LAPPEENRANNAN TEKNILLINEN YLIOPISTO
KAUPPATIETEIDEN OSASTO
Teknologiatutkimus

INNOVATION PROCESSES

Tutkielman aihe on hyväksytty Lappeenrannan teknillisen yliopiston kauppatieteiden osaston osastoneuvostossa 28.5.2004.

Työn tarkastajat: Professori Kalevi Kyläheiko
Professori Jaana Sandström

Espoossa 28.05.2004

Janne Fält
Vanharaide 3 c 51
02610 ESPOO

TIIVISTELMÄ

Tekijä: Fält, Janne

Tutkielman nimi: Innovation Processes

Osasto: Kauppatieteiden osasto

Vuosi: 2004

Pro gradu –tutkielma. Lappeenrannan teknillinen yliopisto 81 sivua ja 9 kuvaa.

Tarkastajina: Professori Kalevi Kyläheiko
Professori Jaana Sandström

Hakusanat: innovaatio, dynaamiset kyvykkyydet, teknologinen muutos

Tässä työssä on tutkittu innovaatiota kirjallisuudessa ja M-realissa. Tekninen kehitys johtuu innovaatioista. Innovaatio on luonteeltaan epävarmaa, polkusidonnaista ja sisältää eri teknologioita. Innovaation vaikutukset ulottuvat usein myös asiakkaisiin ja toimittajiin. Yrityksen eri funktioita ja hierarkiatasoja tarvitaan kaupallistamaan uusi idea tai keksintö. Dynaamiset kyvykkyydet erottavat muutokset ympäristöstä ja niitä tarvitaan innovaatioiden toteuttamisessa. Yrityksen ympäristö muuttuu ja joustavuutta tarvitaan projektien toteuttamisessa. Reaalioptiot tarjoavat joustavuutta projektien toteuttamisessa. M-realissa on vahva tekninen osaaminen, mutta asiakkaat ovat jääneet vähälle huomiolle innovaatioprosessissa. Innovaatiota ei myöskään ajateltu koko yrityksen tehtävänä. Tästä johtuu osittain vaikeudet saada ekstravoittoja. Paino M-realissa on kehittää palveluinnovaatioita.

ABSTRACT

Writer: Fält, Janne

Title: Innovation Processes: Case M-real

Department: Business administration

Year: 2004

Master's Thesis. Lappeenranta University of Technology. 81 pages and 8 figures.

Supervisors: Professor Kalevi Kyläheiko
Professor Jaana Sandström

Keywords: innovation, dynamic capabilities, technological change

This study has examined innovation in literature in general and in M-real particular. Innovation is the reason and response to changes in the environment. Literature view has showed that by nature innovative activities are uncertain, path dependant and multi technology. Innovations also affect the whole value chain of the firm and may have affect to the whole value network. Different functions and managerial levels are required to commercialise an idea or invention. Dynamic capabilities detect changes in environment and are needed to implement innovative activities in a firm. Consumer preferences, competitors' actions, technological advance and governments' actions change markets. Flexibility could raise the value of a project and the real options deliver flexibility. Innovation in M-real has technical focus. Customer end is often neglected and innovation was not understood as a corporate wide task. This make gaining innovation rents difficult. Service innovations are in central focus in M-real at the moment.

ALKUSANAT

Tutkimustyössä hyvä keskittymiskyky on avainasemassa. Olen huomannut oman työskentelyni aikana, että hyvään työskentelyvireeseen päästäkseen täytyy myös olosuhdetekijöiden olla kunnossa. Näillä olosuhdetekijöillä on suora vaikutus työtehokkuuteen tai – tehottomuuteen ja työn laatuun. Vaikka tutkielmaa tehdessä joutuu yksin pohtimaan erilaisia ratkaisuja ja päätöksiä, niin kuitenkin useammalla henkilöllä on ollut vaikutusta tekemääni lopputyöhön ja edellä mainitsemiini olosuhdetekijöihin. Näitä henkilöitä ja tahoja haluankin kiittää seuraavaksi.

Esitän kiitokseni M-realille työn mahdollistamisesta ja tukemisesta sekä kaikille M-realin Kirkniemen teknologiakeskuksen henkilöille, jotka ovat myötävaikuttaneet tutkielmani valmistumiseen.

Kiitän työn valvojana ja tarkastajana toiminutta Kauppatieteiden professoria Kalevi Kyläheikoa Lappeenrannan teknillisestä yliopistolta neuvoista ja ohjauksesta. Kiitokset myös Jaana Sandströmille Lappeenrannan teknillisestä yliopistolta työn tarkistamisesta.

Erityiset kiitokseni esitän ystävilleni saamastani kannustuksesta työni valmiiksi saattamisen eri vaiheissa. Viimeiset kiitokset kuuluvat David Bowielle, Lou Reedille ja Ismo Alangolle loistavasta musiikista.

Espoossa 12.5.2004

Janne Fält

1 INTRODUCTION

1.1 Background

It is widely agreed that both the productivity growth and the increase in welfare come as the result of technological change (Kyläheiko, 1995, 1). Technological change is based on technological innovation through technological knowledge. How to gain extra rents from the technological change?

New technological knowledge comes often from industrial research and development. Technical aspects play a critical role in industrial innovation, but successful innovation comes from the interaction between the economic and the technical aspects and the understanding of these factors and their effects to the firm and the competitive environment. Simple technology push or market pull models of innovation seldom describe this interaction and understanding. (Mowery and Rosenberg, 1989, 9.) It is not easy because innovative activities are by nature

1. Firm specific and cumulative in their development, which leads to path dependency
2. Differentiated – a result of path dependency
3. Collaborative between professionally and functionally specialised groups
4. Uncertain – technically, commercially and organisationally

Some of these elements are more strongly involved in one innovation and some in others. These facts have many effects on the firms involved. The path dependant nature of innovation constrains firm's choices of technology in the future. What has been learned in the past, affects the firms possibilities in the future. It is difficult and time consuming to start to work with totally new technology and integrate it to existing competencies in the firm. Implementation of new innovations requires collaboration over

functional and divisional boundaries and between different disciplinaries. Learning is needed to exploit the cumulative development and to understand the sources of uncertainty. (Pavitt. 1991.) Communication between hierarchical levels is also vital when resources are allocated. Organisational uncertainty refers to the importance of the organisational processes, which exploit the technological paths open to the firm. Even if a firm can develop a new technology and integrate it to the existing technologies in the firm, commercialisation of an idea or invention may require new organisational thinking to find new ways to make rents. The real options approach provides a useful way of thinking for understanding the uncertainties behind the innovative activities.

To be able to innovate, large innovating firms often manage several different technologies from different disciplines. Technology itself is something that "refers to the theoretical and practical knowledge, skills and artefacts that can be used to develop products and services as well as their production and delivery systems. Technology can be embodied to people, materials, plant, equipment and tools." (Burgelman, et al., 2001, 4). Critical parts of technology are based on tacit rather than codified knowledge. Burgelman, et al., 2001, 4). Teece (1998, 63-64) explains tacit knowledge as that "we know more than we can tell". It is slow and expensive to transmit when compared to codified knowledge such as blueprints or formulas. Because of the difficulty in sharing the technological knowledge, it is a long process to combine new technologies to existing ones in a firm. This makes the management of an innovation also the management of the knowledge inside the firm as well as the managing of partnerships.

Even when innovations are successfully commercialised in one area, firms still have difficulties to see the whole scale of different applications where innovations could be used (Rosenberg, 1995, 17). Also, the academics have difficulties in seeing the effects of an innovation on the economy. Information and communication technology can be used as an example.

Even now it is difficult to tell the positive effects to the businesses. There are four major reasons for this. First, new technologies are often in primitive condition when first introduced. Only after development, like Abernathy and Utterback (2001) describe, the characteristics and possibilities of an innovation can be better known and understood. Second, complementary assets related to innovations (Teece, 1998) also need further improvements and development. They may even be non-existing at the time the innovation was made and only after being combined with the basic innovation, innovation can have greater effects to the firm, industry or economy. Third, new technologies are usually thought as replacements for the old ones in the first place. Fourth, the new technologies must satisfy some needs in the market. No matter how interesting the technical aspects are, the ultimate market test of whether the customers' need are satisfied or not makes the final decision of success or failure in capitalistic economies. (Rosenberg, 1994, 4-5.)

Why some firms are better than others in gaining rents from their innovations? Teece (1998) argues that firms gain and sustain competitive advantage by creating and deploying difficult to replicate knowledge assets. Creating new knowledge through innovation is the first part. Embodying new knowledge into products and production processes forms the second part. And commercialising new technologies is the third part. All these three parts may challenge old organisational forms and old ways of dealing with customers and suppliers and require new approaches to gaining rents from the innovation. Complementary assets are used to transfer the knowledge into products or services. The access to complementary assets can also play a critical role in the way how the profits are divided. These assets can be owned by the seller, the buyer or by third parties (Teece, 2003, 3). Teece (1998, 75) sees that the essence of the firm "is its ability to create, transfer, assemble, integrate and exploit knowledge assets". To do this successfully, a firm needs dynamic capabilities in order to operate successfully in the changing environment. The ability to sense and seize opportunities and nurture its knowledge and

complementary assets and competencies are considered as the firm's dynamic capabilities. They help firms adapt themselves to competition, new technologies and changing customer preferences. At least in the long run, they are therefore vital for the firms survival. (Teece, 1998.)

After the innovation has been developed and introduced, it will diffuse only if information about its user value characteristics is transmitted to the potential users. This can happen by imitating, through selling or through both.

Diffusion of innovation is important when considering the sustainment of competitive advantage with the innovation strategy. When the source of technology is external (supplier, buyer or maybe unrelated industry), it is difficult to take competitive advantage of it. The main reason is that, in most cases, other companies have the same access to this source of technology (Porter, 1985, 183) and if they have the capabilities to utilise it, they will.

As knowledge is the foundation of an innovation, the diffusion of an innovation through imitation to competing firms depends on how easy the knowledge the innovation is based on is to copy. Teece (1998, 67) uses the concept of "the appropriability regime" to describe the easiness of imitation. When there are tight intellectual property rights and the technology is difficult to copy, the appropriability is strong. When intellectual property rights are weak or the technology is easy to copy, the appropriability is moderate. If intellectual property rights are weak and technology is easy to imitate, technology will be copied easily and the competitive advantage of the innovating firm will be lost.

When firms design and implement innovation processes, they typically face complicated issues. Innovation means change and in firms there will always be resistance to change. This is due to the path dependent capabilities. Major innovations may require different ways of doing things

i.e. new routines and capabilities and leave parts of the present knowledge base useless. The paper industry is often seen as an industry where most of the uncertainty comes from market fluctuations and the firm's responses to this fluctuation are often of strategic importance (Ståhle, et al., 2002, 75). However, the production of paper includes several different technologies and disciplines as well, and new technologies are continuously examined. New technologies can make radical breakthroughs and cause changes in the industry. ICT is a good example of this. It can increase productivity in the pulp and paper industry at the same time it provides for example advertisers a whole new medium.

The sources of these new technologies are both on the outside and the inside of the paper industry. This makes innovation management, related to knowledge management, important. Successful development projects need the combination of market opportunities, technological knowledge (new and old) and cooperation of different disciplines and managerial levels in the innovating firm, but also with suppliers, customers and other partners. And as Teece (2003, 6) stresses, "the activities of firms and their managers shape markets, as much as markets shape firms". Even when a firm has all the needed resources but no dynamic capabilities, it cannot earn Schumpeterian rents from new combinations. Building dynamic capabilities to sustain the competitive advantage is more than spending money on R&D.

An important question that arises is the coordination between the functions of the firm and the suppliers (or partners) and customers to identify and link technological options build and market opportunities open to the firm are of increasing importance. (Dosi, et al., 2000, 6.) Still even nowadays some firms (as well as government policies) focus on the technical aspects in their innovation strategies.

1.2 The research problem

Technological change, or innovation, and changes in the competitive environment give some firms a chance to gain (or loose) competitive advantage and earn extra rents. However, managing innovative activities in a firm is a complicated process. The research problem in this study is how to improve the product- and production process innovation processes at M-real in general? At M-real this is important question. Production volumes are low compared to major paper and board producers and this makes the competition with prices difficult or impossible. Being innovative (and customer oriented) is the best way to compete against the bulk product producers. The focus is to study the phases of the innovation process in general and see what advantage real options thinking and a dynamic capabilities view of the firm can contribute to this process.

To study industrial innovation process in a firm level, at least three questions need closer study first:

What is innovation?
At firm level, what kinds of effects different kinds of innovations have?
What elements are needed in an innovative firm?

These are very broad issues and are studied at a general level. Some examples from literature are presented.

The research problem was defined with an instructor from M-real Kirkniemi Technology Centre. The role of R&D in the innovation process is in special focus. One reason why the role of R&D is in special focus is that this work is made in the first place for a R&D unit. Another reason is that industrial R&D has a central role in creating new knowledge for the firm and utilising it. Sometimes this new knowledge is referred to technical goals only.
The chosen way to approach this problem is to see what economic theories can offer in the first place. Also interviews, or preferably internal

discussions within M-real, can provide some new information about the attitudes towards the role of the technology centres in the innovation process at M-real. Also the opinions concerning the importance of innovation can be examined with interviews. These interviews should give an idea of whether the innovation processes at M-real have elements presented in the literature review. These interviews are very qualitative and the interviewee has to be very careful and objective in his conclusions. It is also known that the theories differ in best practices on many cases and ways.

