The role of technology in the shift towards open innovation: the case of Procter & Gamble

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As with all new ideas, the concept of Open Innovation requires extensive empirical investigation, testing and development. This paper analyzes Procter and Gamble's 'Connect and Develop' strategy as a case study of the major organizational and technological changes associated with open innovation. It argues that although some of the organizational changes accompanying open innovation are beginning to be described in the literature, more analysis is warranted into the ways technological changes have facilitated open innovation strategies, particularly related to new product development. Information and communications technologies enable the exchange of distributed sources of information in the open innovation process. The case study shows that furthermore a suite of new technologies for data mining, simulation, prototyping and visual representation, what we call 'innovation technology', help to support open innovation in Procter and Gamble. The paper concludes with a suggested research agenda for furthering understanding of the role played by and consequences of this technology.

1. Introduction

Building on a number of company case-studies of the interactive character of innovation, Chesbrough (2003b) highlights a variety of environmental, strategic and economic factors which have forced them to adopt 'open' approaches to developing and commercializing their technology. He contends that many large industrial firms have become too insular and failed to take advantage of the potential of working with actors outside the organization to find ways to create and then take ideas to the market. In this view organizations need to open themselves up to external networks and relationships in order to gain the full potential of their investments and capabilities in innovation.

Chesbrough's main focus is on the business strategy and organizational changes associated with 'open innovation'. He touches upon the role of new technologies in supporting open innovation but he does not explore it in depth. Many authors have highlighted the role of Information and Communication Technologies (ICT) in vastly increasing the ability of firms to work across different geographic and organizational boundaries (Pavitt, 2003). In doing so, the use of these technologies have helped to support the shift towards more open, collaborative and network-centred innovation practices (Tapscott, 1996; Christensen and Maskell, 2003).

But what specifically are these technologies, and how are they used to support open innovation? How do they, on the one hand, shape the strategic orientation of industrial firms towards their external environment, and on the other facilitate the creation and realization of actual innovations?

Using the case study of Procter & Gamble's (P&G's) 'Connect and Develop' strategy, we examine how the use of technology supports the movement towards open innovation. We extend previous analyses by moving beyond the role of ICT (computers, Internet, communications devices, etc.) and focus on a range of new technologies, including simulation, modelling, virtual reality, data mining and rapid prototyping technologies and their role in the movement towards open innovation. We show that alongside, and building upon, the use of ICT, P&G uses these new technologies that support the innovation process in a number of ways, including by forging closer links between market information and technology development. We call these technologies Innovation Technology (IvT) (Dodgson et al., 2005a) and show in the case of P&G that use of these technologies is reshaping the way it manages its innovation process.

We present the theoretical and empirical background to the paper in Section 2, focusing specifically on the use of technology in the innovation process itself. In Section 3, we describe the method of our study. Section 4 considers P&G's Connect & Development programme, and its associated organizational and technological changes. Section 5 offers conclusions of this case study and discusses its relevance to the future development of thinking about open innovation.

2. Theoretical and empirical background

There has been a long tradition in innovation studies emphasizing the interdependencies – the mutual dependencies and reciprocal relationships – in the innovation process. A number of forms of analysis, for example, emphasize the systemic nature of innovation. Various systems are argued to impinge upon the innovation activities of firms. Innovation systems, comprising combinations of institutions and relationships, operate nationally, regionally, sectorally and locally (Allen, 1977; Freeman, 1987; von Hippel, 1988; Camagni, 1991; Lundvall, 1992; Nelson, 1993; Powell and Koput, 1996; Edquist, 1997; Cooke and Morgan, 1998; Malerba, 2002). Similarly, different production systems around various forms of contractual and cooperative relationships exist between producers and their suppliers, and affect the propensity for innovation (Best, 2001). Technological systems, driven by the commercial advantages of scale and scope, facilitated by open systems computer architecture, and evolving hierarchies of integrators and suppliers, also affect innovation (Tuomi, 2002). Analyses of the innovation process itself highlight its highly integrated and iterative nature (Kline and Rosenberg, 1986; Brown and Duguid, 2000). For others, this high level of internal integration is complemented by extensive external integration, with customers, suppliers and sources of knowledge, which is crucial for successful innovation (Freeman, 1991; Rothwell, 1992; Szulanski, 1996; Dodgson, 2000; Laursen and Salter, 2004).

Similarly, there has been a long tradition examining how, theoretically and empirically, the creation and use of knowledge takes centre stage in explaining firm behaviour and determining firm competitiveness (e.g. Penrose, 1959). These traditions analyze the firm as bundles of resources, routines and capabilities, and consider their construction, internal configuration and reconstitution as the primary determinant of business competitiveness. These theories emphasize the significance of knowledge, and place the practices that surround the use of knowledge as fundamental elements of firm constructs. For example

- resource-based theories (Penrose, 1959; Barney, 1986; Grant 1996) consider firms as bundles of assets comprised of both tangible and intangible resources and tacit knowledge.
- Behavioural theories of the firm (March and Simon, 1958; Cyert and March, 1963) analyse the development of firm-specific routines and the conditions necessary for the production of knowledge;
- 'Learning' theories (Argyris and Schon, 1978; Senge, 1990; Nonaka and Takeuchi, 1995; Brown and Duguid, 2000) consider the creation and application of knowledge at various levels, its centrality to organizational performance, its construction at an individual and group level ('communities of practice'), and the ways in which individual learning becomes an organizational property;
- Evolutionary theory (Nelson and Winter, 1982) identifies the significance of routines as the economic analogues of genes in biology. Routines are the organizational memory for an organization, its repository of knowledge and skills.
- Dynamic capabilities theory (Teece and Pisano, 1994) encompasses the ability of firms to learn to sense the need to change and then reconfigure internal and external competences to seize opportunities created by rapidly changing environments. In this theory, the essence of the firm is its ability to create, transfer, assemble, integrate and exploit difficult to

imitate assets, of which knowledge assets are key (Teece, 2002).
- the concept of absorptive capacities (Cohen and Levinthal, 1990) indicates that a firm's own R&D improves its ability to learn from others. It is essentially a theory of the importance of internal R&D in the integration of external knowledge.

