

The Positions of Virtual Knowledge Brokers in the Core Process of Open Innovation

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Abstract: Several companies are implementing the strategy of open innovation in their research and development operations. They become more dependent, therefore, on their capabilities to exchange knowledge and technology with external parties. To facilitate these exchanges, virtual knowledge brokers use web-based information systems. In this paper, we study how they take position in the core process of open innovation. Virtual knowledge brokers connect problem owners with potential solvers, showcase technological solutions to potential buyers, or arrange alliances and joint ventures between parties. These core processes correspond to the outside-in, inside-out and coupled, respectively. This study shows that virtual knowledge brokers tend to take position in the outside-in process. Three case studies—Yet2.com, NineSigma and Innocentive—are provided as illustrations. The discussion brings up hypotheses for further research on sectoral patterns of innovation, the codification of knowledge and the internationalisation of research and development.

Keywords: Research and Development, Open Innovation, Virtual Knowledge Broker, Technology Transfer, Knowledge Transfer, Web-based Information System

Introduction

OPEN INNOVATION IS a hot topic in the field of innovation management. Several companies like Cisco, DuPont, Phillips and Procter & Gamble take after it to organise their research and development (R & D) operations. The concept was introduced in the literature by the pioneering study of Chesbrough (2003a). In open innovation, knowledge passes through the company's boundaries, both from inside to outside and the other way around. The commercial success of an innovation depends strongly on its corresponding business model. Hence, companies can open up transfer channels to obtain technologies that fit their business model, or they can get rid of technologies that do not fit. We will assume that, if several companies are shifting towards that R & D strategy, the flows of knowledge and technologies increase. A market opens up for the mediation of transactions between parties.

Innovation intermediaries who seize the opportunities of the innovation market offer services that facilitate access to external knowledge and technologies (Chesbrough 2006a). In effect, companies that implement open innovation might experience difficulties in scanning the environment in search of new knowledge and technologies. If they choose to operate independently from inside their organisation, they have to commit additional technical, human and

financial resources. It follows that they may consider contracting out the services of innovation intermediaries before implementing the service inside their organisational structure. Several companies already act as innovation intermediaries. Marketing companies survey consumers for product design; engineering firms offer ultimate product designs and manufacturing solutions by compiling the knowledge of their clients; and lawyers make arrangements between companies for the use of licences on patents.

The networking possibilities brought about by the internet, in combination with the information storage capabilities of computer databases, lead companies to change the management of R & D. Several studies previously investigated companies that control web-based information systems to support products innovation (Nabisam 2002; Sawhney et al. 2005; Dodgson et al. 2006; Piller and Walcher 2006; Nambisan and Baron 2007). For instance, virtual environments enable average customers, lead product users or former company's employees to get involved at different stages of the innovation process. Web-based information systems can be used in product ideation, design, testing and service. Another group of studies focuses on computer-based information systems that enhance communication and data sharing in the innovation process (Rothwell 1994; Antonelli et al. 2000; Kessler 2003; Dodgson et al. 2005). Engineers increasingly rely on computer-aided design tools, simulation modelling systems and data sharing pro-



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ocols. All these technologies have important effects on R & D performances.

This paper deals with virtual knowledge brokers—companies that use web-based information systems to obtain market information for innovation (Verona et al. 2006). How do they operate their systems to mediate knowledge and technologies between parties? How do they find solutions to R & D problems by pooling the expertise of research scientists, engineers and physicians? How do they use the internet to showcase available patents for license? To provide answers to these questions, we start by reviewing theories on open innovation and virtual knowledge brokers. Next, we determine the position of virtual knowledge brokers in the core process of open innovation, following Gassman and Enkel (2004). The findings suggest that virtual knowledge brokers tend to take position in the outside-in process. Three case studies—Yet2.com, NineSigma and InnoCentive—are provided as illustrations. The conclusions bring up hypotheses for further research on sectoral patterns of innovation, the codification of knowledge and the internationalisation of research and development.

Theories on Open Innovation and Virtual Knowledge Brokers

One school of thought claims that corporate R & D has become increasingly fragmented and decentralised. R & D departments interact with external parties such as customers, suppliers, competitors, scientific research institutes, etc. Several authors emphasise the importance of these external sources to enhance innovative capabilities (Pavitt 1984; Cohen and Levinthal 1990; Rothwell 1994; von Hippel 1998 and 2005; Chesbrough 2003a). They stress the importance of external sources of knowledge for the innovation process and state that the innovator of a particular product is not necessarily the manufacturer. Any party which derives benefits from that product can be the source of an innovation (Von Hippel 1998). It is suggested to distribute innovation among external sources and to equip lead users with product development tools to enhance their involvement in the process of innovation (Thomke and von Hippel 2002; Von Hippel 2005). In addition, the use of know-how of any external actor through licensing-in or outsourcing of R & D can increase the capability to innovate (Rothwell 1994).