1.3 The structure of the study

The study is divided into seven chapters. In first chapter the background, research problem, objectives and the scope of the study are defined. The second chapter presents innovation in general and the most important characteristics of innovation in particular. The aim is to introduce the effects of an innovation to the firm. The third chapter focuses on the theories about the firm. Focus is on the dynamic capabilities view of the firm and innovation. The discussion of the Penrosian view of a firm and the evolutionary theory of the firm lays the base for on the dynamic capabilities view of the firm. The fourth chapter presents different innovation process models offered in economic literature. The real option approach to the innovation process is presented in the fifth chapter in the context of innovation and innovation process. The sixth chapter presents the case study and the results of the interviews. In the last chapter are the summary and the conclusions of the study.

2 INNOVATIONS

All industrial innovations, technological product and process innovations as well as commercial innovations, can be divided into groups by their effect to the firm's present knowledge base and technological and market opportunities. These effects to the existing knowledge base are presented in Figure 1. Innovations can reinforce or destroy the present knowledge of the firm and affect its competitive advantage. When present knowledge is destroyed, new knowledge and new organisational thinking are required.

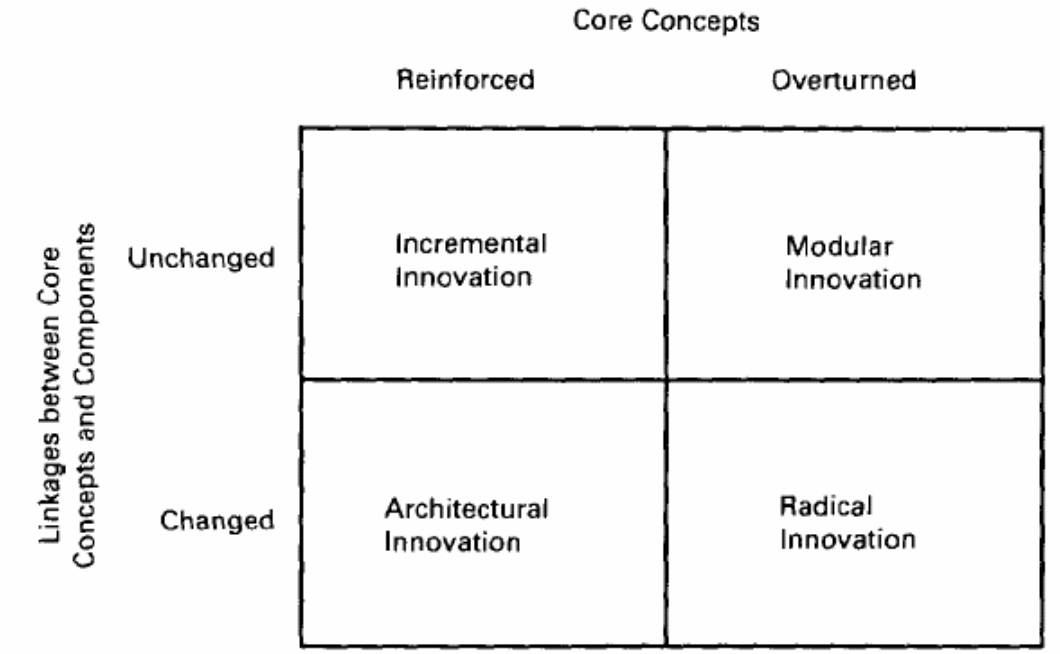


Figure 1. Architectural innovation (Henderson and Clark, 1990, 12)

Schumpeter (1943, 82-84) argues that capitalism is an evolutionary process and that economic change is part of the nature of capitalism. This change comes from the new products, new production methods and new forms of organisations. All this follows innovation. Schumpeter calls the processes, where new economic structures destroy the old ones, creative destruction. The capitalist competition is the competition caused by "the new commodity, the new technology, the new source of supply and the new type of organisation" (Schumpeter, 1943, 84). This competition can

change the competitive environment in the way that existing firms could be replaced with new ones. This is true at least in the long run.

This idea of creative destruction has inspired several consultants and other authors to write books and articles about radical innovations, and how incumbent firms can survive. Rosenbloom and Christiansen (1998, 215) suggest, that one of the major threats for existing firms is the radical change in their dominant technology. This gives the new firms the so called “attacker's advantage”. Briefly, this so called “attacker’s advantage view” is far from reality.

In the more advanced economic theories (evolutionary theory, the dynamic capabilities view of the firm) the firms change, but it takes time and most changes take place in small steps. If there is a need for radical changes and a firm does not posses the necessary dynamic routines, it is impossible to make radical changes to adapt to the changes in the market environments. The firms can change mainly by developing their existing routines. In the management of technology research, the development based on steadily changing routines and capabilities is called competence enhancing. Sometimes there are radical innovations as well, which bring the need for new routines and capabilities. These are called competence destroying innovations. One way to respond to the need for competence destroying innovations by seeking new routines to face the new challenges. Another possibility is to copy successful ideas. One major thing that limits the use of these kinds of innovations is the history of the firm. All the future possibilities are constrained by the firm's strategic choices made in the past. (Ståhle et al., 2002, 53-54.)

Schumpeter (1939, 87) defines innovation "as the setting up of a new production function". This does not tell the whole idea behind innovation. An innovation can also be seen as the production of new technological knowledge (Mowery and Rosenberg, 1989, 230). Due to these facts, innovation essentially means change, both in the knowledge base

described earlier and in the technology. Technological change can take place in products and services and in the way they are created and delivered. The latter is often called process innovation and the former product innovation. Sometimes it can be difficult to recognise the difference (Tidd et al. 2001, 6). Innovation can be totally new, but normally it denotes something renewed or altered (Granstrand, 1979, 8). Innovation can be new to the company, like imitation, or new to the world (OECD, 1997, 52). Even when the innovation is new to the company or even to the world, it is always based on the existing routines and capabilities of the firm.

The criterion for the success of a technological innovation is often commercial, rather than technical: a successful innovation is one that returns the original investment in its development plus some additional returns (Burgelman, et al., 2001, 4). An innovation is a successfully commercialised idea or invention. Therefore, invention differs from innovation. The innovation process is the process where the idea has been developed to a practical state (new or improved production systems) and/or commercialised (new or improved products). This makes a difference, because when an idea is generated or even technically finalised, it still may not benefit the firm. Only when a developed idea is adopted internally as a new or improved production system or customers adopt it as a new or improved product, it can be called an innovation and only if it brings innovation rents to the company. Often new products need major improvements in existing production capabilities or totally new production lines. Also some of the existing organisational routines become useless and new are required.

Innovations can be divided into technological and commercial innovations. Technological innovations can be process or product innovations. These innovations can be further divided to incremental or radical.

2.1 Technological innovation

Technological innovations can be new or improved products or processes. A successful product innovation is one that is "sold to customers in a quantity and at a price which more than covers total costs" and a process innovation is successful "if it enables lower cost production than an available alternative process" (Nelson, 1987, 10).

A product innovation can also be a process innovation for the end user (Tanayama, 2002, 19; Pavitt, 1999a; Porter, 1985, 183). Pavitt (1999a) uses technological trajectories to describe the sources of technology. There are also differences in the nature of innovation (incremental or radical).

2.1.1 Product innovation

New product development is an important capability, because the market environment is constantly changing (Tidd, et al., 2001, 4). This refers to new technologies from competitors and changes in customer's preferences. Long-term competitiveness of any manufacturing company depends ultimately on the success of its product development capabilities (Wheelwright and Clark, 2001, 881).

New products help capture and retain market shares, and increase profitability in those markets. Not only by offering low prices (commodities), but also offering a variety of non-price factors, like design, customisation, and quality (Tidd, et al. 2001, 4). These non-price factors may be difficult to sell in some commodity-like products and easier in some luxury products.

A technological product innovation can be one with new technological characteristics or when product is used in different ways, i.e. the product is used in a different context, for instance like a laser is used both in reading CDs or used in eye surgery. This could be a result of a combination of existing technologies or from new use of excisting knowledge. A product can also be technologically improved. (OECD, 1997, 48-49.)

2.1.2 Process innovation

Whilst new products are often seen as the cutting edge of innovation in the marketplace, process innovation plays just an important strategic role. For example, the Japanese dominance in the late twentieth century across several sectors - cars, motorcycles, shipbuilding, and consumer electronics - owed a great deal to their superior abilities in manufacturing. (Tidd et al., 2001, 5.)

Changes in products may often lead to changes in the production process. This can be seen in the pulp and paper industry. These changes in the process can be minor adjustments or small changes. In some cases, minor changes in products or processes may also require heavy capital investments in the production equipment.

Technological process innovation includes technologically new or improved production methods. These new methods can be a result of changes in the production equipment, production organisation or both. (OECD, 1997, 49.)

To sustain competitive advantage, both product and process innovations are needed. Sometimes it is impossible to improve the product without production improvements.

2.2 Incremental and radical innovations

Technological innovations can be either new or improved product or process innovations. Different scholars have different ways to define incremental and radical innovation (Rosenbloom and Christiansen, 1998, 217). New products and production processes are called radical innovations. Incremental innovations are improved products and processes.

Kyläheiko (1995, 51) sees that innovations based on recombinations and modifications of existing technological and organisational capabilities in existing markets (regular innovations) or new markets (niche innovations) are more common in low uncertainty environments. Technology advances in paths and enhances the competencies in the firm. These kinds of innovations can be seen in capital-intensive industries like the pulp and paper industry. Innovations are often improvements in existing production capacity and products.

Radical innovations based on new capabilities and old markets (revolutionary innovations) or new capabilities and new markets cause changes in existing competencies and create radical changes in competitive position. (Kyläheiko, 1995, 51.) Radical innovations are not that common in the pulp and paper industry level. Often these innovations come from other industries in the first place, such as the information and communication technology.

2.2.1 Incremental innovation

Technologically improved products and processes are called incremental innovations (Tanayama, 2002, 21). Incremental innovations involve the adaptation, refinement and enhancement of existing products and services and/or production and delivery systems (Burgelman et al., 2001, 4). The effects of incremental innovations can be relatively small, but combined

they have an important effect (Tanyama, 2002, 21; Rosenberg, 1994, 15). Abernathy and Utterback (2001, 150) estimate that countless minor product and system improvements could account for more than half of the total ultimate economic gain of a major innovation. Porter (1990, 51) goes even further. He says that constant improvement and upgrading is the most important reason for competitive advantage. Porter's view does not include radical changes in the technology or in the customer's preferences. In commodity production his argument is more reasonable.

2.2.2 Radical innovation

Radical innovation has many effects. It can change the nature of the customer relationship and restructure the economics of the marketplace (Leifer et al., 2000, 2). Radical innovations are technologically new products or processes (Tanayama, 2002, 21). They involve entirely new product and service categories and/or production and delivery systems (Burgelman et al., 2001, 4). A radical breakthrough can change the character of an industry. Still, these innovations are rare (Marquis, 1988, 80) and take time.

Rosenbloom and Christiansen (1998, 219-220) define radical innovation as follows: "an innovation is radical, when it introduces a discontinuity in the way that performance is evaluated. Radical innovations disrupt the established trajectories of technical advance; incremental innovations reinforce and extend them." They also classify innovations by their need for substantial capabilities in science or technology. Other criterion is the need for a new value network. They found out in their study of disk drive innovation that radical innovations need much more than technological activity. Complementary assets, like new commercial capabilities, need to be created or acquired. (Rosenbloom and Christiansen 1998, 233.) Leiponen (2000, 28-30) arrives at the same conclusion. Investments in R&D and manufacturing learning are more beneficial, if there are investments in marketing competencies as well.

It is not likely that in a radical innovation the technologist will have a vision of the business opportunities associated with the innovation (Rice et al., 2001, 410). It may take a long time and further development until all the benefits from the innovation are utilised. The risk is that others may capture the benefits of the innovation, if the opportunities are not understood. In incremental innovations the technologist may have a better vision of the benefits of the innovation.

2.3 Commercial innovation

Commercial innovations involve knowledge, which is in intangible form. An example can be the lean manufacturing what Europeans and Americans adopted from Japan in 1980s. These production techniques are new ways to manage and organise manufacturing. (Tidd et al. 2001, 13.)

OECD "Oslo manual" defines commercial innovation as one that,

> "includes the introduction of significantly changed organisational structures, the implementation of advanced management techniques or the implementation of new or substantially changed corporate strategic orientations. Organisational change counts as innovation only if there is a measurable change in output." (OECD, 1997, 55.)

These "significantly changed organisational structures" or "advanced management techniques" could be, for example, total quality management (TQM) or business process re-engineering (BPR) (Tidd et al., 340-342). Teece (1980) examines the diffusion of the M-form organisation model as an administrative innovation.