These theories reveal the ubiquity of notions of knowledge in certain theories of the firm and strategic management and how the construction of the core elements of these approaches to strategy – resources, routines, and capabilities – is associated with the creation and use of knowledge (Dodgson et al., 2005b).

These theories of the centrality of knowledge and the systemic and interdependent nature of innovation provide, in part, justification for the interest in the notion of open innovation. Open innovation potentially has the capacity to develop into a theory of innovation and systemic knowledge. At present, however, any theory of open innovation is still in gestation and it remains important to identify the significance of any mechanisms which can assist the formulation and use of knowledge contributing to an interdependent and systemic innovation process.

Chesbrough (2003a, b) emphasizes the interdependencies in the innovation process. He argues the decline in the strategic advantage of internal R&D is related to the greater range of producers of knowledge and the increased mobility of knowledge workers, making it more difficult for firms to appropriate and control their R&D investments. The open innovation process redefines the boundary between the firm and its surrounding environment, making the firm more porous and embedded in loosely coupled networks of different actors, collectively and individually working towards commercializing new knowledge. Chesbrough also suggests there are many innovative solutions developed at the boundaries between disciplines and the new model of innovation therefore needs to find ways of leveraging this when it may not be possible to own all the capabilities in-house.

While technology is identified as one of the factors that facilitates knowledge flow and an interdependent innovation process, its contribution is not widely researched in the open innovation literature. It is well established in the broader innovation literature that technology assists in integrating internal and external inputs in innovation. Rothwell (1992), for example, describes the use of a 'new electronic toolkit' being applied to the fifth generation innovation process. The role of these technologies in enabling interaction and providing better information about organizational processes is well documented (Zuboff, 1988). From these perspectives, ICT is seen as providing a ubiquitous digital infrastructure for the inexpensive, rapid and secure storage and transfer of information and data. It facilitates the exchange of ideas and information moving from one place to another. ICT infrastructure supports a whole range of value-adding services, such as web services, enterprise resource planning and customer relations management. Its development trajectory is directed towards improved speed, processing power, connectivity, and interfaces. The benefits of ICTs are based on large improvements in these areas coupled with cost reductions in equipment, and open computer systems architectures that enable the cumulative development of technological advances.

Others refer in the literature to new kinds of technology that assists in the innovation process itself (Thomke, 1998a, b, 2003; Debackere, 1999; Henderson, 1999; Schrage, 1999; von Hippel, 2001; Debackere and Van Looy, 2003; D'Adderio, 2004). This technology is the focus of our attention. We examine the impact of a suite of technologies, what we call IvT, used for *creating* innovation (Dodgson et al., 2005a). IvT, including a wide range of design, simulation, modelling, and visualization technologies, is increasingly being applied to the innovation process.[1] It provides the means by which people are technologically assisted in their creative tasks. The development trajectory of IvT is towards achieving economies of effort and definiteness of aim in innovation (Dodgson et al., 2002). These technologies help create new environments for people to think about new options, to engage other parties, such as users, in design, to play or experiment with different futures and to ensure that other technologies are used to maximum effect in the delivery of product, process, and service innovation. IvT influences the ways knowledge is constructed, shared and used. They affect the ways in which we think about and conceive innovations. It affects the way we experiment with, test and prototype new products, processes and services (Thomke, 2003). It is part of the process of what Schrage (1999) calls the 'serious play' of prototyping. IvT builds upon the massive computing power and the infrastructure and tools provided by ICT, such as broadband and open systems. They can be integrated with advanced manufacturing technologies, such as computer-aided machine tools, and marketing and customer management systems, thereby linking product, service and process innovations.

In his Preface to Chesbrough's book, John Seeley Brown notes that the movement towards open innovation has been strongly influenced by this new kind of technology: 'with the power of today's computers to simulate massively complex and non-linear systems coupled to phenomenal visualization techniques, the customer can be brought ever closer to the design process' (Brown, 2003:x–xi).[2] Despite the acknowledged importance of these technologies to the innovation process, little research and analysis has attempted to link their use to open innovation practices. Yet, these technologies are often critical in assisting the interdependencies and knowledge flows that occur in open innovation.[3] Focusing purely on ICT and its impact on open innovation provides a partial picture of the way technology shapes innovative activities and focuses attention on means of communicating ideas rather than generating them. By focusing on IvT, it is possible to gain a fuller understanding of how practices and processes of firms are changing in open innovation circumstances. As Schrage (1999) suggests, these technologies provide a window into the engine room of the innovation, where new innovative ideas emerge, are selected and acted upon.