Open innovation is a theory that belongs to this school of thought. Chesbrough defines it as ‘the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively’ (2006b: 2). After investigating several case studies of multinational companies, Chesbrough concludes that closed and open innovations are opposed to each

other. In closed innovation, companies have complete control over their R & D operations, which they hope will lead to innovations. These companies perform by themselves all the required activities to turn ideas into products. They organise R & D operations under the umbrella of a centralised corporate organisation. It follows that, after having made investments in internal R & D, they are reluctant to trade their intellectual property. Moreover, they try to recruit R & D personnel from the industry’s most talented people. Chesbrough (2003a) uses a funnel-shaped model to illustrate closed innovation: at one end of the funnel enter the promising ideas that came from R & D, while at the other end only the most promising technologies emerge. No outside ideas are allowed to enter the funnel, not from the outset and not during the process. Ideas that did not make it through to the end of the funnel are shelved by the R & D department, not to be used again in most cases.

At the turn of the twenty-first century, however, closed innovation lost its sovereignty in several industries. According to Chesbrough (2003b), this was due to the increasing mobility of knowledge workers and the growing amount of private venture capital. The increased mobility of workers made it difficult to control ‘leaking’ of expertise and ideas outside company’s boundary. The rise in venture capital enabled workers to quit a company and through start-up companies realise ideas that would otherwise end up on the shelf. For instance, Xerox has lost several groundbreaking technologies developed in its R & D laboratories. The economic benefits were captured by spin-off companies using business model tailored to these new technologies (Chesbrough and Rosenbloom 2002). Other R & D-intensive companies have experienced similar spin-offs based on their knowledge spillover. Instead of trying to control this from happening, some companies recognised the advantages of shifting from closed to open innovation.

In open innovation, companies do not demarcate the strict organisational boundaries that characterise closed innovation. As Chesbrough (2003b: 36–7) puts it, ‘firms commercialize external (as well as internal) ideas by deploying outside (as well as in-house) pathways to the market.’ R & D managers have realised that they cannot hire all the bright people in their domain. They must instead open up their laboratories to external sources of knowledge and technologies. They also try to capitalise on their intellectual property rights by looking for alternative ways to commercialise technologies that do not fit their core business. They make increase profits by supplying intellectual assets to other companies through licensing agreements or joint ventures. Among the factors that contribute to the adoption of open innovation, Chesbrough mentions the ease-of-access to knowledge through the new information

and communication technologies. He does not elaborate, however, on the role of virtual knowledge brokers.

We will fill this void by referring to the theory of virtual knowledge brokers. Verona et al. (2006: 765) defines virtual knowledge brokers as 'information intermediaries who leverages the unique capabilities of the internet to absorb valuable market knowledge for innovation.' Traditional knowledge brokers are consultancy firms that recombine knowledge and technologies acquired in various industries (Hargadon and Sutton 1997; Hargadon 1998). For example, Ideo, a firm specialised in innovative design, absorbs knowledge across industries and recombines it to deliver tailored solutions to clients. Ideo has some five hundred designers, engineers, social scientists and business strategists in its offices around the world. The business model of knowledge brokers changed, however, with the diffusion of web-based information systems from the 1990s onwards. Virtual knowledge brokers started to absorb knowledge over the internet, store information in computer databases and supply it to clients upon request. Various authors have studied this phenomenon, mostly from the perspective of transferring customer knowledge to other companies (Nabisam 2002; Sawhney et al. 2005; Dodgson et al. 2006; Piller and Walcher 2006; Verona et al. 2006; Nambisan and Baron 2007).

Compared to traditional knowledge brokers, virtual knowledge broker have a different approach to business (Verona et al. 2006). First, the traditional knowledge brokers usually provide inter-industry contacts as sources of knowledge, while the virtual knowledge brokers also provide extra-industry contacts on a worldwide scale. Most of the virtual knowledge brokers are able to reach communities of innovation, which include researchers from industries, universities, government institutes, research hospitals, etc. From a theoretical point of view, it includes any internet user who can communicate valuable knowledge through a web-based platform. Second, traditional and virtual knowledge brokers differ in the nature of the outcome of their business activities. While traditional knowledge brokers provide recipient firms with solutions for product design, virtual knowledge brokers also provide ideas and knowledge to stimulate innovation, which can trigger the emergence of multiple innovations from a single idea. The high level of interactivity of the internet enables a continuous, rapid interaction process rather than point-to-point knowledge recipient to knowledge supplier interaction.

Determining the Position in the Core Process

The concept of core processes can be used to determine the position that virtual knowledge brokers occupy in open innovation. Gassman and Enkel (2004) pinpoint three processes. First, the outside-in process corresponds to a company absorbing the knowledge and technology from its suppliers, customers and other external parties, in order to enrich its own knowledge base and enhance its capabilities to innovate. The companies manufacture modular products that integrate technologies owned by suppliers. In addition, they are used to buy patents or licences to acquire the necessary technology. Second, the inside-out process occurs when a company discovers that another company is better suited to bring an innovation to the market. Such research-driven companies cannot adapt their business model to every new idea that emerges from the R & D department. It is better, therefore, to get additional revenues by selling or licensing intellectual property and stay abreast of industrial progress by maintaining a broad range of technologies. Third, the coupled process combines the outside-in and inside-out processes. Parties co-operates through joint venture, association or alliance to increase their collective knowledge and technologies against other competitors. Companies co-operate in the development of complementary products with critical interfaces.