The diffusion of administrative (or commercial) innovation is expected to be similar to the diffusion of a technological innovation. The simple reason

for this is, that in market economy all innovations create opportunities for profit and this makes firms adopt innovations. An example of an administrative innovation could be the M-form structure in organising large firms. Still there are some differences. First, there are no patents or other legal means to protect an administrative innovation. This makes the diffusion of an administrative innovation easier than a technological innovation. Second, administrative innovation needs a reassignment of tasks and responsibilities. The third difference is that technological innovation can be adopted partially, but an incremental innovation approach may not be possible in administrative innovation. (Teece, 1980, 464-465.) In some cases, although not in the case of M-form organisation structure, it is possible to try an administrative innovation in one only business unit or area, for example. This gives a change to the incremental approach.

2.4 Systemic and autonomous innovations

To be useful, an innovation may be related to other innovations. These innovations are called systemic innovations. When an innovation can be introduced (or commercialised) without other innovations or major modifications to other innovations it is called autonomous. A systemic innovation needs significant changes to the complementary innovations before it can be introduced to markets. (Chesbrough and Teece, 1996, 67; Teece, 1988, 268; Granstrand et al., 1997, 19.) An example of an autonomous innovation can be the transistor. It replaced the vacuum tubes in the radio, but the radio itself did not need to be changed. Instant photography can be viewed as an example of a systemic innovation. The camera needed modifications and so did the film used in it. (Teece, 1988, 268.)

This systemic character of innovations has implications for development (Brusoni et al., 2000, 7) and in commercialising (Chesbrough and Teece, 1996, 67) such innovations. Granstrand et al. (1997, 20) argue, that if an

innovation is systemic and the number of external technology sources is low, firms should do most of the research themselves.

The development and commercialisation can be done in a decentralised and even virtual organisation, if the innovation is an autonomous one. Systemic innovations need more control in their development and commercialisation. (Chesbrough and Teece, 1996, 67.) When innovation is systemic, common ownership of the innovations is best choice. (Teece, 1988, 269.) The ownership of the complementary assets is important in innovation strategy and innovation process planning.

It is also important, that corporate organisational competencies are developed because different management styles affect how economies of scale and scope are exploited (Granstrand et al., 1997, 21). Learning in one capability needs integrated learning in to the other capabilities to gain the best output.

2.5 Architectural innovation

Henderson and Clark (1990) argue that innovations should be classified as radical or incremental innovations. An architectural innovation changes the way that components of a product are linked together. Architectural innovation destroys the architectural knowledge of the product, but the knowledge about the product's components is still useful. Figure 1, presented earlier, gives two dimensions to an innovation. Horizontal dimension presents the effects to the components and vertical presents the effects on the linkages between the components. Radical innovation affects the design and incremental innovation changes components, but the design stays the same. Modular innovation changes the core design. Architectural innovation changes the way that components are combined and destroys the previous knowledge about the architecture. Technological knowledge about the components is not changed.

Sometimes changes in components, like miniaturisation, can trigger architectural innovation.

Petit-Gras (1997, 51-53) argues that the paper industry is mainly concerned with incremental innovations. These innovations are found mainly in production processes and include some changes in the products. Petit-Gras sees also that these changes can be seen as modular innovations. In process technology these changes can be control systems, test and quality control systems and production monitoring equipment changes. The production of new types of fibers, pulp, fillers or coatings can be seen as modular innovations. Still when M-real developed a new raw material from aspen, the knowledge, at least partly, about previous raw material became less valuable. Of course the whole company does not use this new material and some characteristics remain the same. It can be seen as a radical innovation for the company, but maybe not for the customers and end users.

However, technological change still has different effects on different firms. This is due to the fact that work is organised in different ways in different firms. The radical (and incremental) innovation has different kinds of effects in different organisations. (Kugut and Kulatilaka, 2001, 748.) Also the hardware can be different in different firms.

An innovation can also make some competencies in the firm's value chain more valuable. Also totally new competencies may be needed to gain the rents from an innovation. On the other hand, an innovation may also cannibalise or destroy competencies in a firm. In some cases different managerial skills are needed (Laurila, 1995, 12) or different organisational set-ups are required. Innovations can also have effects on the customers and the markets. (Abernathy and Clark, 1988, 56.)
Freeman and Perez (1988, 46-47) describe the changes in technology systems and in techno-economic paradigm. Changes in technology systems are based on both radical and incremental innovations and

organisational and managerial innovations, which affect more than one firm. They use synthetic materials, petro-chemicals and machinery innovations for example. Nowadays ICT could present an example of such innovation. Changes in the techno-economic paradigm has effects throughout the whole economy.

2.6 Some stylized facts of innovation

The literature on innovations presents different kinds of characteristics in the innovative activities and innovation, which affect the innovation process. The next step is to examine these in more details.

2.6.1 Uncertainty

Innovative activities are highly uncertain. Only one in ten R&D projects are commercially successful and most often there is failure because projects do not meet commercial targets. (Pavitt, 1999b, 62.) Marquis (1988, 82) is more optimistic. He says that one or two products out of five make break-even point. Reasons for this uncertainty are changing market environments in the first place and technical and organisational capabilities in the second.

One source of uncertainty is the future. It is not possible to know all the future events. The other source is the bounded rationality of the decision makers. It is not possible to evaluate all the possible outcomes. (Ståhle et al., 2002, 182.) But what is the origin of uncertainty? Dosi and Egidi (1991) see that there are two sources of uncertainty. The first source is "the lack of all the information which would be necessary to make decisions with certain outcomes". Second source is "limitations on the computational and cognitive capabilities of the agents to pursue unambiguously their objectives, given the available information". (Dosi and Egidi, 1991, 145.) The former is called substantive uncertainty and the latter procedural uncertainty. Substantive uncertainty can be divided to weak and strong

substantive uncertainty. Weak substantive uncertainty is analogous to risk, and it can be defined "as all those circumstances where uncertainty simply derives from lack of information about the occurrence of a particular event within a known list of events"(Dosi and Egidi, 1991, 148). Cases of strong substantive uncertainty are those "involving unknown events or the impossibility, even in principle, of defining the probability disruptions of the events themselves" (Dosi and Egidi, 1991, 148).

In a study of DuPont's Biomax's push for commercial applications (Leifer et al. (2000, 22) categorised uncertainty in four different groups, organisational, recourse, technological and market uncertainties. They also stress that these uncertainties interact with one another and each dimension of uncertainty can on at least one occasion cause the end of the project.

It is very difficult to predict the technical and commercial outcome of innovative activity in a changing world. Most often personnel in research are very optimistic about the costs and benefits. This is especially the case in radical innovations. (Pavitt and Steinmueller, 1999, 17.)

2.6.2 Technological diversity

There is technological diversity in large corporations. Products are becoming more and more "multi-technology" in the sense, that there are increasing numbers of different disciplines involved in one product. Also certain technical knowledge cannot be linked to only one product. (Pavitt, 1999c, 107.) And because products are becoming multi-technology, large firms are also becoming multi-technology firms. They have wider range of technologies than products. (Patel and Pavitt, 1999a, 74.)

Granstrand et al. (1997) propose that technological diversity in firms is needed for controlling changes in supply chain and to understand widening technological opportunities. Even when some production inputs are outsourced, that does not mean that the technological knowledge is

outsourced, or even that it should be outsourced. To be able to use and improve outsourced inputs, large firms need in-house capabilities. This is especially necessary when the supply chain is complex. Large firms are also looking for new opportunities through science and technology for possible use in the future (exploratory research). In this field commercial opportunities are difficult see in advance and even more difficult it is to calculate net present values for these projects. Integrating these new competencies emerging from science and technology is a “dynamic learning process” (Granstrand et al., 1997, 13). This process may require acquisition of external technology and also increase in R&D expenditures. (Granstrand et al, 1997, 10-13.)

Granstrand et al. (1997) also classify the technological competencies in four different categories. These are distinctive or core, background, marginal and niche competencies. Distinctive competencies are the source of the technological advantage. Background competencies are used for co-ordination in the supply chain. Marginal competencies make benefiting of technological opportunities possible in the future. Niche competence takes only a small share of corporate resources. (Granstrand et al., 1997, 14-16.) These are the competencies that become more or less valuable in a firm. There should be several open paths for the firm in the sense on technological competencies.

2.6.3 Technological path dependency

Industrial innovation can be depicted as a process of know-how accumulation, or a learning process, involving elements of internal and external learning. (Rothwell, 1994, 26-27.)

Technological knowledge is cumulative, because major innovations show direction to the future and complementary technologies. These major innovations initiate long sequences of path dependent activities. Because these sequences, technological knowledge grows in a path dependent way. Even important scientific discoveries do not disrupt path dependency.

Exploiting new science commercially depends on the technological and social capabilities available in the economy. Social capabilities are understood as organisational, management and marketing capabilities. (Rosenberg, 1994, 15-18.)

Essentially the path dependent nature of the technological progress means that, what firms can do in the future is constrained by what they have done in the past (Dosi, 1988, 225). This is due the specialisation of technological assets within a firm (Coombs, 1994, 385). A firm can open new technological paths by integrating new technologies to existing ones or simply developing new technologies. This development can be basic research or studying how existing technologies can be used in other contexts. It can also include hiring new employees and joint ventures.

2.6.4 Technological trajectories

There are several possible sources of technology inside and outside the firm. Inside the firm there are R&D laboratories and production engineering. Outside the firm there are suppliers, users and government financed research. (Pavitt, 1999a, 27.) Ideas for incremental innovation can come from engineers and others more related to the production process or from customers (Tanayama, 2002, 21) and incentives are mainly cost reduction and quality improvements (Abernathy and Utterback, 2001, 154).

Pavitt (1999a) studies patterns of technological change and trajectories. He studied data from about 2000 significant innovation in Britain since 1945. He found four major technological trajectories; supplier dominated, production intensive, scale intensive and specialised suppliers and science based. The determinants of technological trajectories were sources of technology, type of user and means of appropriation. Typical core sectors for supplier dominated firms are agriculture, services and traditional manufacturing. Supplier dominated trajectory firms have only a

small role in developing their technology. Technology comes mainly from the suppliers of equipment and materials. This gives little opportunity for firm specific technological knowledge accumulation. The firm's focus is mainly in incremental innovations (Tidd et al., 2001, 113). The core sectors for production intensive firms (scale intensive) are bulk materials, consumer durables and cars. Sources of technology are production engineering, suppliers and R&D. Specialised suppliers' typical products are machinery and instruments.

This study was originally finished in 1984. Later Pavitt, Robson and Townsend (1989, 96) have added software as a typical core product for specialised suppliers. They also added a fifth technological trajectory, the information intensive. The main sources of technology are design and development, and users. In science based category typical core sectors are electronics and chemicals, and sources of technology are R&D, public science and production engineering.

Chemistry and the information technology are seen as the major contributors to paper technology. Also life sciences and medicines are becoming more relevant in production process technology. (Autio, et al., 1997, 6.) Chemistry has been used longer in paper technology. Some of the benefits from information technology can already be seen. Some benefits from these new technologies will be contributed in the longer run, rather than the short run.

2.6.5 Technological trajectories in the pulp and paper industry

Technological trajectories play an important role in the paper industry. Together with related industries such as equipment manufacturers, chemical suppliers, control and info systems and electricity generation, pulp and paper industry constitutes an industry cluster. Technical flows in this cluster are one major driver for technological development and

change. The main constituents of the pulp and paper industry cluster are illustrated in Figure 2. (Autio, et al., 1997, 14-16.)

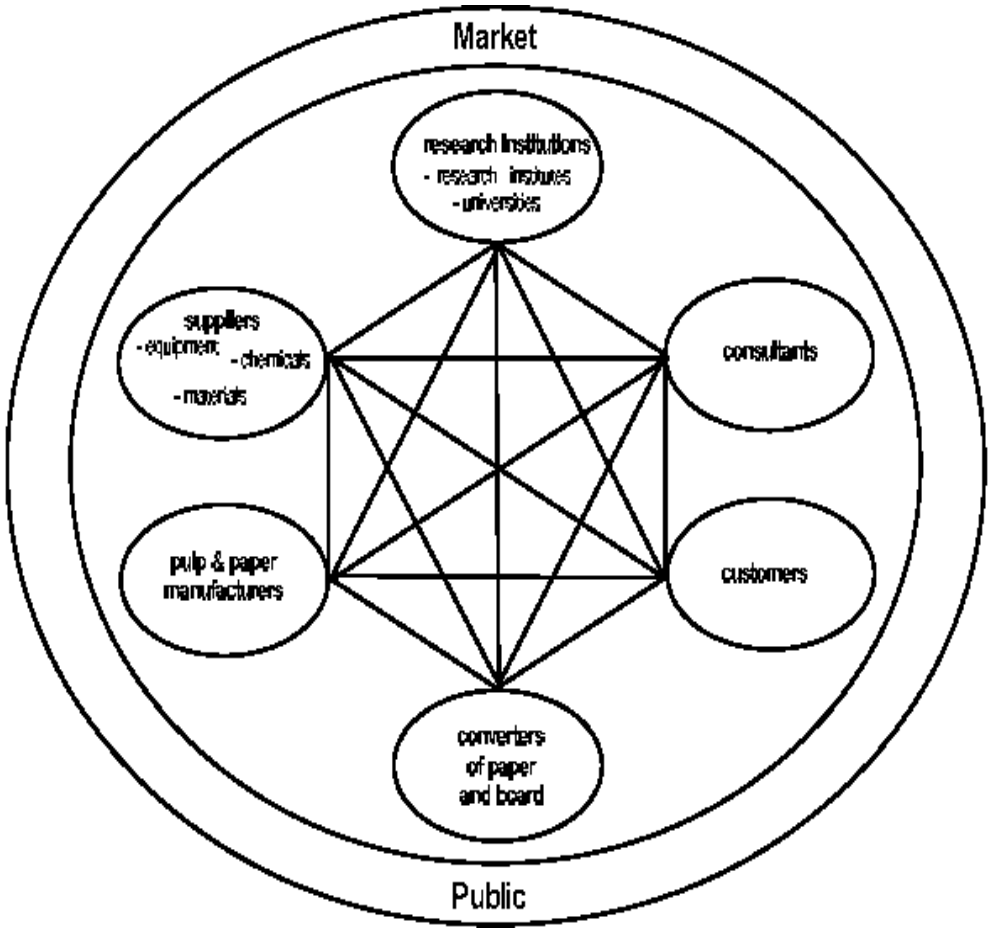


Figure 2. The main constituents of the pulp and paper industry cluster (Autio et al., 1997, 16)

Autio et al. (1997, 16-18) say, that the pulp and paper manufacturers have five roles in this innovation system. The first role is that they are technology users. Their second role is as a creator of knowledge. The third role is as an organiser of innovation projects. The fourth role is to provide machinery for the trial production for suppliers and research institutions. The fifth role is to fund research institutions operated by the industry.

