to search for a match that maximizes the utility of the final product, given time and cost constraints. The agents are randomly distributed in a two-dimensional space and perform a search of their surrounding to identify agents of the complementary type to complete their product. The details on the search and on the decision criteria on when to stop the search are described in the following section 3.2. For the moment, it suffices to say that agents pay a fixed cost of search for every period in which they are looking for a partner.

It should be noted that the agents perform a local search in their two-dimensional space but that, because of the random assignment of utilities to different product configurations, the random distribution of the agents in the simulation space, and the fact that the agents are assigned a random set of features for their subsystem, the search of the agents is local with respect to their two-dimensional simulation space but cannot be considered local with respect to the product space (the multidimensional space defined by the string of product features). This means that when a seeker S_i gains information on the utility that it would

derive from a provider P_i , this knowledge will not yield any information on the utility that would be given by partnering with a provider P_j that occupies a position in the agent space that is adjacent to P_i .

I use this basic model structure to answer the research questions posed in Section 2.2 by exploring the search behavior of the agents in the simulation space and the outcomes of their search. At this stage of the model development, it has been decided not to model intermediaries as separate agents, in order to be able to build a solid foundation before making the model more complex. When agents use an intermediary, they increase their search space and they pay a fixed cost at the beginning of their search.

3.2 Model Implementation

The model has been implemented using the software NetLogo 5.0.5. This section explains the mechanics of its implementation. The model goes through an initialization phase, which creates the agents and the simulation space, and then into an active simulation phase, which models the agents' behavior.

First, the model defines the types (or “breeds” in netlogo terminology) of agents, and the variables associated with them. Seekers and Providers both have variables indicating:

- What features of the product they possess, expressed as an array of three binary variables.
- Their current utility level.
- Length of their current relationship.
- Total cumulative cost.
- Total number of moves.
- Radius of their search space.
- A binary variable indicating whether they decided to use an intermediary.

Some general variables are also defined, that keep track of the environment and set specific values for environmental parameters, such as the number of agents of each type, used to simulate the level of scarcity of innovation markets. The setup procedure initializes all variables and assigns utility values to each combination of 6 product features. Each agent is also assigned a “fall-back” utility that represents the utility that it would get if it decided to develop the product in-house. If intermediaries are included in the scenario, each agent has a 50 percent probability of deciding to use an intermediary, in which case a fixed amount gets added to their search cost and their search space increases.

After the setup phase, the program starts simulating the environment by setting the time period variable to $t = t + 1$ and calling a set of subroutines that determine the agents' behaviors. Each time period, the program goes through the following steps:

1. The program checks if the condition for stopping the simulation has been met. The condition is that every agent in the simulation has either found a partnership or decided to develop the product in-house.

2. Each agent checks if any of the condition to stop the search are met. The condition is that the agent created a link with an agent of the complementary kind for more than a predetermined number s (user defined) of time periods or that the agent has not found a suitable partner for the same number s of periods.
3. Each agent moves in a random direction.
4. Each agent examines the agents of the complementary kind within a radius r to evaluate the utility that would result from a partnership.
5. If an agent finds a higher utility than the one of the product that it holds at the moment, it establishes a new relationship.

In every period, the agents repeat the random move and the search, and if they find a better relationship they establish a new one; otherwise they stay in their current situation. If a relationship lasts for a specified amount of time, then the agents settle. If they don't find a suitable partner (i.e., they don't find any relationship that offers a better payoff) agent set for their fall-back utility, which represents the utility that they get for developing the whole product in-house. For each turn that an agent is engaged in active search, it pays a search cost associated with its movement. Finally, when intermediaries are present in the market, each agent can choose to increase its search space by a factor of i (user defined) at the beginning of the simulation. Finally, the last part of the code deals with the computation of summary statistics ("reporters" in NetLogo terminology).