3. Method

The research is based on an inductive case study. It forms part of a wider study carried out as part of a 4-year project on the intensification of innovation undertaken by the authors. P&G was one of the major company cases undertaken for this study, and involved a deep engagement at a number of levels with the company over a 2-year period from 2002 to 2004.

P&G was one of the four companies invited to a day-long meeting of the Innovation Club (established by Imperial College London, with the Universities of Sussex and Brighton), to discuss a paper by the authors on the 'intensification of innovation' (Dodgson et al., 2002). P&G's response to this paper included a presentation which particularly related to the emerging Connect and Develop strategy. This led to a continuing dialogue, and to an invitation to conduct a day-long workshop at P&G's Newcastle, UK laboratories on 'Innovation and Connect and Develop'. At this workshop, the ways in which P&G engaged customers in product development was explored by around 40 participants. The event was facilitated independently by a former director of research at ICI and the results were documented. During this process, a number of key interview respondents were identified, including Dr Mike Addison (New Business Development), Larry Huston (Vice-President of Knowledge and Innovation P&G Worldwide R&D) and Neil McGlip (Head of the Corporate R&D, Packaging).

Before the Workshop and interviews, background evidence was assembled by the authors into material from which detailed questions were generated relating specifically to the use of technology in open innovation. A semi-structured questionnaire was used in all interviews (see Appendix A). This was slightly adjusted during the research process in order to ensure that questions better reflected the experience of the interviewees. The interviews provided an opportunity to explore different organizational environments, highlighting the particular features of P&G's history and managerial approach to using new technology in problem-solving and innovation. The interviews were conducted by two members of the research team, taped, transcribed, written-up, and returned to interviewees for verification. The notes were also sent to knowledgeable members of project teams for checking and verification.

The Connect and Develop strategy at P&G has elicited considerable attention in the popular press, and there are numerous reports and interviews available on the Internet (see, for example, the interview with the CEO of P&G in *Fortune* (Sellers, 2004)). These added to the background knowledge of the research team, and in combination with the workshop material and interviews led to improved understanding of developments in the company. Furthermore, a number of cases of suppliers of particular IvTs to P&G are available, and two of these from: SGI, and Simulation Dynamics are reported in the case. In addition, a member of the research team attended a 1-day workshop on Managing Discontinuous Innovation at Cranfield Business School, where a major case of P&G was presented by Roy Sandbach, P&G Research Fellow, and manager responsible for new product direction-setting and innovation in Europe.

Case studies are well suited to the study of how and why a particular technology is being used. They enable a deep understanding of an issue to develop through the use of several supportive research methods; in this instance: interviews, participant workshops, and literature and smaller case study searches and reviews. They enable the testing and enrichment of the open innovation approach by adding further information on its extent and nature, and by describing mediating conditions and factors. The case of P&G adds to knowledge about the range of the applicability of the open innovation concept (into consumer products firms), and to the central importance of technology in enabling and assisting many of its associated practices. The case provides an example of the way a large established firm, with an historical and well-established system of innovation can transform its innovative activities by adapting open innovation practices.

4. Open innovation in P&G

4.1. Background

P&G is one of the world's largest and most successful consumer businesses. It operates in almost every country in the world, with net sales over $40 billion and nearly 100,000 employees. Products include world-leading brands such as Pampers, Pringles, Ariel, and Tide. In 2002 three of the top ten new non-food products introduced into the United States came from P&G.[4]

P&G has a substantial R&D organization, with over 6,500 scientists. It has over 29,000 existing patents with another 5,000 added on average each year, making P&G one of the largest holders of United States and global patents. Comparable companies in ownership of patents include Microsoft and Intel. Presently, on average, P&G spends around $5 million on R&D and registers eight patents a day.

P&G possesses strong brands and is always looking for brand growth (Swasy, 1994; Dyer et al., 2004). However, it operates in an extremely competitive, mature, global market, hence the company is continually searching for new, innovative ideas. Throughout the late 1990s it experienced lower than expected sales growth and attributed this to shortcomings in its ability to produce new products to satisfy consumers' changing needs. No new major product of the scale of Tide or Pampers had been developed for over two decades.[5] P&G recognized that to meet sales growth targets its innovation rate would need to increase significantly. P&G's management also realized that the cost of investments in R&D, technology and innovation were increasing faster than sales growth, and that this was unsustainable.

But innovation remains the key to P&G's strategy. Chairman of the Board and President and Chief Executive A. G. Lafley has said, 'Innovation is our lifeblood – new ideas and new products that make consumers' lives better, build customers' sales and profits, and build P&G's market share, sales, profits, and Total Shareholder Return'.[6]

Among the problems identified within the company were that P&G did not always benefit from its existing knowledge and did not listen to, and learn enough from, the outside world: it operated with a closed innovation system.

4.2. Towards an open innovation strategy

In June 1999, P&G launched a new strategy to increase growth through innovation called *Organisation 2005*. One of the main aims of *Organisation 2005* was to stimulate innovation by making P&G's internally focused and fragmented communications more outwardly focused and cohesive (Schilling, 2005). Gordon Brunner, Chief Technology Officer, and Head Worldwide R&D, at the time said he wanted to create a culture that connected people and technologies in a more effective way. To emphasize the point Brunner said that R&D could become C&D – 'Connect and Develop'.