The research of the research institutes is more collective. Their main customers are the pulp and paper industry and their suppliers and

customers. In Finland and Sweden the pulp and paper companies are the main owners of these research institutes (KCL in Finland and STFI in Sweden). The equipment, chemicals and raw material suppliers are also important source of innovations and an important part of the innovation process delivering specialised knowledge from different areas. This is mainly because the pulp and paper industry does not have much in-house manufacturing in all areas anymore. Consultants have several services for the pulp and paper industry. They offer business analysis, engineering services and R&D solutions for innovation and production problems. Customers usually are not developing new products (or processes) and then introduce them to pulp and paper industry. The main customers of the pulp and paper industry are printers and industries using paper as packaging materials. Customers are more likely to be a source of ideas for new innovations. (Autio, et al., 1997, 17-24.)

In this industry cluster Finland has a rather special position. There have been long time equipment manufacturers, raw material suppliers, consultants, research institutes (both public and industry's own) and paper and board manufacturers in Finland. Most of the customers of this cluster are to be found abroad.

2.6.6 Patterns of industrial innovation

Abernathy and Utterback (2001) discuss the patterns of industrial innovation (Figure 3). After major innovations product innovations become usually incremental and the products standard. After a while there are more process innovations and production process becomes more efficient instead of being flexible to the cost of inefficiency. First innovations are stimulated by users and technical inputs and later by the pressure to reduce costs and improve quality. (Abernathy and Utterback, 2001, 154; Utterback, 1994, 94.)

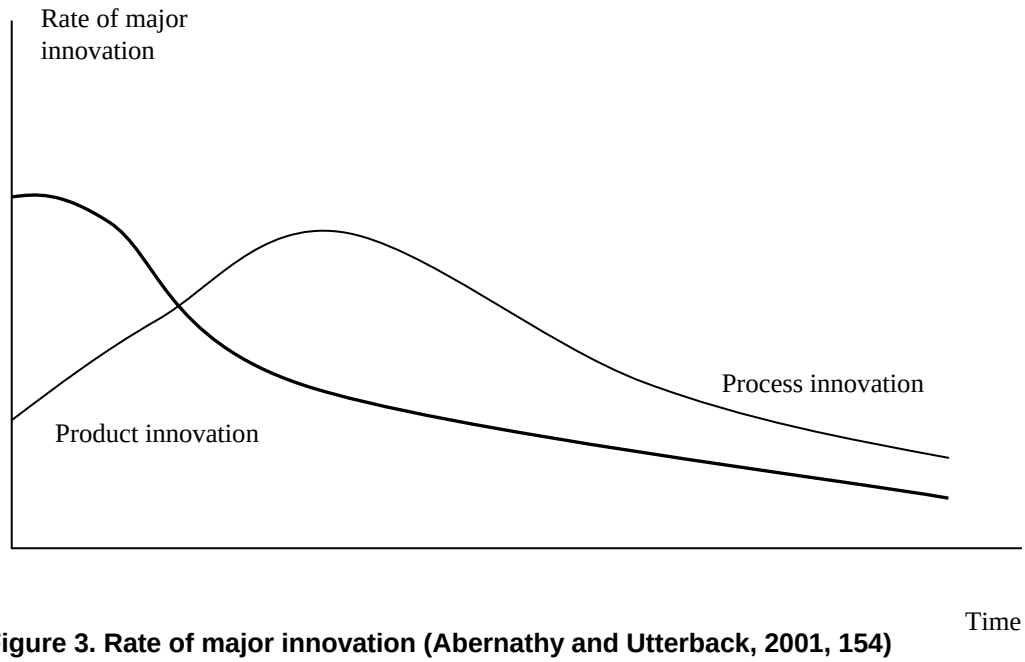


Figure 3. Rate of major innovation (Abernathy and Utterback, 2001, 154)

These changes happen in three phases. These phases are called the fluid, transitional and specific phase. Most of the changes in the product technology in the fluid phase happen and the outcome is highly uncertain. Uncertainty can be divided to target and technical uncertainty. Target uncertainty exists because most of the early innovations do not have existing markets and success in building new markets is difficult to tell advance. Technical uncertainty refers to the difficulty in placing the R&D in the right technology.

If the new product gains market, there will be transitional phase. In this phase production becomes more important. Product and process innovations are more closely linked and economies of scale determine the competition. In the specific phase manufacturing is efficient and the quality becomes the basis of competition. Changes in the products or processes, even small ones, are difficult and expensive. (Utterback, 1994, 92-6.)

This is often seen as the case in the pulp and paper industry. Even an incremental change in the process or product can cause trials in pilot plants. This is to avoid enormous capital investments. There are several

interrelated variables in the paper making process and factors affecting the characteristics of the paper multiply when moving from pulping to papermaking and conversion to final application. (Autio, et al., 1997, 7.) Still, small investments and improvements in the production process can increase capacity of a paper mill 1-2% per year (Diesen, 1998, 127.) These minor improvements can also affect the quality properties and production costs. For example the quality is better and environmental problems less severe when thinking about the increase in production capacity in the past 50 years. This means that several radical innovations occurred in the pulp and paper industry. Machinery suppliers are mainly responsible for these innovations in production and waste handling.

Because of these intangible properties of innovation, it may be difficult to calculate the total effects of incremental innovations. Another reason is that it is difficult to tell when one innovation has changed to another due to learning.

By nature major or radical innovations are path dependant, uncertain (technical, commercial and organisational uncertainty) and multi technological. Uncertainty comes from the changing market environment and from the organisations capability to solve problems and their adaptation to new competitive situations. Systemic innovations may require other innovations (in complementary assets or whole new products) to be successful. They are collective and may affect the whole value chain and follow incremental innovations after technology is more standardised. Some innovations can make present knowledge of the firm useless when new technology breaks through.

These are important characteristics when designing innovation processes in a firm, and planning the need for future capabilities. The innovation process can be designed to handle the uncertainty, to include different diciplinaries in the development process and to include different functions of a company. These characteristics only give an idea about what things

should be considered when planning an innovation process. Due to the path dependency of the firm, it is not possible to copy an innovation process from another firm. It is possible to get some ideas in general. And just as Lundvall (1988, 362) stresses the importance of creativity in the innovation process, it is difficult to make it too structured.

The final conclusion of this chapter is that an idea or invention is not yet an innovation. An innovation is a commercialised idea or invention. This process from an idea to innovation rents is called an innovation process. Some characteristics of an innovation give imperatives to the innovation process. These characteristics can have very different kinds of effects on different firms. The next chapter presents different theories of the firm and how innovation is presented in these theories. They should help in understanding why some firms manage innovation and change better than others.

3 INNOVATION IN THE DYNAMIC CAPABILITIES VIEW OF A FIRM

3.1 From services to routines and capabilities

There are different economic theories on the firm. Our focus will be in dynamic capabilities view of a firm. Now it is time to study the theories of a firm and what does innovation and technical change mean in this context and what these theories can offer for innovation process planning. The aim of this chapter is to examine what the dynamic capabilities view of a firm can offer to the innovation strategy. The resource based view is introduced first. The second is evolutionary theory. These give a base for the dynamic capability view of a firm. The dynamic capability view of a firm offers ground for establishing innovation strategy and for later innovation process.

The pulp and paper industry is not often considered very dynamic. The uncertainty in the industry comes from market fluctuations. There are still firms that cannot compete with mass production. M-real is in a rather difficult position. It is not possible to compete with bigger firms in bulk products. They need to be innovative and sense the changes in the environment and combine them into the technological assets of the firm. Shortly, this means combining the market opportunities and technological possibilities.

3.2 The resource based view of a firm

3.2.1 By Edith Penrose

“The theory of the growth of the firm” by Edith Penrose (originally published in 1956) build the base for the resource based view of a firm. A A Penrosian firm consists of physical resources like a plant, equipment and land. Another set of resources are the human resources available. They are skilled and unskilled labour, administrative, legal, technical and

managerial staff. When an employee leaves a firm and takes his abilities with, his firm suffers a loss. A valuable view here taken by Penrose, which is often neglected in industrial firms, is that

> "it is never the resources themselves that are the 'inputs' in the production process, but only the services that the resources can render. The services yielded by resources are a function of the way in which they are used - exactly the same resources when used for different purposes or in different ways and in combination with different types or amounts of other resources provides a different service set of services". (Penrose, 1995, 25).

The Penrosian view to resources is, that they consist of potential services and it is these services that, not the resources, that are important. All productive resources operate in an administrative framework, which also affects the amount and type of services that the resources yield (Foss, 1997, 15). (Penrose, 1995, 24-25.) Just summing up the existing resources, without thinking what kind of services these resources can offer, is practically a waste of everyone’s time.

3.2.2 Innovation in a Penrosian firm

Entrepreneurs are providing entrepreneurial services. These services are new ideas of products, locations, changes in technologies, acquisition of new managerial personnel, changes in administrative organisation and expansion. Entrepreneurs can be found from different locations of a firm. They can be individuals or found in groups. The contrast to managerial services is that the managerial services "relate to the execution of entrepreneurial ideas and proposals and to the supervision of existing operations" (Penrose, 1995, 31-32). Entrepreneurs can be divided to two types according to their ambition. Some entrepreneurs are focused on profitability and growth. They are more interested in the production of goods and services. Another type is more interested in building an

industrial empire through acquisition and the elimination of competitors. (Penrose, 1995, 31-40)

The increase in the knowledge of the physical resources can increase the range and amount of services possible. More services become available and some services become useless. What is also important, is that this knowledge, which could improve the performance of the firm also "shapes the scope and direction of the search for knowledge" (Penrose, 1995, 77). This relates to the path dependant nature of the firm and that the firm can leave possibilities open for future paths. This increased knowledge of resources affect to the productive services available and how the firm sees demand. The capability to innovate is related to the knowledge and experience in the firm. (Penrose, 1995, 77-119.)

3.2.3 Sustaining competitive advantage with resources

Barney (1991) argues that a resource needs to have four attributes to hold sustained competitive advantage. By sustained competitive advantage Barney means value creating strategy, which is not implemented by current or potential competitors. Other firms must also be unable to duplicate the benefits of this strategy. (Barney, 1991, 102.). The resource must be valuable, rare, imperfectly imitable and non-substitutable. Resources are valuable, when they improve the firm's efficiency. A rare resource means that not too many other firms posses the same resource. An imperfectly imitable resource is related to the path dependency. These resources are gained after a long and cumulative learning process (Dierickx and Cool, 1989, 1506). Non-substitutability means that similar strategies should not be possible to implement with different resources. (Barney, 1991, 105-112.)

This view of a firm differs from Porter’s model, which is based mostly on external factors derived from neoclassical economics. However, Porter has interesting things to say about technology and its effects on a firm and a competition.

3.3 Technological change and the value chain

In Porter's well-known "five competitive forces"-model, technology can raise or lower entry barriers by economies of scale and by increased fixed costs. It can also raise or lower switching costs. One can face switching costs, when one has made "significant durable investments in complementary assets that are specific to that brand of machine. These investments have differing economic lifetimes, so there's no easy time to start a new, incompatible system". (Shapiro and Varian, 1999, 104.) Technological change makes changes in bargaining relationships possible. It can eliminate the need to purchase from one supplier to new one. It can change the lock-in situations. Shapiro and Varian (1999, 104) explain lock-in situation: "When the costs of switching from one brand of technology to another are substantial, users face lock-in". Technological change can also affect the relative value of the products and create new products and product uses that substitute for others. (Porter, 1985, 173-5.)

Porter's value chain consists of the “physically and technologically distinct activities a firm performs" (Porter, 1985, 38). The five generic value activities are inbound logistics, operations, outbound logistics, marketing and sales and service. Support activities are the firm’s infrastructure, human resource management, technology development and procurement. Here we have the focus on technology development. There is technology in every value activity. Technology development takes many forms like basic research, product design and servicing procedures in many parts of the firm, not just R&D and engineering. (Porter, 1985, 36-42.)