Web-based information systems can facilitate the flow of knowledge and technology between companies that adopt open innovation along any of these core processes. Two kinds of systems can be distinguished in terms of the controller. In the first kind, the main party controlling the system creates links between recipients and senders of technology and knowledge. The information system is generally located in the main web site of the controller or there are direct links from the main web site to the system. It is obvious to the parties that the system and the information it contains belongs to the controller. The realisation of transfer of knowledge and technology thus depends upon the consent of each party. An example of a recipient-controlled system is the toolkit developed by Addidas for idea competition (Piller and Walcher 2006). Conversely, web pages of several multinational companies that showcase technologies available for licensing are sender-controlled systems. The former system also enables outside-in processes, while the later only facilitates inside-out processes. In the second kind of systems, a company controls the web-based information system with the aim of mediating parties. Only the broker exerts control over the system and the information it contains. These systems are a salient feature of virtual knowledge brokers.

Following these distinctions, we focussed our research on companies that control web-based information systems with the aim of mediating exchanges between parties. Company cases were culled from the literature on knowledge transfers, innomediators, infomediators and knowledge brokers. In addition, companies were identified through internet searches. The criteria for the inclusion in our sample included the compliance to the definition of Verona et al. (2006). The total population consist of 21 virtual knowledge brokers (*see* the Appendix). A pilot study was done to obtain a rough understanding of how these companies operate. Information was retrieved about the year of founding, sources of knowledge and technology, industrial sectors of specialisation and the position in the core processes. Relevant cases to study were selected according to the relative frequency of citation in the scientific literature. (Hence, the three most cited companies—Yet2.com, NineSigma and InnoCentive—will be discussed in the next sections.) Information was gathered on these companies through desk research. Their services were analysed in terms of the parties involved, the economic motivations of the sender of knowledge and technology, as well as the use of the knowledge and technologies by the recipients.

The virtual knowledge brokers included in our population have expanded their business activities thanks to the connecting possibilities offered by the internet. Hence, the emergence and growth of these companies follows the technological development of information and communication technologies. Early mover Knowledge Express began in 1991. The company evolved to support technology transfers, sale of intellectual property rights, licensing and joint ventures in the sector of biomedicine. It is positioned in all the cores process of open innovation. The peak in the creation of virtual knowledge broker companies occurred in the period ranging approximately

from 1996 to 1999. In the meantime, the number of internet services providers and connected users increased, and commercial internet applications took off. The range of economic sectors covered by virtual knowledge brokers broadened to include automotive, women's products, information technology and real estate. In these cases, the knowledge comes from the customers and can be used by companies for product design and marketing research. In other cases, virtual knowledge brokers provide solutions to R & D problems by calling on the expertise of researchers located in universities, government institutes and companies. Although companies serve different markets and have different sources of knowledge, they tend to take position in the outside-in process of open innovation (13 companies out of 21). The remaining companies have mixed approaches (5) or their positioning is unknown (2).

Two value chains correspond to the outside-in and inside-out processes of open innovation (*see* Figure 1). The upper value chain relates to firms that practice open innovation and have a need for outside knowledge. The lower value chain corresponds to firms that practice open innovation and aim to diffuse their knowledge outside the boundaries of the firm, in a business-to-business context. Most of the virtual knowledge brokers established their business model to take advantage of the upper value chain. Their competitive advantage lies in their ability to establish worldwide partnerships with universities and government research institutes to supply problem solvers. Indeed, the ability to make successful connections between recipients and suppliers of knowledge and technology increases with the volume of codified information stored in the web-based information systems. The following case studies show how virtual knowledge brokers take position in the core process of open innovation.

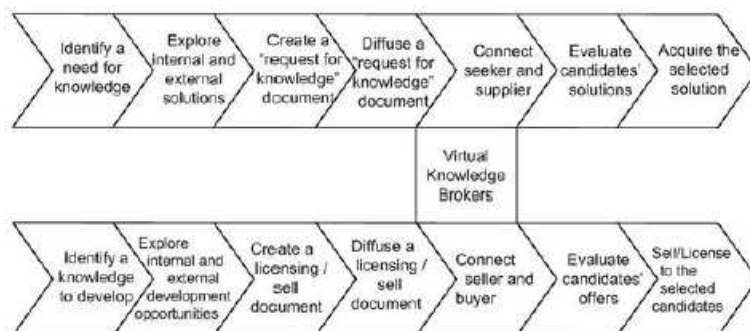


Figure 1: Value Chains for the Acquisition and the Diffusion of Technological Solutions for Innovation

Yet2.com

DuPont, one of the world's top R & D chemical companies, began to commercialise the polymer

textile fibre Lycra in 1994. Ben Du Pont, at the time responsible of the project, made the Lycra patent available for licensing on a website. The idea expounded to capitalise on the constant stream of patents for technologies that were developed in

DuPont's laboratories. Five years later, Ben Du Pont and Philip Stern, an experienced general manager and strategy consultant, created Yet2.com. Its headquarters were established in Cambridge (Mass.), with subsequent branches in the United Kingdom and Japan. Yet2.com connects sellers and buyers of technology through a web-based information system, and operates like a technology stock market: companies willing to license patents are put in contact with potential buyers, and Yet2.com takes a commission for each transaction. In 2001, Yet2.com had some 85,000 users and showcased an average of one hundred new technologies a month (Prado 2001).