To answer the research questions proposed in Section 2, I ran different scenarios that simulate different types of environment. The scenarios have been created manipulating the number of providers (to reproduce different levels of scarcity in technological innovation) and whether intermediaries were present in the simulated environment. The number of innovation providers was set at one hundred, two hundreds, or five hundreds, while the number of innovation seekers was left unchanged at five hundreds. When the option of using an intermediary was available, the agents were assigned randomly to work using an intermediary or not. The length of relationship (s) required to settle has been set to 10 periods and the search space when using an intermediary (i) has been set to 5. The next section will discuss the results of the simulation.

4 Results

Each scenario has been run 2000 times to test the effect of different conditions on the utility and search cost of different types of agents. The Appendix (Table A.1) reports a detailed summary of the simulation outcomes; all differences in utility and cost are significant ($p < .05$). In the rest of this section I will examine the more interesting results as they pertain to answering the research questions advanced in Section 2.

First, the simulation answers some questions about the general effect of entering into a partnership as well as the effect that the presence of intermediaries has on the market. The left side of Figure 1 shows that the presence of intermediaries does not significantly contribute to the average utility of seekers when the market for innovation is thin, that

is, when seekers significantly outnumber providers. Conversely, the right part of Figure 1 shows that providers always benefit from the presence of intermediaries across every scenario. When the market is evenly matched, both seekers and providers achieve a higher utility when intermediaries are present. However, Figure 4 shows that when the market for innovation is not developed, the presence of intermediaries does not create benefits for all seekers in the network, but only for those who decide to use them and end up finding a suitable partner. On the other hand, the mere presence of intermediaries in the market greatly helps providers by clearing the market more efficiently and hence making it easier for them to find higher-utility partners, whether they use an intermediary or not. Therefore, the answer to RQ1 is that intermediaries result in generalized benefits only for providers.

Figure 1: Average utility across scenarios

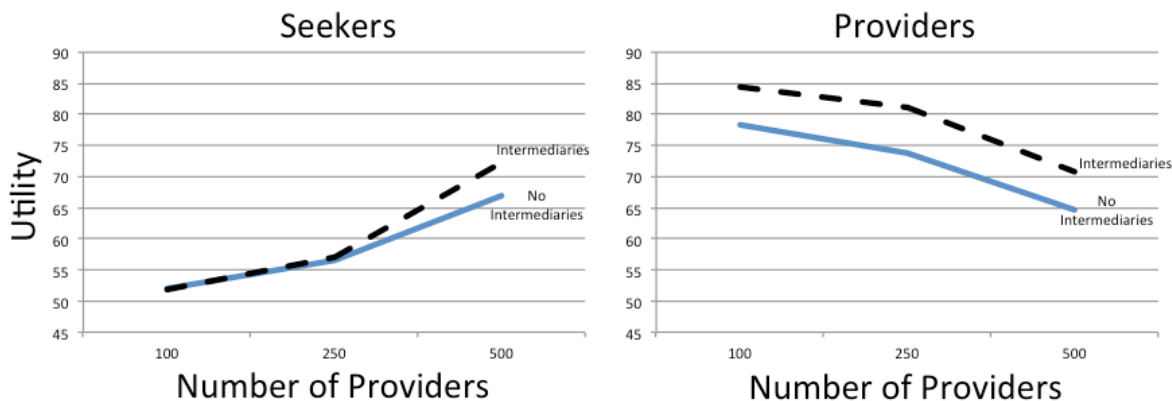
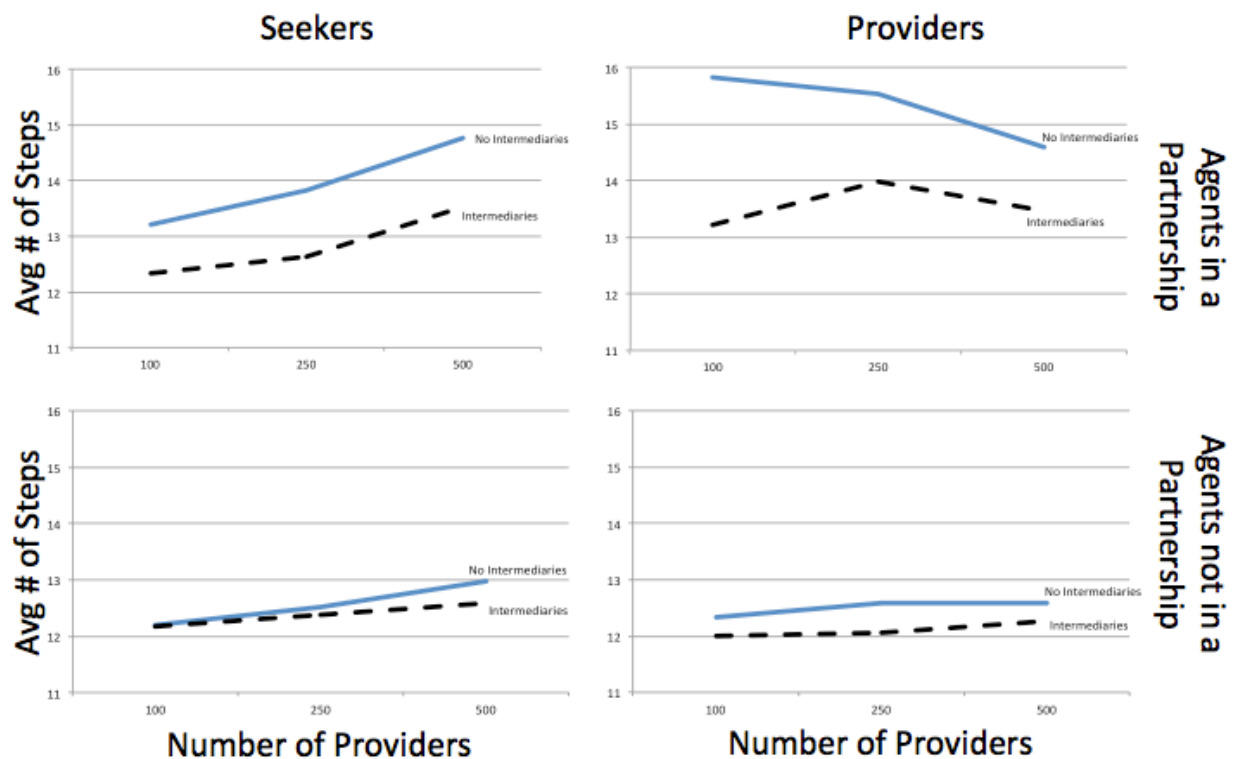