The concept of Connect and Develop was fundamental to the *Organisation 2005* strategy. P&G was founded on making successful innovative connections. Its business evolved from connections such as that from candles to soap, from the animal fat in soap to the first all vegetable shortening. This led to discoveries in emulsifiers and surfactants, used today in products such as shampoos and dishwashing liquids. P&G's history was rich with innovative new products made through connecting what was not obvious. As P&G's Dr Mike Addison put it at a Connect and Develop Symposium in February 2003, 'Innovation is all about making new connections. Most breakthrough innovation is about combining known knowledge in new ways or bringing an idea from one domain to another'. This is characteristic of the 'technology synergies and fusion' elements of Rothwell's fifth Generation Innovation Process (Rothwell, 1992; Dodgson, 2000).

The recognition that the vast majority of solutions to P&G's problems lay outside of P&G was a critical first step in the development of Connect and Develop. Larry Huston describes how prior to its inception he discovered that P&G operated in around 150 areas of science. At that time, P&G employed more than 7,500 R&D staff, yet it was estimated that there were approximately 1.5 million researchers around the world working in these areas of science and technology at levels equal to or better than P&G's internal expertise. The challenge was to access this external resource, and to change the culture within P&G in order to encourage and facilitate searching outside of the company for innovations.

P&G's strategy for growth through innovation, and innovation through building connections is, therefore, not so new. What are new are the organizational practices and technological media that assist its implementation.

4.3. Organizational changes

Traditionally P&G was protective about its patents and wary of licensing them to outsiders. In 1999, before the Connect and Develop programme was introduced, less than 10% of P&G technologies were being used in products (Sakkab, 2002). The objective of the new strategy using open innovation practices is to turn more technologies into products. As a result of its Connect and Develop strategy, P&G aims to drive new innovation through collaboration with external partners in at least 50% of cases. A number of organizational initiatives have been introduced to assist the process (Sakkab, 2002).

P&G has created a Technology Acquisition Group (TAG). This group is part of the new attitude to licensing at P&G and it actively seeks out new complementary technologies from external sources. In addition P&G is active in licensing its own technologies to increase its returns on investment.

P&G brought the many sources of information for innovation together at *Innovation 2000,* a 'deal-making/technology trading expo', where P&G showcased its most promising technologies. Over 5000 P&G researchers attended. Those who could not attend were able to take part via web casting and satellite technology, which acted in the same way as a news TV station with broadcasts, news flashes and commercials. In addition P&G distributed cell phones to P&G employees so they could record new ideas and make new connections. External suppliers were also invited to showcase their technologies in the hope of making new connections. The event was heralded a success, with over 2,200 ideas for new products and new applications for P&G technologies.

P&G has also pursued other initiatives, including buying entrepreneurial companies and the creation of internal seed funds. Crest Spin-Brush is an example of the former. This product was developed by four entrepreneurs. It was initially licensed by P&G, which went on to buy the company and subsequently employed three of its founders. The product has been an outstanding success and returned the company's investment ten times over in only 2 years.

The Pur Sachet is an example of a product developed through internal seed funding. P&G provides seed funding between $20,000 and $50,000 for innovative new ideas. This product emerged in the company's Newcastle, UK laboratory from a project team hoping to recycle rinse water with detergents in it. The researcher concerned was funded to help with the larger problem of transforming dirty water into drinkable water, and the product, Pur Sachet, which could prove to be a truly significant global innovation, is the result.

Both these cases reveal the extent of changes in the organization and culture of P&G. It is prepared to bring in ideas from outside sources, including using the entrepreneurial advantages of small firms, and it allowed a young and relatively inexperienced individual researcher a free hand in the development of the product, in contrast to its past autarkic approach and high-level supervision culture for new product development.

Throughout the study, numerous members of P&G staff referred to the significant cultural changes accompanying the move towards an open innovation strategy. Neil McGlip, says that 'C&D is more a way of life than a technological strategy. It is about your mindset. It is ensuring you are open day and night to new possibilities'. According to Larry Huston, such changes in organization require a deep cultural change which in P&G's case took place over decades. The change was assisted by the company pursuing an intermediate strategy in between that of its historical centralized self-reliance in R&D to its current global networking model. During the 1980s, P&G adopted an internal networked model of R&D, with decentralized research activities around its key global markets (Bartlett and Ghoshal have described this strategy as 'mutual interdependence (1989, p. 129). See also Bartlett and Ghoshal, 2000). Had this strategy of decentralization not already been pursued, Huston considers that the present transition to C&D would have been difficult to achieve.

4.4. Technological changes and open innovation

The Connect and Develop project is enabled by the technological advances of the last decade or so that assist the creation, transfer and utilization of knowledge across organizational boundaries.

These technologies include data searching and mining, simulation and modelling, and virtual and rapid prototyping. Examples of the ways these technologies are used will be described, followed by an example of one group within P&G that benefits from the combination of all these technologies in its interdependent innovation process.