Yet2.com offers two services which correspond to the inside-out and outside-in process, respectively. The first service, TechPak, offers companies the op-

portunity to sell or license patents. It offers participating firms an opportunity to get a return on their R & D investments. This is especially valuable for technologies for which a company has neither the financial resources nor the production capabilities to exploit. Multinational companies with R & D intensive activities sell licenses on their patents via Yet2.com web-site. For example, in 2004, DuPont Venture established fifteen licensing deals through Yet2.com, representing half of all deals made that year (Wood and Scott 2004). By early 2007, Yet2.com offered 4,919 technologies from twenty-eight industrial sectors. More than half of these technologies originated from the manufacturing, communications, medical, environmental and chemistry sectors (*see* Table 1).

Table 1: Technologies Showcased by Yet2.com's TechPak Service, Ranked by Technology Sector, Compiled from Yet2.com Data in February 2007

Sector	Number	Percent
Manufacturing	608	12.4
Communications	595	12.1
Medical	477	9.7
Environmental	465	9.4
Chemistry	412	8.4
Biological sciences	390	7.9
Materials	268	5.4
Energy	256	5.2
Electronics	207	4.2
Mechanical	176	3.6
Remaining sectors	1065	21.7
Total	4919	100

An example of a technology licensed through Yet2.com's website is an adhesion strip technology. The invention was posted by Avery Dennison, an American company that specialises in pressure-sensitive technology and self-adhesive products. It consists of multi-layer strips to be used for strengthening target strips on products such as diapers. The description of this invention-for-sale informs potential buyers of the technology differentiation and uniqueness. It also lists specific advantages of the technology and informs on the development stage of its product, the intellectual property status of the technology, and the demography for marketing. It aims to demonstrate the relevance of the technology by promoting the brand image of the company. In this case, Avery Denison is interested in selling or licensing the technology. By selling or licensing, the company wants to generate additional revenues outside its core market. This example shows how

TechPak is positioned in the outside-in process of open innovation.

The second Yet2.com service, TechNeed, helps firms to buy available technologies. It reduces the cost of R & D by avoiding the development of already existing solutions. It also reduces the time-to-market of new products, processes and services. By early 2007, Yet2.com listed 374 technologies in demand, covering twenty-six industrial sectors. More than half of all demands for technology came from the sectors of materials, consumer products, electronics, optics, manufacturing, biological sciences, electronic data processing and industrial (*see* Table 2). The number of demands for technologies in TechNeed is less than ten percent of the number of technologies on offer in TechPak. Yet2.com has a significantly higher volume of business activities from the inside-out process than from the outside-in process.

Table 2: Technology Needs Listed by Yet2.com's TechNeed Service, Ranked by Technology Domain, Compiled from Yet2.com Data in February 2007

Sector	Number	Percent
Materials	45	12
Consumer products	32	8.6
Electronics	31	8.3
Optics	21	5.6
Manufacturing	17	4.6
Biological sciences	15	4
Electronic data processing	15	4
Industrial techniques	15	4
Communications	14	3.7
Health, wellness, personal care	14	3.7
Remaining sectors	155	41.5
Total	374	100

Suppose that a company is looking for a technology that will enable a flame-resistant fastening between two fabrics. The name of this company is kept secret in TechNeed, which provides protection against disclosing the plan for the commercial use of the technology. This is important with respect to the company that owns the technology. It also prevents the owner of a solution to bypass Yet2.com. The request for a technology states the requirements of the company that wants a solution. In the above cited case, the company seeking the solution defines the technical constraints to which the technology must comply, in terms of breaking strength, direct flame resistance, aesthetics, toxic emissions, failure rate, ease of assembling and disassembling, etc. The requesting company also describes the areas in which it wants to apply the technology, and the expected outcome thereof. In these descriptions, the technology seeking company tries to integrate external competencies with its own R & D operations. The external technology is acquired to increase the company's innovativeness and to fill gaps in product performance. This example illustrates how TechNeed is positioned in the outside-in process of open innovation.

Another example is a company that requests a technology or a partnership for the production of a flexible photovoltaic roofing sheet. The request includes a description of the technology needed, the expected outcome, and a description of previously attempted solutions, which provides reasons for why this company requires an external technology or a partnership. The company demography contains only the geographic location, the annual revenue, the company type and the number of years the company is in business. The requesting company remains anonymous for the reasons mentioned above. The re-

quest involves a link called 'Licensing terms', which specifies the requesting company's terms and conditions for buying the solution technology, or to establish a partnership with the company that owns the solution. This example illustrates how the coupled process in open innovation is also triggered by Yet2.com.