Figure 2 reports the effect of the presence of intermediaries on the search costs of the agents, as measured by the average number of steps taken before the search comes to a stop and the agent settles in the current partnership (or lack thereof). All agents that end up in a partnership experience a substantial reduction of their search costs when intermediaries are present: it is interesting to note that this reduction is experienced by agents whether they used the intermediary themselves or not. Although the benefits of intermediaries did not materialize in the utility levels for seekers in an unbalanced market, it does significantly impact the efficiency with which they can perform their search. The effect is markedly higher for agents that end up in a partnership going all the way to almost zero for seekers not in a partnership when the market for innovation is extremely scarce (i.e., when there are only 100 providers per 500 seekers). These results suggest that, in agreement with the findings of previous literature, the presence of intermediaries makes the market more efficient (therefore answering RQ2). In addition, my results indicate that when the market is thin it is much more difficult for providers to find a partner than it is for seekers. This result runs counter to the common wisdom, which suggests that when innovation is scarce, the seekers would be the ones benefiting more from better-organized markets. However, on closer inspection this finding adequately reflects the situation present in the closed innovation system: when the market for innovation is not developed, most of the seekers end up developing their product fully in house, therefore making more difficult for providers to find a buyer for their technologies. Although this state of affairs has always been interpreted under the light of

an attempt by firms to protect their intellectual property, we show that a similar behavior emerges even when all legal and patent protection concerns are removed from the scenario.