4.5. Data mining and searching

P&G's Connect and Develop strategy is founded on the use of technology to connect internal and external resources such as a corporate Intranet and 'smart' reporting systems for knowledge sharing. Nabil Sakkab, P&G senior vice president, R&D, explains how the technologies available today provide a modern version of the laboratory lunch table where connections for innovation were made when he first started out in his career. To modernize the 'lunch table' P&G created a Global Technology Council, made up of business unit technology directors, corporate R&D heads and other key R&D decision makers. Sakkab says the Council explores ways to leverage P&G's technologies and acts as an 'incubator' for research exploration and early stage new product development (Sakkab, 2002). P&G employees distributed around the world can talk to each other through an internal website called InnovationNet. Sakkab claims that InnovationNet acts as P&G's 'global lunchroom;' researchers use this to make connections and share data and information from internal and external sources. In 2002 there were over 9 million documents online, and this number was growing rapidly. InnovationNet is automated and Artificial Intelligence is used to support data mining that acts in a similar way to Amazon.com by taking account of users' interests when sending back information on material the user may be interested in, and connecting people with the same interests. Sakkab believes InnovationNet's true value to P&G is its ability to accelerate innovation by allowing thousands of innovators across the globe to make new connections, collaborate with co-workers and cross-fertilize their knowledge in a variety of specialized fields. It also facilitates through extranet communication with external business partners and serves as a link to external databases (Sakkab, 2002).

One of the purposes of these Internet-based systems is to facilitate communications within and between 'communities of practice' (Brown and Duguid, 2000). P&G has numerous communities of practice, such as bleach, polymers, analytical chemistry, flexible automation and robotics, technology entrepreneurs, fast cycle development, and organic chemistry. Part of the personal development plans of researchers is involvement in one or more of these communities of practice.

One of the most important external sources of capability to be developed by P&G is the Technology Entrepreneurs network. This is an extended network of 70 individuals that help link P&G to external innovation possibilities. The technology entrepreneurs are scientists and specialists in the technology needs of one of P&G's Global Business Units.[7] They are expert data mining specialists that use the most advanced data mining visualization tools to search billions of web pages, scientific literature and databases and global patent databases. Nabil Sakkab, claims this allows P&G to find the 'needle in the haystack' and then link this to business needs.[8] Larry Huston says the 'technology entrepreneurs are really key to the connect and develop strategy'. To date they have identified more than 10,000 products, product ideas and promising technologies (Huston and Sakkab, 2006).

P&G has also been instrumental in creating and supporting a number of Internet-based innovation intermediaries which help link externally sourced solutions to internal problems, such as InnoCentive, Yet2.com, and NineSigma (Dodgson et al., 2005a).

4.6. Simulation and modelling

Simulation and optimization techniques are used in the design of P&G's logistics networks. Since 1995, P&G has operated under a concept known as the 'Ultimate Supply System', which attempts to tightly couple suppliers through the integration of information, material and products, and financial activities. With 300 brands and 120 manufacturing facilities, supply chain management is obviously of considerable importance. The objective of this system is 'to significantly increase sales, reduce costs, increase cash flow and, ultimately, to provide the right product at the right time at the right price to our customers' (Wegryn and Siprelle, undated).

P&G has an internal operations research group, called Global Analytics, which uses optimization and simulation techniques for the design of supply networks. These technologies enable the selection of the most effective solution from among thousands of options simultaneously to determine a supply chain structure. The advantages of using IvT in this process are described by Glenn Wegryn, Associate Director of IT Business

Solutions – Global Analytics at P&G and Andrew Siprelle, President of Simulation Dynamics Inc.:

> Simulation modeling allows time-based, execution level events to be represented, analyzed, and understood. Simulation provides a rich environment for experimenting with different approaches to operating strategies that may be effective. Until recently, simulation has extensively been used to examine manufacturing operations for removing throughput bottlenecks, improving operating efficiencies, testing sequences of operations, material handling, etc. More instances of utilizing simulation technology on broader supply chain issues are being reported ... Within the context of supply chains, simulation allows close analysis of inventory positions, their deployment and how they are affected in downstream demand signals, and the re-order policies in place to respond to those signals. Synchronizing planning cycles and production schedules with up- and down-stream supply chain partners, as well as understanding capacity utilization issues in response to closer coupling of supply chains are issues that can be addressed with simulation modeling (Wegryn and Siprelle, undated).

4.7. Virtual and rapid prototyping

One of the major ways P&G uses IvT is in its use of virtual and rapid prototyping systems. Here we report the perspective of one of the technology suppliers of IvT to P&G. The way P&G uses simulation and computer-aided engineering in encouraging innovation is highlighted in a case study conducted by SGI.[9] The study describes how SGI's Origin 3800 supercomputer is used by P&G to create and test prototypes of products and the machines that manufacture them in a virtual state, thereby eliminating past requirements for early physical prototypes. It also allows them to simulate the effects of production line changes without building actual equipment.

The case study describes two 'moments of truth' for P&G customers. The first is when the customer decides to buy the product on the basis of its price and perceived value. The second is when the customer opens the product and assesses its performance. IvT is used to help P&G in both. Firstly, it helps evaluate suitable materials, their effectiveness, and the capacity to manufacture them economically. It 'helps to ensure that product containers don't break or crack when dropped, viscous fluids flow easily from their containers, and lids of every type don't leak'. Secondly, it helps play a role in determining how P&G products function during actual consumer use: how do they perform in the hands of customers. Simulations are used to evaluate how products perform for people with a range of human physical characteristics.

Tom Lange, Associate Director for Modelling Simulation and Analysis in P&G, is quoted extensively. He describes the company's philosophy around these technologies is to 'Explore Digitally: Confirm Physically'. He says the benefits of this form of IvT are reductions in costs and increases in innovative opportunities. It has enabled the company to pursue a wider range of creative solutions to meet consumer needs, without having to invest in costly infrastructures. Lange is quoted as saying '... virtual prototypes provide a timely and cost-effective means by which P&G can determine the 'fit, work and financial sense' components used to evaluate a product before committing to building a physical representation. Virtual prototyping gives us a chance to ask what-if, and then test it in any number of ways to determine next steps, if any, moving forward'. He refers to documented cases where it has saved P&G millions of dollars and months to years in development time, for both products and the machines that make them.