When choosing technology, it, as well as technological change, affects all of the value chain activities. These choices and developments can improve firm's competitive advantage by lowering costs or by differencing products. This change can take place virtually in any activity a firm has. Different technologies in the firm's value chain are linked together. This means, that when there is change in one technology it may have an effect on other technologies. (Porter, 1985, 166-8.)

This is why large corporations' product and new business development should be part of a strategic process. This requires interaction of different management levels from different functions. So innovation requires a network of different functions of the firm and different hierarchical levels. Kivisaari (1992, 12-13.)

Because of the effects of an innovation may include the whole value chain and certainly involve several functions and managerial levels of a firm, technological innovations are collective. They involve intensive collaboration between functionally and professionally specialised groups. R&D, production, and marketing are needed for implementation, and organisation and finance are needed for strategic decisions. (Pavitt, 1999b, 62.)

3.4 The evolutionary theory of a firm

Nelson and Winter introduced in 1982 their book "An evolutionary theory of economic change", which is seen as the core opus of evolutionary economics. In their theory there are three major concepts, organisational routines, and search and selection environment.

Organisational routines are built ways of doing things. Routines "include characteristics of firms that range from well-specified technical routines for producing things, through procedures for hiring and firing, ordering new inventory, or stepping up production of items in high demand, to policies

regarding investment, research and development (R&D), or advertising, and business strategies about product diversification and overseas investments" (Nelson and Winter, 1982, 14). These routines determine the behaviour of the organisations. Routines are like genes in biological evolutionary theory. Routines are difficult to change and they create inflexibility in organisations. This means in some parts the routines employed in the past determine the firms behaviour in the future. Not all the decisions are based on predictable and repeated routines, however. To have change in the economy, the purpose of some of the routines is to search for new ways of doing things.

Routines can be divided to three categories. The first are the ones called standard operating procedures. These determine how many procedures are employed under various circumstances and how. The second ones determine the firm's investment behaviour. The third ones involve searching new ways of doing things. This search routine can be focused on any one of the firms prevailing routines. (Nelson, 1987, 22.) By search Nelson and Winter (1982, 400) mean "all those organisational activities which are associated with the evaluation of current routines and which may lead to their modification, to more drastic change, or to their replacement". A firm's search is partly routinised and predictable. If routines are considered as genes, then search routines generate mutations.

The routines can be considered as an organisational memory. Organisations remember a routine by exercising it, which can be partly by cumulative learning. Routines also provide internal control and therefore reduce the costs of supervision. Routine operations also replicate existing routines and imitate routines from other organisations.

The selection environment "is the ensemble of considerations which affects its well-being and hence the extent to which it expands and contracts" (Nelson and Winter, 1982, 401). Conditions outside the firms in the industry and also the characteristics and behaviour of the other firms within the industry affect the selection environment.

3.4.1 Technical change in evolutionary economics

The innovation system in capitalist economies is pluralistic and winners and losers are separated ex post. This means that there is uncertainty about what is the best way to gain technical advancement and competitive advantage. Activities from basic research to applied research and to development are trying to reduce this uncertainty. These activities are done in several different firms at the same time and it is difficult to know in advance which way is the best one. Some new technologies will be successful and dominate others. This uncertainty is resolved in large part by introducing these new technologies and letting the markets choose the best ones. This is the major source of uncertainty in innovative activities. (Nelson, 1997.)

3.4.2 Diffusion of innovation in evolutionary economics

There are two mechanisms for how successful innovations replace dominating techniques. One is "through expansion of production and growth of the company that introduces a profitable innovation". The other one is "through adaptive imitation by competing firms" (Nelson, 1987, 10). There is a difference in how much these mechanisms matter in different industries. The firm’s ability to exclude imitation is one major factor when considering innovating firm. When innovation is more important in competition, the firm’s ability to produce new ideas through research and development and exploit and protect new innovations becomes more important. (Nelson, 1987, 7-11.)

In the evolutionary model innovations as new combinations are in a central role in economic activity. Innovations made by firms and changes in markets require the firms to adapt to a new market environment or die. Because firms are characterised by routines, firms that have better routines will manage change. Firms with inferior routines will grow relatively less or die. (Nelson, 1987, 20-21.)

3.4.3 The role of routines and capabilities in innovation

Innovation changes routines in some way. Innovations may involve new combinations of existing routines. Problem solving is one way to innovate. Normal problem solving activities can lead to an innovation and change in routines. This is what Nelson and Winter (1982, 129) mean when the "useful questions arise in the form of puzzles or anomalies relating to prevailing routines". It simply means that normal problems or exceptions arise during normal working routines. And solving these problems or exceptions may lead to incremental or radical improvements. (Nelson and Winter, 1982, 126-131.)

Another way of to innovate, besides problem solving, is activity directed towards innovating. There is more uncertainty in this kind of innovation. First, there is uncertainty in the results, whether they are useful to the firm or not. The search follows a simple pattern. Second, when the search, or the innovation process, is started there is also uncertainty in the process itself. Some of the ways to produce innovations are routinised, like hiring a consultant or starting a R&D program. Nelson and Winter (1982, 132-133) use the theory of heuristic search, developed by Newell, Shaw and Simon, to describe these issues. "A heuristic is any principle or device that contributes to the reduction in the average search to solution" (Nelson and Winter, 1982, 132). All fields of competence have several heuristics. Also high-level decision makers have heuristics, for instance corporate strategy. One difficulty in heuristics is that the best practice may change quicker than the decision heuristics (Kogut and Kulatilaka, 1994, 55).

3.4.4 Static and dynamic routines

Ståhle et al. (2002, 55-57) divide routines into two categories, static and dynamic routines. The former is for replicating existing capabilities and allows predictability and contingency in the company. The latter makes adaptation and actual change possible. In a firm, dynamic routines make developing and reorganising existing organisational and technological capabilities possible. They also make possible new combinations by integrating knowledge both from the outside and from the inside of a firm. The ability to renew is necessary, when the firm's environment is changing. This usually means technological progress, consumers' preferences change or competitors change markets with their moves. Changes in technology force firms to develop new technological routines and capabilities. Changes in consumers' preferences make the firm develop new marketing and design routines and capabilities.

Pavitt (2002b) argues that a firm's innovating routines have to deal with increasing specialisation in knowledge production, technological practice that is ahead of science and matching organisation to changing technology.

3.5 The dynamic capability view of the firm

Firms achieve and sustain competitive advantage by developing strong dynamic capabilities in order to respond to exogenous events. Markets are global and product innovations and management capabilities to coordinate competencies are in a central place for achieving and sustaining competitive advantage. The dynamic capabilities view of the firm is mainly based on Schumpeterian competition, Penrose's resource based view of a firm and evolutionary economics. (Teece, et al., 2002, 334-338.)

Because the market environment is changing, the word ‘dynamic’ refers to the ability to adapt and create new competencies matching the environment. “The term ‘capabilities’ emphasizes the key role of strategic management in appropriately adapting, integrating and reconfiguring internal and external organizational skills, resources and functional competences to match the requirements of a changing environment” (Teece, et al., 2002, 337). The firm’s nature is path dependant, because the firm follows a path of competence development. Dynamic capabilities “reflect an organisation’s ability to achieve new and innovative forms of competitive advantage despite path dependencies and core rigidities in the firm’s organizational and technological processes” (Teece, et al., 2002, 339). The competitive advantage is based on the firm’s managerial and organisational processes, its present position and the paths available. Firms are organised in a non-market-like fashion. Managerial and organisational processes determine how things are done in a firm. These processes cannot be purchased from markets. Firms need to build them. This means that they cannot be easily replicated. Position in the market means the location of the firm and its business assets. These assets do not include plants and equipment, unless they are specialised. Assets mean technological, complementary, financial and locational assets. Paths refer to strategic alternatives available to the firm. (Teece, et al., 2002, 339-346.)

Some of these paths are opened with technological innovations and by building up technological understanding. Some paths are opened by purchasing intellectual property rights, opening new sales channels or by mergers and acquisitions.

3.5.1 Innovation and dynamic capabilities

Dynamic capabilities adapt the firm to environments changes. These changes come from the competitors, the customers, from radical changes in technologies and the suppliers. Dynamic capabilities combine existing resources to the new knowledge. They sense and understand signals from the environment, know the internal and external competencies related to these signals and they can implement the change in the organisational structure. Ståhle, et al., 2002,74.) Madhok and Osegowitsch (2000) argue, that due to the path dependant nature of capability development, in dynamic industries it is likely that firms do not have access to all the knowledge needed to maintain competitiveness. This means that collaboration with other firms with complementary skills is one way to solve this problem. These actions, found for instance, in the biotechnology industry in USA, can be acquisitions, greenfield subsidiaries, licensing agreements and marketing arrangements and research contracts.

Fujimoto (2002, 246) presents three levels of capabilities based on his earlier studies. Static capability influences the level of competitive performance, improvement capability affects the pace of performance improvements and evolutionary capability influences the change in capabilities. The latter two are related to dynamic capabilities. The evolutionary capability is non-routine capability.

Laurila (1998) studied how upgrading a paper machine from low value added product (newsprint) to higher value added product (coated magazine paper) affects the management. This is a situation where previous capabilities become less valuable and new capabilities are needed. Radical innovations in product and production technology do not happen very often on the industry level. Individual firms and their production units face technological discontinuities more often. He argues that paper producing companies need two kinds of capabilities. First is the ability to build technology needed in paper production. The second is

related to the long term operation. This is related more to incremental innovations. These are very similar to what Fujimoto (2002) referred to static and improvement capability.

Because technologies need to be known and utilised, Carlsson (1994, 15) introduces economic competence. It builds on four components, selective and organisational capability, and technical and learning ability. These components create entrepreneurial spirit, which needs to be involved in relevant economic agents.

Some of these roles are the responsibility of R&D. Cohen and Levinthal (1989) argue that R&D has two roles. First it produces new information and second, it allows firms to exploit existing information. So generating innovations is only one role of the R&D. Another role is that it "develops the firm's ability to identify, assimilate and exploit knowledge from the environment" (Cohen and Levinthal, 1989, 569). They call this learning or absorptive capacity. This is also one part of new knowledge creation. This "knowledge from the environment" can be from competitors or from outside the whole industry. This means that there should be competencies from different areas in the company's R&D. Otherwise new possibilities cannot be detected and utilised. These competencies may not be relevant for the present product or production technology. These should be the roles of the whole organisation, not just R&D.

If innovation and imitation are two roles of R&D (Cohen and Levinthal, 1989), Pavitt (2002, 7) argues that co-ordination of changes in the products in the knowledge networks is third role for R&D.

The value of the firm is partly in the processes it has. The ability to create new products and adapt to the changing environment and technology needs innovation. This need may be constant in some industries to keep up the pace of development.

How firms sustain competitive advantage in markets are presented in Figure 4. Dynamic capabilities sense new possibilities and recognise and adapt the potential of the organisation. They also see the risks and can prepare for them. (Ståhle et al., 2002, 78.)

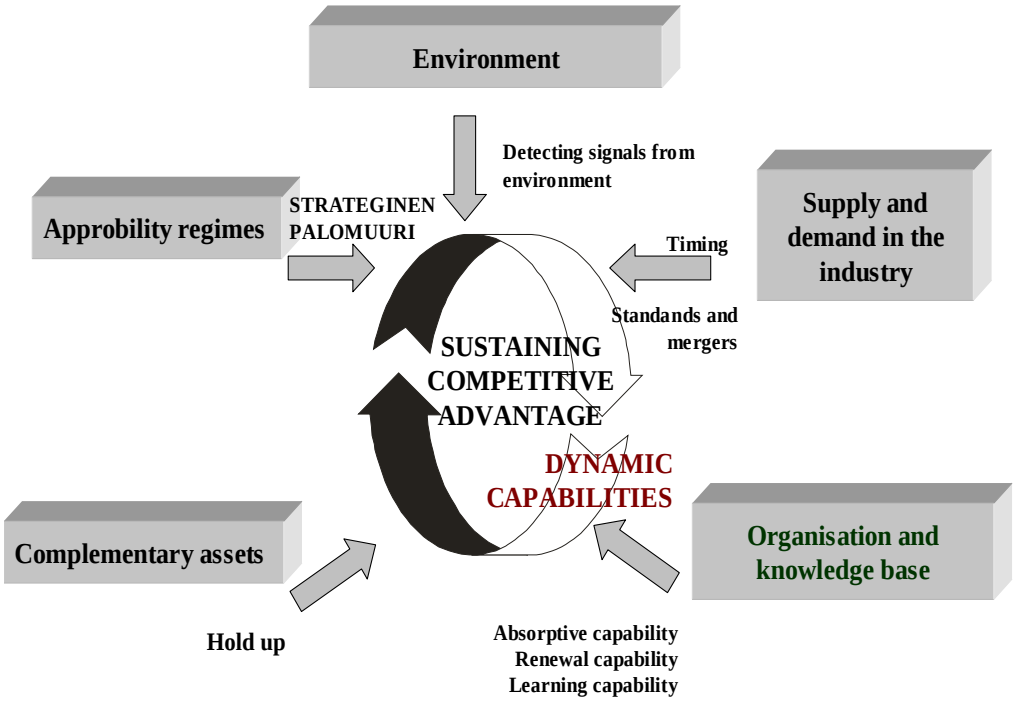


Figure 4. Sustaining competitive advantage with dynamic capabilities. (Ståhle et al., 2002, 78)

The new knowledge is rather easy to copy in the paper industry. It takes approximately two years to copy a competitors' new products. The focus should be on how to protect new innovations and new knowledge. This may be rather difficult because most of the innovations include equipment and raw material producers. They are often keen to sell their new ideas to the competitors. But it is not possible to do everything in-house. M-real should, for instance, focus on searching for new partners to develop the products and production technology with from the market environment. New sciences can have a strong impact the industry. The supply and demand dominates the pulp and paper industry. The development times

are long and may require heavy capital investments. If a project ends at the low turn of the economy, it is still difficult to postpone the start of a new mill, if that is the result of an innovation process. There should be plenty of flexibility in the timing, although this may be difficult to arrange. There is also a need to consider the technological paths open to the firm. Totally new knowledge may be required in the future and developing it is time consuming. Thinking new ways to develop partnerships is vital. It may be possible and reasonable to outsource some operations and do some previously outsourced work in-house.