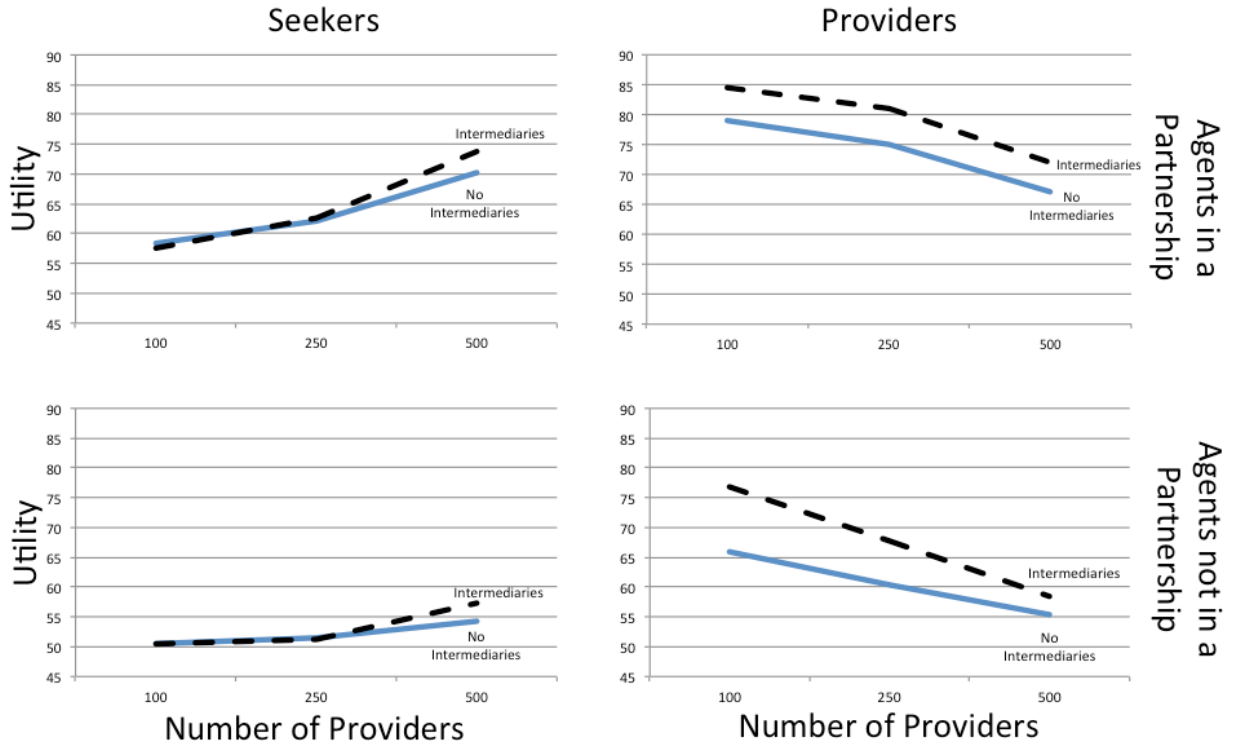
Figure 2: Average cost across scenarios



As expected, Figure 3 shows that, when the market for innovation is thin, providers consistently achieve higher levels of utility than seekers, whether they end up in a partnership or not. Similarly, we see that agents that enter into a partnership achieve higher utility levels than agents that do not. Figure 3 also shows that the presence of intermediaries always results in higher utility for providers but results in higher utility for seekers only when the market is even.

Figure 4 shows in more detail the results of the scenarios in which intermediaries are present. When intermediaries are available, seekers that used them achieved higher levels of utility in thin innovation markets compared to seekers that did not use them, but only when they found a suitable partner. If no suitable partnership was found, using the intermediary only constitutes a cost without a benefit. Innovation seekers in a thin market face the possible reward of higher utility if they use an intermediary to find a partner, but risk to incur in a substantially higher cost without any benefit if they do not find a partner. On the other hand, providers always benefit from using an intermediary, whether they end up in a partnership or not. The answer for RQ3 is therefore that providers always benefit from using an intermediary but the situation for seekers is more complex. Seekers always benefit from intermediaries when the market is balanced (a very rare condition in the real world); in all other situations, however, they face the possibility of a substantial gain in utility (if they end up finding a partner) or a substantial cost with no benefit if they end up having to

Figure 3: Average utility of entering into a partnership



develop the product in-house.