NineSigma

Engineering professor Mehran Mehregany founded NineSigma in 2000. Mehregany was used to participate in industry-university cooperative research programs at Case Western Reserve University. When he designed NineSigma's business model, he putted into practice the basic principles of open innovation. In addition, he organised the company according to the six sigma quality-enhancement methodology developed by Motorola. NineSigma established its headquarters in Cleveland (Ohio), and opened a subsidiary in Tokyo and sale offices in Europe. President and chief executive officer, Paul Stiros was formerly R & D director at Procter & Gamble. Within three years after its inception, NineSigma committed to Procter & Gamble's open innovation strategy, which ordains that half or all new ideas must come from outside the company. NineSigma exhibits among its main clients Avery Dennison, Delphi, DuPont, General Mills, Hershey, Johnson Controls, Kimberly-Clarck, Kraft, Phillip Morris and Unilever. NineSigma generated annual revenue of \$10 million in 2006 (Reisch 2006).

In Managed Exchange, NineSigma's web-based platform, companies request solutions for R & D problems they encounter. To find the proper solution, NineSigma continuously updates a pool of scientific organisations, professional groups and other organ-

isations involved in scientific research throughout the world. Technical and scientific experts registered in the database are periodically providing solutions to problems posted by companies. They have four weeks to submit a proposal by using the appropriate form; the request is withdrawn after this period. That

explains why NineSigma maintains a low volume of active requests. NineSigma posted fifty-five projects covering sixteen industrial sectors by early 2007. More than half of the requests originate from chemistry, mechanical and food industries (*see* Table 3).

Table 3: Active Projects Posted by NineSigma for Solution Providers, Ranked by Technology Domain, Compiled from NineSigma Data in February 2007

Domain	Number	Percent
Chemistry	20	36.4
Mechanical	5	9.1
Food	5	9.1
Electronics	3	5.5
Environment	3	5.5
Materials	3	5.5
Optics	3	5.5
Automotive	2	3.6
Biotechnology	2	3.6
Hydraulics	2	3.6
Remaining sectors	7	12.7
Total	55	100

Client requests for technological solutions are retrieved from the website via forms designed for proposal and for information. A request for proposal is a service of the Managed Exchange platform enabling knowledge recipients to browse through innovative solutions, supplied by solution providers that match their R & D strategy on a cross-industry and worldwide basis. A request for proposal is usually a tentative contract for an agreement on a future partnership between the supplier and the recipient of knowledge. A request for information, also supplied by the Managed Exchange platform, enables knowledge recipients to browse information from a specific community in order to establish, in the future, the terms of a longer interaction, which does not necessarily mean that the knowledge recipient aims at a partnership. The solution provider simply submits its competencies and skills for further reference. This business model corresponds to a coupled outside-in and inside-out process of open innovation, as shown by the following examples.

The first example involves a leading global automotive manufacturer looking for solutions to develop a sensor to measure the angle between a car and a trailer. This call for solutions was posted through a request for information form, and yielded more than ten expert solutions in a wide range of technical approaches that were competing with the solutions that were proposed by the company's R & D division. In this case, the request for information form was

primarily used to identify consultants and experts, but also to build a supplier network on a contract basis. Moreover, the request for information form was used to trigger the acquisition of expert knowledge in order to find external solutions to a technological problem. This approach fits the outside-in process of open innovation.

The second example involves a consumer products company that does R & D on products that hide cellulite manifestation on the skin surface. The company aimed at conquering new markets by introducing innovative products. It posted its R & D problem via a form for problem request, which resulted in the identification of several high-quality respondents in firms located in Europe and the United States. Later on, the requesting firm signed a contract with two solution owners to establish a joint development strategy. This latter example corresponds to the coupled process.

InnoCentive

Like all of its competitors in the pharmaceutical industry, Eli Lilly introduces new drugs on the market after many years and huge spendings on R & D. To enhance innovation capabilities, research manager Alpheus Bingham decided to involve the customers through a new division that operates a web-based information system. The web platform e.Lilly connects the pharmaceutical company with doctors,

hospital clinicians, healthcare providers and patients. This initiative provided a solution to the innovation problems, by getting in touch with users (Shawney et al. 2005). In 2001, Bingham and Jill A. Partena founded InnoCentive using funds provided by Lilly Venture. At that time, Eli Lilly was suffering huge losses of income, notably after the patent on the blockbuster drug Prozac had expired. InnoCentive's platform would contribute to decrease R & D expenditures, as Eli Lilly had calculated that solutions through InnoCentive cost on average only one-sixth of solutions from its own R & D department.

InnoCentive runs a web-based market for knowledge and technology exchanges. Solutions sent by solvers are matched to problems posted on the website by seekers. This approach requires a constant maintenance of the pool of scientists and leading users who can help solve the problems posted by the companies. The scientists receive a financial award when they provide an acceptable solution to a customer's problem. To maintain a large number of problem solvers in the pool, the company signed agreements with universities and government research institutes in Russia, China and India. InnoCentive's pool is composed of approximately 95,000

scientists from 175 countries. In 2006, about 35 percent were located in Asia-Pacific, 26 percent in North America, 15 percent in Western Europe, and 9 percent in Eastern Europe and Russia. The pool contains more than sixty scientific disciplines. Almost two-third of all the solutions comes from the United States (Thayer 2006).