P&G also uses simulation-based product evaluation tools, such as virtual reality shopping malls to test consumer reaction to its products compared to competitors. These tools, for example, provide information from factors such as eye movement analysis not easily determined from traditional focus group and telephone product evaluation.

Lange also refers to the way in which P&G will continue to make physical prototypes in the latter stages of product development as these '... still carry many intrinsic tactical consumer findings that simply cannot be replaced virtually'.

According to Larry Huston,

> ... the ability to ... virtually create the brand story, to virtually create products, to take virtual models and test them interactively with consumers over the Internet ... to simulate the storage shelf with that virtual product on it and see whether people buy it ... this is the future, the *future* ...

4.8. CreateInnovate

CreateInnovate is a small group within P&G that is an extensive user of IvT. The group produces new packaging to help P&G create brand identity.

Packaging design is hugely important in consumer product markets: it helps sell products. CreateInnovate uses IvT to increase innovation in the packaging and marketing of P&G's products through the integration of different sources of knowledge within and outside of the firm in the process of design, through the use of a visualization suite in order to test representations of package designs with consumers, and through a 3D computer-aided design (CAD) system which can simulate and model prototypes, linked to rapid prototyping technologies.

CreateInnovate has 18 staff in Egham, Surrey, and Brussels, and it works closely with another 18 non-employees in design and prototyping companies, providing considerable flexibility in capacity. Its objectives are to create new ideas for packaging, and then to develop designs and rapid prototype them. Its aims are 'to make consumers want to buy P&G products: to make them go wow!'

The group spends a lot of effort brainstorming internally and externally with design houses such as IDEO (Hargadon and Sutton, 1998). The aims of these brainstorming exercises are to bring together a number of multi-skilled people with different but relevant knowledge and experience, in a structured way, in order to create ideas. Ideas for new packaging concepts are described in text and in sketchs, often with the help of sketch artists. This is called the 'ideation' phase. From these rough sketches, 3D CAD models are quickly produced; usually in 1 or 2 days. This CAD model will be used throughout the entire development and manufacturing process: from initial concept to Computer Numerical Control manufacturing. As the head of this group, Neil McGlip says 'this digital model will live with the product idea until it goes to manufacturing. We only create one model and then play with it'.

Once the model is produced and virtual product testing begins, teams of people from around the world examine the virtual model and comment on what they like and what they do not like. The image is very close to the real thing. It moves the same way and it is shaded appropriately. As Neil McGlip puts it

> Once it has been created digitally you can show it to people and see what they think. You can change it and tweak it to see if people's attitudes towards it improve. We also make little videos of the products and how they work and then send these to panels of users. There is no need even to create a physical product at this time. For the users, seeing is believing. They sift through various ideas and you can get a quick idea of what works and what does not. Using the new technology helps us get a richer representation of the new idea and almost immediate feedback from users. The whole process takes days not months. The new tools allow people to play easier. In some ways, the virtual prototypes are like games where users can play with the design, exploring different design options. It provides vivid, accurate representation of the project. It allows you take 100 ideas and kill the 98 of them that are no good.

These technologies are interconnected with manufacturing technology. Rapid prototyping technologies are used extensively. CreateInnovate uses rapid prototyping machines that were originally developed for Formula 1 motorsport, where is it essential to be able to create high precision parts quickly. The group works with local rapid prototyping tool developers and shares experiences with them about how best to develop prototypes. According to McGlip, rapid prototyping enables designers to quickly get a feel for new components, how they look and feel, and how they fit together.

An example how the process works in practice is the development of the Tide StainBrush, which is now on the market in the United States. The product idea derived from the application of the Connect and Develop policy. The group took the Crest spin brush (a low cost electric tooth brush) and tried to see what else could be done with it. One idea that emerged was to use the brush to remove stains. The Tide StainBrush is a battery-powered brush with an oscillating head that helps Tide Liquid penetrate into stains. The fabric-safe bristles rotate back and forth, working the liquid into the fabric and loosening stains.

In total, it took 1 year from initial concept to full market launch. The process began in October 2002. A CAD design of the Crest spin brush was available, but the design needed to be radically altered to make it work as a stain remover. A new grip needed to be created so that the brush could be pressed down upon the stains. It was also necessary to redesign some of the internal mechanical features of the Crest spin brush for it to gain more power. The group tried to use or recycle as much of the Crest brush as possible. By December 2002, the first working prototype was developed in-house. It was held together by duct tape, but it showed that the concept was viable. However, the motor had a tendency to stall when material was rubbed, and the group set to work to fix this problem. The CAD files for the new brush were sent to China where 100 physical prototypes of the new product were produced. These prototypes were sent around for testing in April 2003. The product worked well in the trials and the decision was made to go for full market launch in August 2003. It was 10 months from the initial idea to the product being within P&G internal shops for testing among employees. Once in the P&G internal shop in the United States, the product sold out in a day. This indicated that it might be a popular product in the market. Mass production began in autumn 2003 and the product was launched on the US market in December 2003.