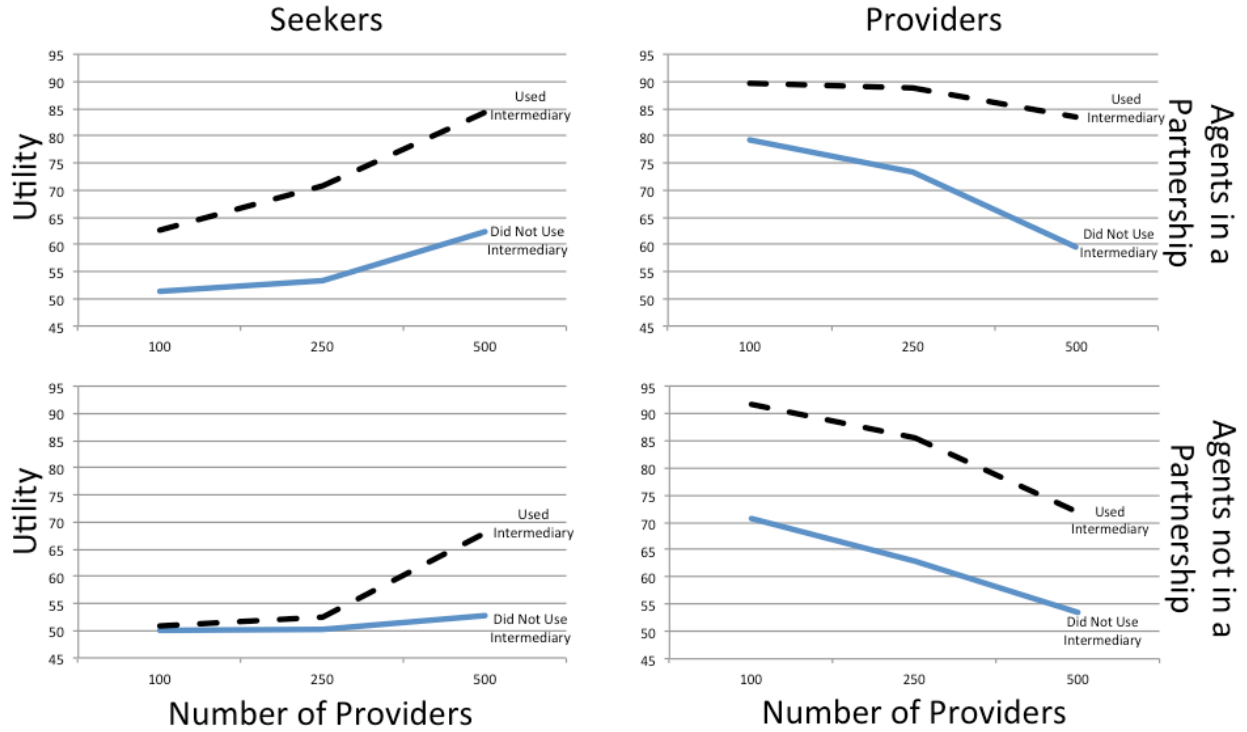
5 Conclusions and Limitations

This paper develops an agent-based model of an open innovation network, in which different types of firms (innovation seekers and providers) look for suitable partnerships to solve their innovation problem. The simulation also explores the effect of innovation intermediaries (i.e., firms that facilitate the partnership search of the agents) on the functioning of the innovation network. Given the relevance of intermediaries in modern innovation markets, their inclusion in the model creates the potential to significantly contribute to the current debate (Hargadon and Sutton, 1997; Howells, 2006).

First and foremost, the model shows that intermediaries always make the search process more efficient by their mere presence in the market. Average cost of search is reduced for every agent in the network, regardless of the fact that they use an intermediary themselves or not. This results highlights the fundamental role that intermediaries can play in the creation and development of open innovation networks and therefore lends support to the systemic attempt of several governments to expand the role of firm incubators to technology brokerage between firms and research institutions.