InnoCentive's revenue comes from the companies that post scientific challenges. A yearly subscription to the virtual laboratory service cost \$10,000. Problem solvers receive an award that ranges from \$10,000 to \$100,000 depending on the challenge. A financial reward provides a strong incentive to tackle a problem and share the solution, instead of attempting to exploit it independently. Registered scientists receive a notice upon publication of a new challenge by a company. They can also browse the website in search for problems in their domain of expertise. All problems posted are classified in the industrial sectors of biology and chemistry, the latter sector representing approximately twice as many problems than the former (*see* Table 4). A deadline of four months on average is set to prevent the obsolescence of problems.

Table 4: Active Challenges and Challenges in the Two Technological Sectors at InnoCentive, Source: Compiled from InnoCentive Data in February 2007

Sectors	Active		Evaluation		Total	
	Number	Percent	Number	Percent	Number	Percent
Chemistry	55	62.5	31	70.5	86	65.1
Biology	33	37.5	13	29.5	46	34.9
Total	88	100.0	44	100.0	132	100.0

By accepting a reward, the winning problem solver agrees to transfer his intellectual property rights to the company that posted the challenge. All solutions are visible by the company, whether they are awarded or not. The company remains anonymous at all times. Although this system protects trade secrets, it does not protect the intellectual property rights of solvers. Indeed, the company is allowed to review all the solutions submitted to InnoCentive, and only the owner of the winning solution receives an offer for an agreement. This situation leaves open the possibility of using information from the other solutions and even implement them as alternative solutions, for example when the winning solution does not work as expected. InnoCentive operates exclusively in the outside-in process of open innovation. No illustrative case can be provided, because the web-site posts only the description of the problem without disclosing information on the customers.

Conclusions

The virtual knowledge brokers in our study take position in the open innovation process by using web-based information systems. They design business models to take advantage of any combination of the outside-in, the inside-out and the coupled process. Our main conclusion is that they tend to take position in the outside-in process. The case studies illustrate that result. Although NineSigma also offers the inside-out and the coupled process, its core business relies on the outside-in process. InnoCentive operates a web-information system that only facilitates the outside-in process. Therefore, both companies have to continuously maintain a pool of problem solvers scattered throughout the world to improve the chances of obtaining solutions. This practice corresponds to crowdsourcing, a technique that several websites utilise to generate information from benevolent users at a reduced cost (Howe and Robinson

2006). Finally, Yet2.com also takes position in the outside-in process, but the bulk of its business come through the inside-out approach. Its competitive advantage lies in a system that showcases licences on patents for sale.

The business trajectories explain the positioning of the companies in the core process of open innovation. Yet2.com and InnoCentive were created by experienced R & D managers who were formerly responsible for sender-controlled and recipient-controlled information systems. They both started spin-out companies and migrated to web-based information system for mediation. In the case of NineSigma, the founder of the company has experience in conducting technology transfers from the university to the industry. These virtual knowledge brokers are contributing to externalise the R & D functions of companies with which they operate in close collaboration. In effect, Yet2.com and InnoCentive have made alliances with the companies from which they sprouted. In a different setting, NineSigma commits to Procter & Gamble's strategy of open innovation. Through these cooperations, they remain close to major players that shift towards open innovation.

This explorative study may be followed up by further empirical research to verify the following hypotheses. First, virtual knowledge brokers offer services that fulfil the needs for innovation in specific industrial sectors. It was found that innovation comes from sources that vary according to the industrial sector of activity (Pavitt 1984; Malerba 2002). The classical taxonomy distinguishes between supplier-dominated, production-intensive and science-based companies. For instance, electrical and chemical companies, which belong to the latter category, obtain new technologies from in-house R & D and transfers from public research institutions. It appears from this study that virtual knowledge brokers are embedded into the science-based sectoral system of innovation and production. They carry out market interactions for the exchange of product innovations for science-based companies in the industry of chemistry, biotechnology, pharmaceuticals, communications, etc. The properties of web-based information systems—to store large quantities of information and display it to a large audience—might slightly blur the effect of sectoral systems of innovation. Although Yet2.com and Nine Sigma operate mainly in a few selected industries, their web-based information systems enable them to maintain activities in a wide range of marginal industries.

Second, virtual knowledge brokers facilitate the exchange of articulated knowledge whose importance is limited to science-based industries. Articulated knowledge refers to any knowledge that a community records, stores and retrieves following a common codebook (Cowan et al. 2000). It can be distin-

guished from unarticulated knowledge, for which the codebook has been replaced by an implicit source of authority, or for which there is no codebook but a procedural authority. As a general rule, the articulated knowledge has advantages for systems that coordinate the activities of several agents distributed over several sites. This is precisely the case for virtual knowledge brokers. In addition, it has been shown that science-based industries rely heavily on codified sources of knowledge for their R & D operations. According to Brusoni et al. (2005: 230), the use of web-based information systems to support the innovation process 'will have a limited impact on overall rates of innovation'. The reasons given by these authors are that the majority of industries is not science-based and does not much rely on codified knowledge. As this study shows, the outside-in and inside-out processes supported by virtual knowledge brokers require the codification of information (*see* Fig. 1). The outside-in process requires at least a description of the technological problems and solutions; the inside-out process needs a description of the technologies on offers; and the coupled process requires proposals for business partnerships. It follows that the transfers of knowledge and technology through the systems of virtual knowledge brokers relies on references to scientific units, design conventions, industrial standards and professional jargon. These codebooks remove some of the cultural barriers that pose obstacles to the exchange of knowledge and technologies between parties.