Another example of this process is the development of the Stiffer; essentially a dust cloth attached to a pole. Users of the product wanted a liquid system fed into the cloth and so it was necessary to develop a pump system. The basic idea in this project was to take the existing product that had no pump and reinvent it. Overall, it took 12 months of design and development to get the product on the market. It involved specialized engineering to make the product work. A new joint for attaching the pole to the mop end needed to be developed. A trigger mechanism for releasing the liquid was required. It was also necessary to simulate how fluids flow through the pole and how the cavity inside the mop would fill and react.

The technology used in CreateInnovate is freely available in the market.[10] It uses entirely off-the-shelf simulation software; there is no in-house software at all. It relies on new modelling packages and standard CAD tools. There have been no problems in moving the CAD model across different systems.

The use of simulation tools has changed the staffing profile of the group. It previously used almost exclusively to hire people with a relatively narrow background in chemistry, biochemistry or chemical engineering. As it become involved more and more in design, it started to hire a broader church of people. The group has, for example, hired industrial designers and mechanical engineers. The capacity of IvT to represent ideas and prototypes quickly and cheaply assists the interdependences and knowledge flows between this diverse range of people.

Neil McGlip argues that it is still necessary to perform lots of physical testing on the products. 'You need to drop the package on the floor and see what happens. Does it go splat? Does it really work? The simulation tools are predictive, but you still need to try it out physically'. His overall evaluation, however, is that the major effect of the using the tools has been to compress time scales for creating and prototyping new products.

There are limits to the contribution that IvT can make: it does not provide all the answers to P&G's innovation problems. This is seen in the case of Okido. The Okido project received seed funding from P&G and was developed from a technology that produced heat when exposed to the air. The technology used for Okido was traditionally used in products such as pain relief heat treatments for muscular aches and strains. As there were already products like this in the market, P&G provided seed funding to explore potential ways to apply the technology for use in different products and or markets.

The lead researcher, a chemistry analyst, was awarded seed funding to come up with a new product within a year. A cross-functional team consisting of marketing, advertising and R&D staff was formed. They came up with the concept of a portable, safe, scented candle. The team used CAD, and rapid prototyping, to come up with product variations. However, a trial of the product to P&G staff via the Internet was unsuccessful. Unsurprisingly, the scented product was not ideal to sell over the Internet.

After significant development costs, the product was scrapped. The company took the strategic view that the market for such candles was too saturated for a new product to make much impact. The costs in dollars and in human man-hours could have been avoided by a strategic overview of the potential of the candles market being interjected at the beginning of the project. There should have been a clear market analysis before new product development proceeded. This can, perhaps, be attributed to the view that: we have the technology so we should do something with it.

In this case, the use of IvTs may have speeded up the design and development process, i.e. its *efficiency*, but it did not assist with the strategic decision of whether it was the right product to produce, i.e. its *effectiveness*.

5. Discussion and conclusions

Chesbrough's open innovation model encapsulates the business strategy and organizational changes occurring as innovation becomes a more distributed activity across a wide range of different actors. The attractiveness of open innovation as a business strategy is the way it leads to exploiting the benefits from imported ideas from outside the firm and exporting intellectual capital that had hitherto been idle. The model also engages with new forms of finance enabling large corporations to become more entrepreneurial, supporting start-up businesses through new venture funds and the like.

P&G is cited as an exemplar case of open innovation in practice. We have seen how P&G's Connect and Develop strategy has involved many of the features of an open innovation model, including the creation of a TAG, venturing and involvement with various Internet-based innovation brokers.

Case studies, such as the one we report here, usefully add to the stock of knowledge about open innovation, and are particularly helpful in identifying its moderating and contingent conditions. In an attempt to contribute to understanding the range of factors that affect open innovation we have explored how technology has helped to shape P&G's approach to open innovation. Information and Communications Technologies have played an important role in facilitating P&G's open innovation strategy, particularly in assisting communications within and between 'communities of practice'. The paper argues, furthermore, that another kind of technology has been important to P&G's strategy: IvT. The simulation and modelling, virtual reality, data mining, and rapid prototyping technologies used in P&G have been instrumental in helping the company with its interdependencies in innovation. It has helped engage suppliers, customers and other sources of knowledge into P&G's innovation process. In doing so, innovation technologies support the shift to open models of innovation. The focus on IvT has helped to provide deeper knowledge about the ways in which data and information is not only exchanged but also manipulated and used creatively within a distributed innovation process. For example, simulation, virtual reality and rapid prototyping tools enable technologists to explore new ideas and integrate market information while working in geographically dispersed teams.

It is too soon to tell whether these dramatic changes in P&G's approach to innovation will produce its objectives of new blockbuster products. What is clear is that the company has become much more successful at accessing external sources of technology and is extensively using IvTs. Larry Huston says that the company's goal of leveraging external assets for 50% of its innovations is very ambitious, given that historically this figure was probably only around 20%. He argues that the changes are still underway and that in 2004 perhaps 35% of innovations were accessed externally. These changes were occurring rapidly; he estimates the number of products in the market place that were linked to external sources increased from four to fifty in 1 year, and that the pipeline of products with such sourcing 'looks impressive'. It is estimated that P&G's innovation success rate has more than doubled, and R&D productivity has increased by nearly 60% (Huston and Sakkab, 2006).

Although it is unwise to generalize from case studies, in addition to some of the observations made throughout previous sections about the benefits of IvT, based on this study of P&G we can venture a number of broad observations about technology and organization in open innovation.