3.6 Innovation strategy

Tidd et al. (2001, 65-137) have examined what are the influences on a firm's innovation strategy, based on the suggestion of Teece et al. (2002), that position, paths and processes affect the strategic management of innovation. The environmental factors affecting the firm's innovation strategy are the national system of innovation, like industry clusters, and its market position compared to competitors. Firms still have most of their innovative activities in their home country. Present and future state of technological knowledge and competences in learning and exploiting technological knowledge (that is path dependency), constrain corporate innovation strategy. The most critical processes in a firm are the ones that ensure integration and learning. The innovation process is one of these. One reason for this is, because there is technological diversity in large corporations. Integration in large firms should take account of different disciplines and functions as well as divisions. Innovation strategy should consider three things, the location of R&D within the corporation, the role of R&D and the link between the corporate strategy and innovation strategy. Innovation or technology strategy can be different in individual business units, business divisions or at corporate level (Coombs, 1994, 385).

3.7 Innovation as a learning process

A learning process underlies the innovation process, and that learning process is cumulative, collective and uncertain (Lazonick, O'Sullivan, 1998, 3). The learning process is cumulative when previously learned knowledge is the foundation for future learning and there is empirical evidence that supports the proposition that the capability of individuals to absorb existing specialised knowledge and to generate new, cumulates over time. The collective learning means that, through the interaction of individuals in the knowledge-creation process, specialised knowledge develops as a part of an integrated body of knowledge. By uncertainty Lazonic and O'Sullivan mean that the cumulative and collective learning process is complex, and complexity creates uncertainty. They also classify the uncertainty as productive and competitive. Uncertainty can be productive because the learning process can fail to develop productive resources and competitive uncertainty means that someone else can still generate higher quality and/or lower cost products. (Lazonick, O'Sullivan, 1998, 3-4.)

Lazonick (2000) outlines a theory of an innovative enterprise. He says that there are some key characteristics of the industrial, organisational and institutional conditions that can promote or constrain the innovation process. The industrial conditions are technological, the market and competitive conditions. Technological conditions are productive capabilities and market conditions, such as demand, constrain the ability and incentive of an enterprise to develop and utilise productive resources over time. The success in transforming these conditions to make higher quality and/or lower cost products in turn changes the competitive conditions in the industry.

Organisational conditions are cognitive, behavioural and strategic. Strategic conditions determine if an enterprise responses innovatively or adaptively to the changes in competition conditions. Cognitive conditions

such as cumulated knowledge and available skills and behavioural conditions and the existing incentives, affect the enterprise's strategy or the allocation of recourses.

Institutional conditions are financial, employment and regulatory. Financial conditions mean the way that society allocates financial resources for investments and consumption and the way that financial returns will be distributed. Employment conditions are the ways in which society develops the capabilities of the labour force (present and future). Regulatory conditions mean the society's way to assign rights and responsibilities between different groups.

In this theoretical framework Lazonick characterises the social conditions of an innovative enterprise as financial commitment, organisational integration and strategic control. Financial commitment is the social condition that allocates financial resources. The need for commitment derives from the cumulative nature of the innovation process and the need for learning. To make innovations the enterprise must finance the innovative activities from some source and for some time. Organisational integration creates incentives for learning. The need for organisational learning comes from the collective nature of the innovation process. Strategic control means allocating resources for innovative activities. This characteristic of the social conditions comes from the uncertain nature of the innovation process.

The dynamic capabilities view of the firm stresses the importance of path dependency, position and processes. The innovation strategy has its focus on the R&D activities and the innovation process. In the next chapter first some innovation processes and later the role of R&D in this context are examined. Innovation can open and keep open new paths for the firm. In this view the dynamic capabilities are responsible for detecting what paths are relevant for the firm.

4 THE INNOVATION PROCESS

Dosi (1988, 222) says that innovation means search, discovery, experimentation, development, imitation, and adoption of new products, new production processes and new organisational set-ups. This is often seen as a process in companies (Rothwell, 1994; Cooper, 1993; O'Sullivan, 1998). In the innovation process the firm develops and utilises its recourses to produce higher quality and/or lower cost products (Lazonick and O'Sullivan, 1998, 3).

Rothwell (1994) describes five different innovation process generations from the 1950s to the end of the 1990s. The first two processes are linear in time, the third model is a coupling model (also linear) and the fourth generation of innovation process is more integrated and parallel (Rothwell, 1994, 12). The fifth generation innovation process is similar to the fourth generation process, but in that model "technology of technological change is itself changing" (Rothwell, 1994, 15). There are several management tools for innovation. These include for example conceptual and mathematical models, frameworks, checklists, benchmarking tools and some specific techniques and methodologies. Brady (1995) examines many of these tools.

4.1 The first generation innovation process

Technological knowledge creation is treaded in standard economic models as the outcome of basic scientific research. Technological information is expected to lead to a “zero profit equilibrium where all the initial information advantages are lost” (Kyläheiko, 1995, 76). The innovation strategy focuses on maintaining barriers for the diffusion of technology and for gaining monopolistic rents. (Kyläheiko, 1995, 75-76.)

The first generation innovation process, which describes the situation presented above, took place from the 1950s to the mid 1960s. At that time

there new industries based on technological opportunities were emerging. Attitudes favoured science and technology, and public technology policies focused largely on the supply side. (Rothwell, 1994, 8; Roussel et al., 1991, 24)

Under such conditions the innovation process can be described as technology push as shown in Figure 5 (Rothwell, 1994, 8). The technological change in this model is in accordance with the neoclassical view (Tanayama, 2002, 24).

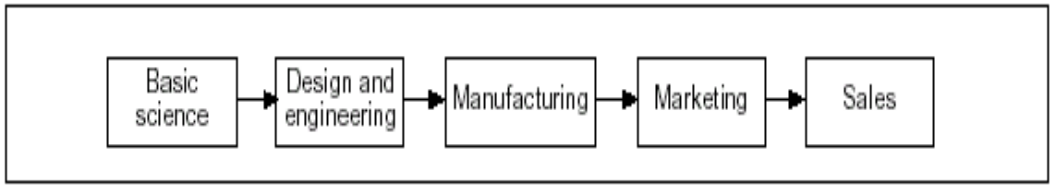
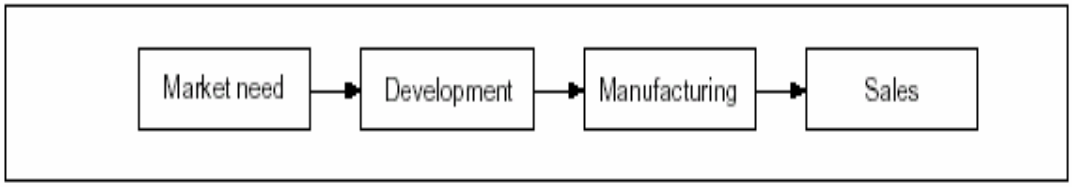


Figure 5. First generation innovation process (Rothwell, 1994, 8)

4.2 The second generation innovation process

The second generation innovation process was from the mid 1960s to the early 1970s, and was called the market pull or the need pull theory. Many new products were introduced, but they were based mainly on existing technologies. Companies started to listen and understand the customers more, marketing took control and technology became market driven (Foster, 1986, 54). R&D had merely a reactive role in the innovation process and there was a danger of neglecting long-term R&D programmes. This process is shown in Figure 6. (Rothwell, 1994, 8-9.)



These models of innovation processes are extremely crude when they are examined, especially afterwards. They may not tell the whole truth, but they give some idea of the innovation strategies, processes and innovation studies of the time. And as Tanayama (2002, 25) nicely puts it, now we can move "toward more sophisticated theories of innovation".

4.3 More sophisticated theories

As Rosenberg (1994, 139) strongly states, "everyone knows, that the linear model of innovation is dead" and we are "in a world in which the economic role of science may reasonably be expected to grow over time". Economic factors that shape the innovation process are mainly ignored in the technology push model (Dosi 1984, 81). In the market pull theory they are praised too highly.

One major problem of the linear innovation theories are the missing feedback loops in the process. They assume that the innovation moves from one function of a firm to another. New problems emerge during the innovation process that need to be solved among different actors. Co-operation also makes possible the taking advantage of tacit knowledge in the company. Collaboration, both internal and external, is vital to obtain information and for learning and knowledge creation. (Tanayama, 2002, 26-27.)

Innovation needs interaction between market opportunities and the firm’s knowledge base and capabilities. Each broad function involves a number of sub-processes. (OECD, 1997, 37.)

Kay (1988, 286) says that demand pull theories may not be relevant at all, except when the development project is closer to completion and there is less uncertainty, when the demand pull can have a more relevant role. This may be true in fundamental research projects, but hardly covers all forms of innovations.

In some cases when a firm is opening new technological paths, the demand pull theory plays a critical role in the end of the process. Development time can be extremely long, for instance as it is customary in the pulp and paper industry. In that time customers' preferences may change and new competing technologies can also occur. Also the competitors' actions to increase certain paper grade capacity affects the market situation. When huge capital investments are at the end of an innovation process, macroeconomic conditions play an important role in valuating the success of the innovation process. During a low turn, when the production capacity is not totally utilised or prices are low, this moves the break even point further.

4.3.1 The role of science

The link between science and technology is not always clear. Science can provide the capability to acquire information about technological alternatives, that are not currently possessed, but it is not a costless process (Rosenberg, 1994, 12). In the technology push theory science was seen as an independent part of technology and that science was causing the technological change. Technology was merely a by-product of science. (Tanayama, 2002, 27-28.)

The diffusion of knowledge cannot be automatic. Useful knowledge has a high degree of tacit element. This is both technological and organisational. (Pavitt, 2002a, 9.) Most technological knowledge is specific and development requires the testing of prototypes and pilot plants (Pavitt, 1999b, 62). Because technologies need to go through various phases

before commercialisation, it is misleading to say that there are technologies on the shelf waiting to be commercialised. Until the final characteristics and the performance is known, they need to be tested, modified and retested several times until they can be sold with some confidence. (Rosenberg, 1994, 13.)

Technical complexity needs to be close to scientific understanding. This is because the feedback loops between the advance in scientific understanding and the improvements in technical performance. Increasing complexity makes this discussion more difficult. (Pavitt, 2002b, 10.) This becomes more difficult when there are technological diversity and all technologies should advance in the same pace.

In one extreme the only thing that separates science and technology is the institutional framework. Innovativeness and competence of users influences the rate and direction of the original scientific discovery. (Lundvall 1988, 364.)

4.4 The third generation innovation process

The time of the third generation innovation process was from early the 1970s to the mid 1980s. Two major oil crises, high inflation rates and demand saturation made companies adopt new strategies. The third generation innovation process is essentially sequential, but it had feedback loops. Rothwell calls the third generation innovation process the "coupling" model of innovation. (Figure 7). (Rothwell, 1994, 9-11.

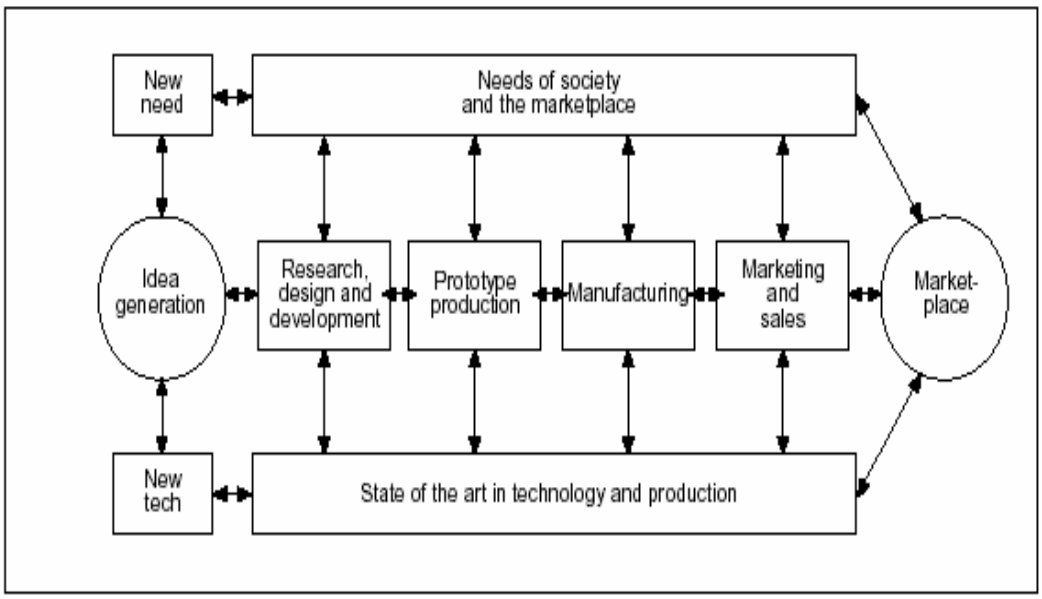


Figure 7. The 'coupling' model of innovation (Rothwell, 1994, 10)

4.5 The fourth generation innovation process

The fourth generation innovation process lasted for a decade from the early 1980s to the early 1990s. A crucial feature of that time was the competitive performance of the Japanese at the world market. Earlier beliefs were that Japanese competition was based only on imitation. Instead, the Japanese were powerful innovators and there were two major features in their innovating activities. First, innovating Japanese companies integrated their suppliers to the development process at a very early stage. Second, they integrated in-house activities of different functions. People worked on the projects simultaneously. (Rothwell, 1994, 11.) This gave, for example, the Japanese auto firms a competitive edge; they produced new models faster, replacing existing product generations every four years (European and U.S. rate was eight plus years) (Wheelwright and Clarke, 2001, 901).