Third, virtual knowledge brokers provide access to networks that resemble an optimal worldwide integrated R & D network. Gassmann and Zedtwitz (1999) point out the tendency of science-based multinationals to adopt the integrated network approach. In this organisational model, the company's R & D units located in sites around the world specialise in different domains. They stay in contact with other company units through information and communication technologies (Howells 1995). The resulting R & D organisation can achieve the adaptation of processes and products according to the local market conditions. At the same time, it has the advantages of a global scale network, because employees support the company's programs from different units. Although they face complex problems of coordination and decision making, the companies with worldwide integrated R & D networks benefit from flows of in-house information. In the same fashion, virtual knowledge brokers that support the outside-in process take advantage of dispersed R & D sites over the world. Companies that call on them can benefit from a sort of integrated network. It is worth of notice that most of the known clients of virtual knowledge brokers have already internationalised their R & D operations. In this respect, virtual knowledge

brokers may represent an alternative to listening posts established close to sites at the forefront of technological research in the world. Virtual knowledge brokers clearly contribute to the ongoing trend in R & D globalisation.

This study on virtual knowledge brokers has methodological limitations that may be solved in further research. The main limitation is that companies are severely restricting access to vital information about their business. Parts of the web-sites allow access to registered users to maintain industrial secrecy. This problem limits the information that can be gathered on deals made through virtual knowledge brokers, clients' demography and profiles of solution

providers. Although this study relied on a qualitative methodology, it revealed some interesting sources of information that produced quantitative indicators. The characteristics of the pool of solution owners can be described by referring to the number of registered users, the field of activity to which they belongs and their geographic distribution. The technologies on sale can be measured in terms of the range of industries covered and the rate of monthly introductions. Lastly, comparisons can be made between the costs of technologies from in-house R & D with technologies obtained from virtual knowledge brokers.

References

- Antonelli, C., Geuna, A., and Steinmueller, W. E. (2000), 'Information and Communication Technologies and the Production, Distribution and Use of Knowledge', *International Journal of Technology Management*, 20 (1/2): 72–94.
- Brusoni, S., Marsili, O., and Salter, A. (2005), 'The Role of Codified Sources of Knowledge in Innovation: Empirical Evidences from the Dutch Manufacturing', *Journal of Evolutionary Economics*, 15 (2): 211–31.
- Chesbrough, H. W. (2003a), *Open Innovation: The New Imperative for Creating and Profiting from Technology* (Boston: Harvard Business School Press).
- (2003b), 'The era of open innovation', *MIT Sloan Management Review*, 44 (3): 35–41.
- (2006a), *Open Business Models: How to Thrive in the New Innovation Landscape* (Boston: Harvard Business School Press).
- (2006b), 'Open Innovation: A New Paradigm for Understanding Industrial Innovation' in H. Chesbrough, W. Vanhaverbeke and J. West (eds.), *Open Innovation: Researching a New Paradigm* (Oxford: Oxford University Press), 1–27.
- and Rosenbloom, R. (2002), 'The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-Off Companies', *Industrial and Corporate Change*, 11 (3): 529–55.
- Cohen, W. M., and Levinthal, D. (1990), 'Absorptive Capacity: A New Perspective on Learning and Innovation', *Administrative Science Quarterly*, 35 (1): 128–52.
- Cowan, R., David, P. A., and Foray, D. (2000), 'The Explicit Economics of Knowledge Codification and Tacitness', *Industrial and Corporate Change*, 9 (2): 211–53.
- Dodgson, M., Gann, D., and Salter, A. (2005), *Think, Play, Do: Technology, Innovation and Organization* (Oxford: Oxford University Press).
- (2006), 'The Role of Technology in the Shift Towards Open Innovation: The Case of Procter & Gamble', *R & D Management*, 36 (3): 333–46.
- Gassman, O., and Enkel, E. (2004), 'Towards a Theory of Open Innovation: Three Core Process Archetypes', paper presented at the *R & D Management Conference* (Lisbon).
- Gassmann, O., and von Zedtwitz, M. (1999), 'New Concepts and Trends in International R & D Organization', *Research Policy*, 28 (2): 231–50.
- Hargadon, A. B. (1998), 'Firms as Knowledge Brokers: Lessons in Pursuing Continuous Innovation', *California Management Review*, 40 (3): 209–27.
- and Sutton, R. I. (1997), 'Technology Brokering and Innovation in a Product Development Firm', *Administrative Science Quarterly*, 42 (4): 716–49.
- Howe, J., and Robinson, M. (2006), 'The Rise of Crowdsourcing', *Wired Magazine*, 14–06.
- Howells, J. (1995), 'Going Global: The Role of ICT Networks in Research and Development', *Research Policy*, 24 (2): 169–84.
- Kessler, E. H. (2003), 'Leveraging e-R & D Processes: A Knowledge-Based View', *Technovation*, 23 (12): 905–15.
- Larson, E. V., and Brahmakulam, I. T. (2002), *Building a New Foundation for Innovation: Results of a Workshop for the National Science Foundation* (Santa Monica, Calif.: Rand Corporation).
- Malerba, F. (2002), 'Sectoral Systems of Innovation and Production', *Research Policy*, 31 (2): 247–64.
- Mol, M. J. (2005), 'Does Being R & D Intensive still Discourage Outsourcing? Evidences from Dutch Manufacturing', *Research Policy*, 34 (4): 571–82.
- Nambisan, S. (2002), 'Designing Virtual Customer Environments for New Product Development: Toward a Theory', *Academy of Management Review*, 27 (3): 392–413.
- and Baron, R. A. (2007), 'Interactions in Virtual Customer Environments: Implications for Product Support and Customer Relationship Management', *Journal of Interactive Marketing*, 21 (2): 42–62.
- Pavitt, K. (1984), 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory', *Research Policy* 13 (6): 343–73.