First, the changes in Connect and Develop described have not occurred overnight. Increased external search activities have, according to many influential managers, required a significant cultural change. This, it is argued, has built upon a previous vintage of organizational change that led to a more decentralized R&D structure. As seen in CreateInnovate's use of IvT, the changes have also resulted in new skills requirements, which take time to manage. Second, the technology does not replace existing practices. We have seen, for example, how managers describe how they still rely on physical prototyping. Virtual prototyping, however, enables physical prototyping to be undertaken later in the process, when there are fewer unknowns in the development path, and also saves time and resources. Third, the technology does not provide a panacea for overcoming the uncertainties of innovation. The failure of one new product, the Okido, confirms that even the best practices and tools will not make a success of a new product development process developing the wrong product.

Case studies assist in raising and sharpening research questions. There remains large numbers of unresolved questions about the use of technology in open innovation. The first relates to the *costs* of open innovation. The costs of managing the new dispersed networks of experts and expertise are uncertain, particularly as the number of interdependencies increases with more sophisticated and often competing demands placed on multiple relationships. It is not yet clear what transaction costs are involved and whether all the benefits expected will be accrued, and by whom, in the open innovation model. Neither is it completely clear how *intellectual property* will be managed in this regime, although the use of Internet-based brokers helps in this regard (Dodgson et al., 2005a).

Other research questions concern the changes in *skills and organization* associated with the use of technology in open innovation. What are the new skills requirements of users of IvT? And what are the dangers of reliance on virtual and simulated environments? The technology has the potential to enable a greater degree of specialization in the supply of services around innovation, and mapping this would be valuable as it may have considerable consequences for *industrial disaggregation*. Research into the *supply* of IvT is warranted. What is the nature of the market for the provision of these technologies? As with all new vintages of technology there are issues of integrating the new technologies, and linking them effectively with existing investments.

Different strategies are likely to be needed in *managing interfaces* between large corporations like P&G, other businesses in supply and distribution networks, small specialist firms and independent individual experts. Their different roles and approaches to operating within a distributed innovation system enabled by IvT could form the subject of further research. As well as improving the company's receptivity to external inputs into its innovation activities, technology also assists internal 'openness', by helping build effective communications between disparate groups in the company. The role of IvT in breaking down boundaries between disciplines, professions and 'communities of practice' provides fertile ground for future research.

Open innovation increases the extent of business and technological interdependencies between firms. This adds to the *complexity* of the innovation process. An important continuing research question is the extent to which IvT enables this complexity to be managed cheaply, quickly, and efficiently.

An open innovation approach has the potential for synthesizing theory around the innovation process by bringing together theories of interdependent and systemic innovation and the nature, creation, and use of knowledge. Examining the role of technology in assisting the production and application of knowledge and innovation for strategic advantage may assist the development and testing of such theory.

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Notes

1. Our studies show its extensive use in a wide range of sectors, from pharmaceuticals to mining, clothing, and construction, in firms of all sizes, and in research, design, engineering, and production tasks.
2. This point on the importance of these technologies is not developed further in Chesbrough's analysis.
3. The extent of their influence is examined in Dodgson et al. (2005a), which argues that they have the potential to reshape the way firms organize their innovative activities, creating a new division of labour within and across organizations.
4. Procter and Gamble website, company information, http://www.pg.com/main.jhtml
5. In 2002, 12 of P&G's 250-odd brands generated half of its sales and an even bigger share of net profits.
6. www.pg.com/science
7. The business units were formed as part of an organizational restructuring at P&G to enable it to move from geographical representation to global business units based on product lines.
8. Nabil Y Sakkab, Connect & Develop Complements Research & Develop at P&G, paper adapted from his presentation at the Industrial Research Institute in October 2000.
9. http://www.sgi.com/industries/manufacturing/eoi/vol3/march/customer.html. The objective in producing this case include, of course, promoting SGI technology, but nevertheless the case usefully reports P&G's overall approach to the use of such technology.
10. In other case studies we have conducted we have found that the price and availability of many IvTs is not prohibitive to even the smallest firms. However, some top-end systems, such as the CAD system, CATIA, are too expensive for many firms.

Appendix

Appendix A. Interview template

Table A1

Background
Type of firm – market, size, competence, products
Organizational structure and context
Innovation problems and challenges being faced
Use of IvT
What technology is being used in the innovation process
What type of business is it being applied to (product, process, flow, mass, etc.)
Origins of the technology (where did it come from? Is it a bespoke or packaged system)
When is it used? (experimentation, concept design, schematic design, detailed design, testing and refinement or implementation)
How is it used? What is the character of the prototyping culture within the organization? (playful/serious, closed/open)
Why was it used?
What is required to enable it use? (e.g. new skills in software)
How is the use of the tool managed? Are any management tools used?
What type of output does does it generate (3D visualization, data, prototypes etc.)?
Impact of use
What impact does it have on the problem at hand or the performance of the project or team?
What impact does it have on the way the engineers or scientists solve problems? Does it change the way they work, and how?
What impact does its use have on the way the engineers or scientists work with partners, clients or customers, suppliers, and across functions and other divisions?
Does the use of the tool change the way the firm manages its innovation process?
What lessons have been learned inside the organization from the use of the tool?
What could have been done to ensure more effective use of the tools and to increase their impact on the innovation process?
Evidence of use
Is there data that can be collected to provide evidence of the impact of use inside the organization? (Performance data, project data)