The main difference compared to the third generation innovation process is that the fourth generation innovation process is a more parallel than a sequential process and suppliers are integrated at an early stage of the

process (Tanayama, 2002, 31; Rothwell, 1994, 12). Preparations or actual marketing for the sales process can be done at the same time when the product itself is still in the development phase.

4.6 The fifth generation innovation process

In the fifth generation innovation process innovation is starting to resemble a networking process. Companies are seeking speed, efficiency and flexibility in their product development. Development becomes more integrated and parallel. Electronic-based design and information systems are used. Collaborative R&D, like joint R&D linkages and R&D-based strategic alliances are more common. (Rothwell, 1994, 22.)

Dodgson et al. (2001) studied more closely the use of the electronic toolkit in the fifth generation innovation process and argue, that by using the electronic toolkit it is possible to intensify innovation. They identified four measures of intensification: speed, cost, predictability and strategic internal and external integration (Dodgson et al. 2001, 12).

Main characteristics of the fifth generation innovation process as proposed by Rothwell (1994, 24-25) are:

-Organisational and systems integration (including external networking).
-Flatter and more flexible organisational structures, including devolved decision making.
-Fully developed internal databases.
-Electronically assisted product development.
- Effective external linkages.

Today, there exist various forms of innovation processes. This is partly because of sectoral differences between industries. Some consumer products have market pull characters and some science-based industries

have more technology push characters. Still, the characteristics of the fifth generation innovation process (especially the electronic toolkit) can offer benefits to different kinds of innovation processes. (Rothwell, 1994, 23.) Now that technology is more complex, collaborative networks make obtaining and exploiting external knowledge possible (Tanayama, 2002, 32).

In the case of design, for example, a firm like IBM can work on a 24-hour day by mobilizing design teams in the UK, the USA and Japan. Teams can work in 'shifts' in different time zones. This can radically shorten the development time and it brings different and complementary knowledge assets together. (Tidd et al., 2001, 26-7) This may not be easy to organise and manage, but it is still possible.

4.7 The stage-Gate

Stage-Gate is a system developed by Robert Cooper, where process management methodologies are used. It is a trade marked version of the fourth generation innovation process on a general level. The process is divided to stages. Between each of these stages, there is a gate and after the last stage a post implementation review. A typical model of Stage-Gate process is presented in Figure 8. The gates are used to control the process. The output of a gate can be kill, go, hold or recycle and the approval of an action plan for the next stage for the go decision. Senior managers hold the gates and act as "gatekeepers". The managers decide if and how the project should continue. The gatekeeping group should be multidisciplined and multifunctional. (Cooper, 1990, 45-46.) Stages consist of a set of parallel activities. These activities are undertaken by people from different functions of the firm or division. (Cooper, 1993, 109.)

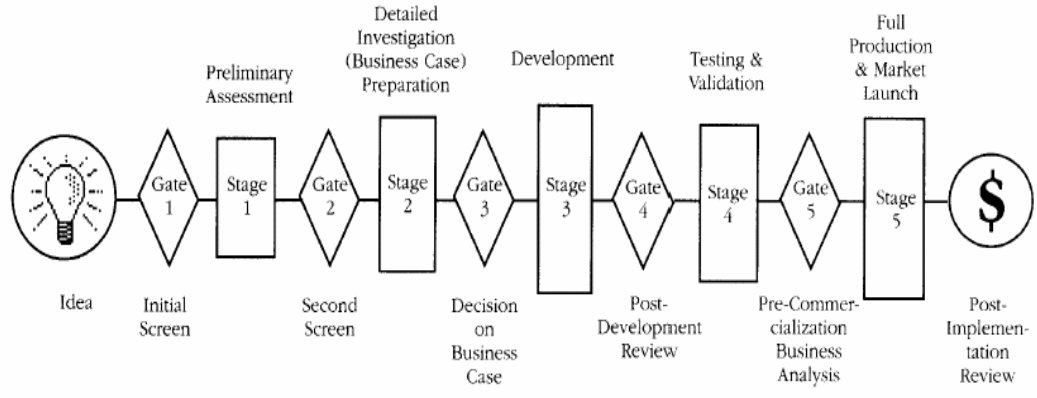


Figure 8. An overview of a Stage-Gate system (Cooper, 1990, 46)

The first, second and third generation innovation processes describe how the idea itself is moving in a firm's different functions. The stages, like in the first generation innovation process, from basic science to sales are “compulsory” to get the production process or the product to the markets. In the second generation innovation process, the source of the idea is the main thing changed. The third generation innovation process is merely a combination of these two with feedback loops. Other processes have more elements of managerial actions to make the whole process more efficient, using external sources of knowledge, ICT and parallel actions. In Stage-Gate, the process path of the idea is sequential, but the process itself is parallel in the sense that the different functions are working parallelly. It is related to the fourth generation innovation process. It is made sequential by the management actions, which decide the future of the project in each step.

4.8 The innovation process in paper mills

Petit-Gras (1997) studied the innovation process in Finnish paper mills. She made three case studies and found that the departmental stage model was not the right model for the innovation process. The innovation process was described similarly to a football team in two business units. The management’s role is to give broad directions. The closest model

found from the literature, was the conversion model. Research activities were found in a business unit from marketing, quality, personnel and R&D department and the laboratory to some extent. Their role is to develop “new combinations, new methods, new concepts and new ways to serve the customers” (Petit-Gras, 1997, 142).

Technology and market demand were not the only factors in innovation. The previous knowledge available also promoted and constrained innovations. So, path dependency exists. One difficulty was also to build a model where all aspects of an innovation were included, including networking. Evaluation of the innovative performance was also a difficult task. Some possibilities for evaluating the innovative performance are to measure inputs to the innovation process, the innovation process and the outputs of the process. (Petit-Gras, 1997.)

4.9 Industrial research and development

Industrial R&D has three major strategic roles. First, it should defend, support and expand the existing business. Second, it should drive new businesses. Third, it should broaden and deepen the technological capabilities of the company. The ways to manage these three roles are incremental, radical and fundamental R&D. Incremental R&D means "small advances in technology" (Roussel, et al., 1991, 15). These are often based on existing scientific and engineering knowledge. The incremental R&D is often associated with reducing manufacturing costs and radical with R&D discovering new knowledge. The fundamental R&D has two major goals instead. The first one is to "to develop a depth of research competence in fields of potential future technology that the company is convinced ... will have great strategic impact in the long term and second, to prepare for future commercial exploitation of these fields" (Roussel et al., 1991, 16-17). (Roussel, et al., 1991, 15-17.) This can be partly done by opening new technological paths to the firm. It could be done by

combining the new knowledge to the existing business or by opening totally new businesses.

4.9.1 The role of R&D in the innovation process

Roussel, et al. (1991) say that there are three generations of R&D management. The first generation had a lack of technology and R&D strategy. R&D was organised to the cost centres by disciplines. There was no guidance from the senior management and the interaction between scientists and marketing and manufacturing was inadequate. (Roussel et al., 1991, 25-28.)

This is related to the idea of innovation presented in the first and second generation innovation processes. In the second generation innovation process, the role of R&D was to develop existing technologies, rather than generating new ones with fundamental R&D.

The second generation R&D management is related to the third generation innovation process. There is communication between the business and R&D management, long rage plans are made and general management also started to understand strategically different R&D plans. Projects were still made separately for each business and for the corporation and R&D resources were not optimised. (Roussel et al., 1991, 30-33).

The third generation R&D management "seeks to create across business units, across divisions, and across the corporation a strategically balanced portfolio of R&D (Roussel et al., 1991, 35). This is done with general and R&D managers working together. The idea is to find synergies and trade-offs in technology projects between businesses.

Tidd, et al. (2001, 39) say that the innovation process is a core process associated with renewal in an organisation and it is a matter of survival and growth. They say that the innovation process essentially includes four elements: scanning internal and external environment signals about change, deciding which signals to respond to, arranging resources and implementing projects. There should be dynamic capabilities in a firm to manage these tasks.

5 THE REAL OPTIONS APPROACH IN INNOVATION PROCESS

5.1 Real options

One way to find synergies, trade-offs and ways to reduce and exploit uncertainty (to manage “the stylized facts of innovation”) is to use the real options approach in designing and implementing the innovation process. Essentially, the innovation process has several options for future steps. “A real option is the right, but not obligation, to take an action (e.g., deferring, expanding, contracting or abandoning) at a predetermined cost called the exercise price, for predetermined time - the life of the option” (Copeland and Antikarov, 2001, 5). As an investment, "a real option is the investment in physical and human assets that provides the opportunity to respond to future contingent events" (Kogut and Kulatilaka, 2001, 746).

Ståhle et al. (2002, 125) say that the real options can be used to reduce the downside risks of a project or to open upside potential with flexibility (Figure 9).

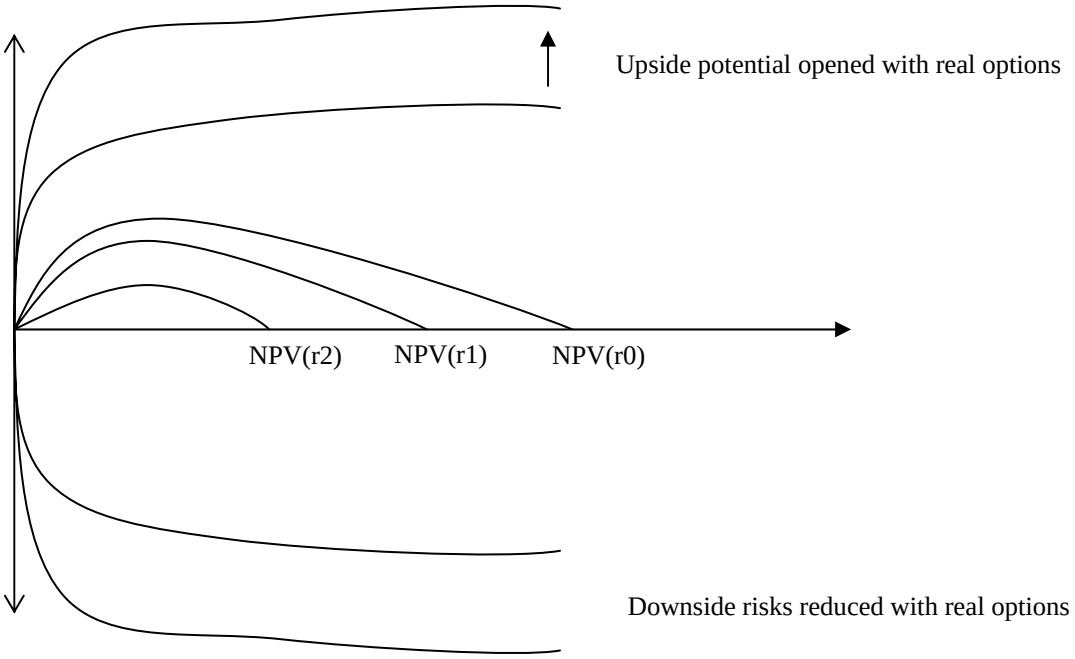


Figure 9. Real options and investment projects (adapted from Ståhle et al., 2002, 124).

- Competence enhancing innovations and learning increase the upside potential.
- Joint ventures and partnerships increase the knowledge base and upside potential.
- Activities aimed to radical innovations can increase the upside potential, but can also increase the downside risks.
- The competitors' moves shift the curve.
- Consumers preferences shifts the curve
- Reduced uncertainty shifts the curve
- Developing strategically important competences shifts the curve up

Real options make it possible to calculate the value of flexibility to these rights, and this flexibility is more valuable when there is more uncertainty. But understanding the source and properties of the uncertainty is also important (Kugut and Kulatilaka, 1994, 53-60). Understanding the source and the properties make it possible to seek the right information rather than wait for things to happen. It also makes the preparing for future actions possible, after different information inputs are analysed.

When a firm decides to enter to a new market with new capabilities, it faces two kinds of uncertainties. First, the development costs and risk. Those are idiosyncratic to the firm. And second, when entering the market, it faces the same uncertainty what other firms in the same market do. (Kogut and Kulatilaka, 2001, 751.)