- Piller, F. T., and Walcher, D. (2006), 'Toolkits for Idea Competitions: A Novel Method to Integrate Users in New Product Development', *R & D Management*, 36 (3): 307–18.
- Prado, A. A. (2001), 'Linking Intellectual Property Buyers, Sellers, Investor's', *Business Daily*, November 9.
- Reisch, M. (2006), 'Corporate Star Search: Start-Up Firm NineSigma Uses Internet to Match Industrial Clients with Inventive Partners', *Chemical and Engineering News*, 84 (12): 30.
- Rothwell, R. (1994), 'Towards the Fifth-Generation Innovation Process', *International Marketing Review*, 11 (1): 7–31.
- Sawhney, M., Prandelli, E., and Verona, G. (2003), 'The Power of Innomediation: Exploiting the Power of Mediated Innovation', *MIT Sloan Management Review*, 44 (2): 77–82.
- (2005), 'Collaborating to Create: The Internet as a Platform for Customer Engagement in Product Innovation', *Journal of Interactive Marketing*, 19 (4): 4–17.
- Thayer, A. M. (2006), 'InnoCentive Opens Research Doors', *Chemical and Engineering News*, 84 (26): 24–5.
- Thomke, S., and von Hippel, E. (2002), 'Customers as Innovators: A New Way to Create Value', *Harvard Business Review*, 80 (44): 74–81.
- Verona, G., Prandelli, E., and Sawhney, M. (2006), 'Innovation and Virtual Environment: Toward Virtual Knowledge Brokers', *Organization Studies*, 27 (6): 765–88.
- von Hippel, E. (1988), *The Sources of Innovation* (Oxford: Oxford University Press).
- (2005), *Democratizing innovation* (Cambridge, Mass.: MIT Press).
- Wood, A., and Scott, A. (2004), 'Licensing Activities is on the Rise', *Chemical Week*, March 24: 20–21.

Appendix

List of Web-based Companies Operating in the Market of Virtual Knowledge Brokers

Name	Year	Source	Specialisation	Position
2XFR	1996	All resources with sufficient expertise in the field	No specialisation	outside-in inside-out coupled
Cnet.com	1993	Customers' knowledge	High-tech consumer products	outside-in
comScore Networks	1999	Customer behaviour	Internet market research	outside-in
Edmunds.com	1994 <i>a</i>	Customers' knowledge	Automotive	outside-in
Experts Exchange	1996	IT experts	Information technologies	outside-in
HelloBrain	Closed	n.a.	n.a.	n.a.
Idea Trade Network	2000	All resources with sufficient expertise in the field	No specialisation	outside-in inside-out coupled
ideaMD.com	Closed	n.a.	n.a.	n.a.
InnoCentive	2001	Scientists' knowledge	Chemistry and biology	outside-in
iVillage	1995	Customers' knowledge	Women products	outside-in
Knowledge Express	1991	Research Institutions Universities of Technology	Biomedical	outside-in
LiquidGeneration	1999	Customers' knowledge	n.a.	outside-in
Move.com <i>b</i>	1996	Customers' knowledge	Home ownership	outside-in
NineSigma	2000	All resources with sufficient expertise in the field	No specialisation	outside-in inside-out coupled
Pharmalicensing.com	1995	Research institutions, universities of technology, and pharmaceutical laboratories	Pharmaceuticals	outside-in inside-out coupled
Pharma-Transfer	1998	Research institutions and universities of technology	Life sciences and pharmaceuticals	outside-in
TechEx	1998	Research institutions and universities of technology	Biomedical	outside-in
UVentures.com	1999	Research institutions and universities of technology	Physical science, nano-technology, chemistry, engineering, and computer science	outside-in

WebMD	1996	Customer's knowledge	Health care	outside-in
Yet2.com	1999	All resources with sufficient expertise in the field	No specialisation	outside-in inside-out coupled
YourEncore	2003	Retired scientists and engineers	No specialisation	outside-in
Notes: a. Edmunds, founded in 1966, started to operate a web-based information system in 1994. b. The company's name was Homestore.com before 2006. <i>Sources:</i> Larson and Brahmakulam 2002; Sawhney 2003; Sawhney et al. 2005; Verona et al. 2006; Dodgson et al. 2005 and 2006; and web search for this study				

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