As a counterbalancing point, intermediaries do not uniformly increase the utility of all agents. Seekers do not all gain similar increases in utility when intermediaries are present. On the other hand, providers always benefit, therefore lending more support to the role of

Figure 4: Average utility of using an intermediary



stimulus that the presence of intermediaries can have on innovation. The last part of the analysis (Figure 4) shows that the choice of using an intermediary for innovation seekers is not a simple one, when the market for innovations is not balanced. On the one hand, they stand to gain large increments in utility if they were to find a partner through an intermediary, because they are likely to find a much better match than they would have without brokerage. On the other hand, they risk to pay the increase search cost needed to use an intermediary and still not find a partner, therefore incurring in a cost without benefits.

This paper shows that the dynamics of innovation networks can become complex even with agents acting according to simple behavioral rules. Nevertheless, some clear indications emerge from the model. Providers are always better off using intermediaries in their transactions, while seekers have to consider the characteristics of the market as well as their own internal capabilities.

Like any research effort, the model presented in this paper has several limitations which chart the way for further developments. The first problem with the current implementation is that agents stop their search when one of the following criteria is met: i) they have not switched relationship status (from one partner to another or from non-partnership to a partnership) in a specified number of time periods; ii) a pre-specified threshold level of utility has been met. These criteria are arbitrary and do not take in consideration cost when deciding their satisfactory level of utility. The first enhancement of the model would be to include an analytically derived stopping criterion.

Second, in the current implementation the seekers and the providers get the same payoff from the same set of features (i.e., in a partnership, seeker and provider get the same utility level). It would be more realistic to hypothesize that the partners gain a different utility from the transaction. Additionally, the payoff should be made stochastic in order to provide a more realistic scenario. The agents would therefore only be able to choose partners based on an expected utility rather than a deterministic one.

Third, a major simplification of this model is that Intermediaries have not been modeled as a separate type of agents. Therefore, an important step in creating a more realistic model would be to introduce them as decision makers in the model and to examine the effects of different strategies.

Finally, several parameters in this model (such as cost of search and utility) have been assigned arbitrary values not grounded in empirical data. Although this strategy is useful in assessing the general dynamics of the system, the model needs better calibration of its parameters to become meaningful in providing guidelines in the real world.

Appendix

Table A.1: Results of the simulation runs (N=2000 per scenario)

P/S ^a	Measure ^b	P/NP ^c	I/NI ^d	Scenarios with no intermediaries			Scenarios with intermediaries		
				100	250	500	100	250	500
P	Count	P	N/A	96.1	229.7	395.2	100.0	249.6	456.8
P	Percent	P	N/A	96%	92%	79%	100%	100%	91%
S	Utility	N/A	N/A	52.03	56.44	66.93	51.86	56.98	72.38
P	Utility	N/A	N/A	78.45	73.77	64.68	84.51	81.05	70.81
S	Utility	P	N/A	58.39	62.20	70.22	57.47	62.73	73.76
S	Utility	NP	N/A	50.52	51.54	54.40	50.46	51.24	57.38
P	Utility	P	N/A	78.94	74.91	67.11	84.51	81.07	71.94
P	Utility	NP	N/A	65.98	60.49	55.39	76.73	67.67	58.46
S	# Moves	P	N/A	13.21	13.81	14.77	12.33	12.62	13.53
S	# Moves	NP	N/A	12.20	12.51	12.97	12.17	12.39	12.58
P	# Moves	P	N/A	15.82	15.53	14.59	13.21	13.97	13.47
P	# Moves	NP	N/A	12.33	12.58	12.59	12.00	12.06	12.26
S	Utility	P	I				62.50	70.78	84.28
S	Utility	NP	I				50.88	52.49	68.06
P	Utility	P	I				89.72	88.89	83.43
P	Utility	NP	I				91.63	85.63	71.88
S	Utility	P	NI				51.27	53.46	62.46
S	Utility	NP	NI				50.07	50.19	52.74
P	Utility	P	NI				79.31	73.23	59.44
P	Utility	NP	NI				70.77	62.92	53.51

^a Seekers (S) or providers (P)

^b Measure for which the Average is Reported

^c Agents ending up in a partnership (P) or not (NP)

^d Agents used an intermediary (I) or not (NI)

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