Real options origin is in financial options and the focus is on reducing the risks and/or exploiting the uncertainty. There are several models of calculating value for purchased options. The focus of this thesis is not on measuring the exact value for real options, but on introducing the idea of real options in the innovation process planning and in strategic thinking in innovation strategy. As Jantunen (2002) argues, real options can be used to evaluate capabilities. This makes understanding the value of the intangible assets easier.

5.2 Real options in strategic planning

Sanchez (1993) says that firms gain strategic flexibility with strategic options. Basically, a firm chooses which products it develops, produces and markets, when it will do so and how the development, production, distribution and marketing is organised. This framework gives product, timing and implementation options to the firm. From the R&D management's side, this means that the decisions about, which technologies the firm now invests in, give the firm flexibility to develop products in the future. It is an option, not an obligation to develop and later market the product. If the product is developed, the firm has marketing flexibility to make the decision in the future to either to market it, or not. The possibility for flexible manufacturing gives the firm more product and timing options with which to respond to the market needs. The firm infrastructure and distribution system also give flexibility for future requirements. Strategic real options open upside potential such as growth options and reduce downside risks (Ståhle, et al., 2002, 124).

Amram and Kulatilaka (1999, 24) say that the real option approach can be used when

- There is contingency in the investment decision.
- Uncertainty is large enough that it is sensible to wait for more information.
- The value seems to be captured in possibilities for future growth options rather than current cash flow.
- Uncertainty is large enough to make flexibility a consideration.
- There will be project updates and mid course strategy corrections.

Kogut and Kulatilaka (1994) argue that platform investments cover two kinds of investments. First is the design of operating flexibility. And second is the growth option. They refer to platform investments as capabilities. Organisational capabilities create a platform into future opportunities.

Organisational capabilities are difficult to analyse financially and too often they are learned because it is the only way to survive.

Core technologies, joint ventures, flexible manufacturing systems and country platforms are four examples of platform investments. Core technologies, or technology drivers, make expansion to other markets possible. They are similar to what Granstrand et al. (1997) mean with core, or distinct, technologies. In joint ventures partners bring different capabilities into the venture. Sometimes it is an option to keep a joint venture alive, because there might be opportunities in the future. Even they are merely a cost at present. They give possibility to enter the uncertain markets with developed capabilities and shared risk. One way to respond to the changing markets is a flexible manufacturing system. This can be achieved, for example, by sub-contracting or with product design. Country platforms can be established distribution channels or learning how to do business in a foreign market. Such investments may look like a waste of money on the short term, but as a platform it is more attractive. (Kogut and Kulatilaka, 1994, 62-66) It is possible to argue that all major innovations, presented in the light of Abernathy and Utterback (2001), are platform investments. They follow incremental innovations and make modifications possible.

It is easy to recognise that the innovation process in major projects has at least some of these elements. In some cases, like incremental production process improvements, it may be easier to see the effects and benefits of the innovation and the time perspective is often shorter. They might be obvious investment decisions, unless it is possible to see that some new technology will destroy the value of the assets in these investments.

5.3 Different types of real options in strategic thinking

Ståhle et al. (2002, 140-141) divide options to growth seeking and flexibility options. Real options can be divided also to options to buy or to sell something. They also use seven different types of options, which can be used in the real option language.

- The option to wait. The management can leave the investment decision to a later date.
- Time to build a option. The investment can be divided into phases. If some information is against building the next phase, it can be left undone. Each phase is an option for the next one.
- The option to alter the operating scale is an option where production can be expanded or reduced.
- The option to abandon leaves a possibility to abandon existing projects and sell inputs of the projects, if it is possible.
- The option to switch gives a chance to change the product mix or production inputs.
- The growth option is a possibility for creating future investments and growth possibilities.
- The multiple interaction option. Most often projects include different kinds of options.

5.4 Real options in the innovation process

If the innovation process is sequential, the real options technique can be used to evaluate whether or not it is reasonable to continue the process. Here the focus is to see how real options can be used in planning the innovation process and using real options in evaluating, not calculating, what is the next step in the process.

Jägle (1999) argues that sequential new product development (NPD) models can be evaluated using an option tree approach and that R&D projects can be compared using the option tree. The interest in this thesis is on the former application on the general level. Jägle's proposition is also to evaluate the value of the company using real options. He argues that "a company's value of growth opportunities is the sum of all its future innovations" (Jägle, 1999, 278).

Using flexibility in the NPD process, or the innovation process, a firm can respond to demand fluctuations, changing user preferences, changing patterns of distribution and the emergence of new customers and competitors. The more turbulent the market environment is, the more flexibility is needed. (Jägle, 1999, 277.)

The sample model is a stagegate approach, presented earlier in this thesis. In this model costs, required time and uncertainty are easier to evaluate. Sometimes it may not be easy to find clear phases to divide the process into. However, for example pharmaceutical R&D has clear milestones. The five standardised phases are the preclinical phase, Phases I, II and III of the clinical trials and the regulatory phase. These phases come from the regulator. The idea is to use the next phase in the innovation process optionally. If the previous phase is successful, there is the option to continue. Decisions at the gate are go, or no go. (Jägle, 1999, 276-278.) Even when there are no clear phases from the regulator, option thinking can be used. The phases should be defined in the innovation process planning.

The other element of real options is still missing. Jägle (1999) is concerned about capturing the upside potential and he leaves the possibility for reducing the downside risk. He is more concerned about the pure growth opportunities that future R&D creates. Also the decisions are go/no go, even it is possible to consider feedback loops and other possibilities in the decision making. In the innovation process, or in an

investment project, there is typically a collection of real options and the combined value may have a huge impact to the value of the project (Trigeorgis, 1993, 2). But the fact that the writer is a consultant and the paper is written at the end of the twentieth century and has its focus on technology-intensive companies, may explain why it is focused on growth options.

Ståhle et al. (2002, 164-166) have a more realistic view of real options in research and development projects (or the innovation process). R&D project gives an option, but not an obligation to proceed to the commercialisation of the product or service. This way the sunk costs of R&D can be the only loss, even thought it can be a huge loss. In the beginning of the project, market potential is explored. After that, technological uncertainty is the dominating factor in the project. When the commercialising phase is closer, firm starts to analyse the market uncertainty more closely. When projects are clearly phased, it is always possible to use the option to abandon the project. Even when a project is abandoned, the firm gains knowledge about the technology and markets. In this way the process is parallel and needs information from the markets in the earlier phases of the project.

The real options approach is useful when R&D projects are analysed. With the real options approach the firm can handle uncertainty, flexibility, learning, path building and long term thinking. It also gives a tool to see different connections in the project. It is especially useful, when investment in commercialising is large compared to R&D, future cash inflows are uncertain, development time is long and when learning from markets and technology is strong. (Ståhle et al., 2002, 166-167.) In the pulp and paper industry new product development project often leads to an investments in production. These investments can be minor modifications in the present production process or a totally new production capacity. This choice should be thought of as a real option.

6 SOME ANALYTICAL RESULTS FROM M-REAL

M-real is listed in the Helsinki Exchange. The turnover of the company in the year 2002 was about 6,6 billion euros, 5% less than in the year 2001. Operating profits were 324 million euros (-17%). The number of personnel at the end of the year was 20 323 (-6%), more than 5 900 of which were working in Finland. About 0, 6% (26 million euros) of the annual turnover was invested to research and development in the year 2002. (M-real Oyj, 2003.)

M-real has five business areas, consumer packaging, commercial printing, home & office, publishing and map merchant group. Consumer packaging produces paperboard grades for consumer packaging. The main customers are international brand manufacturers. The main product of commercial printing is coated fine paper. Main customers are paper merchants. Home & office produces uncoated fine paper. It is used in printing and office paper. Customers for the home & office products are paper merchants, purchasing departments of big companies and small companies and home users. The publishing business area produces coated magazine papers. These paper grades are used in magazines, direct mail campaigns and catalogues. The customers of this business area are magazine publishers, printing houses, design offices and direct mail companies. The map merchant group has 50 000 customer in 23 countries in Europe. These customers include publishers, printing houses, advertising agencies, banks and retail chains. The map merchant group sells also other paper manufacturers products as well. (M-real Oyj, 2003, 8-11.)

Research and development projects are handled by five technology centres, which are located in Finland, Sweden and Germany. The technology centres handle radical and exploratory research and the mills are responsible for incremental research projects. Funding and steering to exploratory research come from the M-real corporation. Business areas

are responsible for the radical innovations. Each technology centre has one business area as their key customer.

Because M-real cannot compete with economies of scale in production it needs to focus on products where production efficiency is not dominating. This puts great emphasis on innovation and an ability to adapt to new market environments. This is also recognised at M-real.

Differences in the innovation processes are also related to the different R&D projects. Some projects, such as fundamental research, have a very strong technology push element. There may not be a direct link to a customer or even to a product. Fundamental research should create and develop competencies needed in the future. At M-real most of the radical R&D projects and every incremental project has a customer (mill or business area) and these projects have (from the R&D point of view) a customer. These projects have a very strong demand pull element. Projects are managed as in the Stage-Gate process.

6.1 The design of the study at M-real

The design of the study came from the supervisors at M-real. They introduced people from different business areas and corporate functions. These people were interviewed in groups of one or two.

6.1.1 Study questions

The focus was to obtain information about innovation and the innovation process at M-real. There was another related project on at the same time. Interviews were made at the same time to save the interviewees time. Only a few of the interviewees were working directly with R&D. General information about innovation, innovation process and R&D projects were presented. The results to be presented in the next section were gathered from free discussion.

6.2 The results

This section is based on the interviews and other discussions inside the company if not otherwise mentioned. After these interviews were made, the structure of M-real's organisation has changed and some persons currently have different positions as a result.

Map merchants works quite separately from M-real. They are not involved in the innovation processes and are more a customer to M-real (and the other paper producers). One reason they see for this is the lack of recourses on their side. Most of their customers are small printers, who do not have much knowledge about paper technology. Their existence is based on local entrepreneurship and services provided to customers. Focus on their side in innovations is naturally on services since they do not produce the products. On their side new or improved products have a strong technology push element.

Some considerable changes have been going on in the consumer packaging division. They have been constructing their value chain to better serve their customers. These customers who need a new value chain are international fast moving consumer goods producers. In consumer packaging innovation processes technology push and demand pull have been the driving force. They describe the process model as

similar to the fourth generation model. They have also had “24 hour” innovation processes such as described in the IBM example earlier. The problem they see in their innovation processes and in general is the commercialising part. The product development side of the innovation process is done well, but there is difficulty in gaining rents from the innovations. They think that the technology centres should be the owners of the innovation processes. Even there, there might be a lack of knowledge about the markets.

In the commercial printing division most of the volume is sold through merchants. There are several different end users and there are differences between countries. Innovative company culture is needed, because mills are small and cannot compete with product prices. There are differences in customer orientation between the mills. Some of the new products are made with lead user customers. They see that the fourth generation innovation process is the process used, just as the M-real’s project manual suggests. It is not difficult to get resources committed if a new idea is good. Because Map is used to sell their products, they see that it should be utilised in the innovation process.

In strategic marketing, the focus is more on service innovations. Otherwise they see that innovations are product driven and customer orientation is weak in reality. R&D is strong in product development, but the understanding of the customer’s needs is still too weak.

In the publishing division incremental product development is strong. Radical innovation is generally weak. The division is technically advanced. The innovation process was seen as a combination of the third and fourth generation innovation process, but the benefits of the fourth generation process were easy to see. Difficulties were once again in gaining innovation rents. Innovation in the publishing division, and in general at M-real, was not understood as a corporate wide task. They see that there is an attitude problem, which should be changed.

Focus in the publishing division is on service innovations. Technical service should be improved and services developed in addition for existing products. They see that getting profits from services is difficult. One reason can be that the sales people are not used to selling services and they do not know the customers well enough. Also the incentives are based on volume, not value. One difficulty that also came up was that the customers are also very conservative, which makes it difficult to introduce radical ideas and changes to the printing industry.

In the home & office division the innovation process was seen as the third generation model with technology push element. The focus is on moving towards the fourth generation innovation process. There are still problems in getting the customer end tied to the innovation process. Another part that needs improvement is the idea selection process. The printing equipment is developing and this puts demands on the paper. There is need for new organisational models and access to several knowledge sources because the development is sometimes very fast. This makes networking important.

Innovation is recognised as a corporate wide task. R&D often sees the technical side of the innovation and the commercialisation is not understood at all. More inputs from customers are needed. Sometimes there are organisational barriers in development projects between business areas, which makes the project management difficult and total benefits are not utilised. There is need to measure the benefits of the innovation process, not just the R&D part. That would help to evaluate the projects as well.

6.3 Summary

The original purpose of this study was to focus on product and production process innovation. This rather narrow study shows that focus of development at M-real is in service innovations.

Product and production process development have traditionally been strong at M-real. The difficulty seems to be on the customer end in the innovation process (an idea or an invention developed to a new or a better product) and in gaining innovation rents from the new products. This gives some base for developing the innovation process in the first place. It is not enough to plan the technical details and focus on the commercialising after everything else is done. One difference is of course in fundamental research. It can be evaluated differently. But the innovation process itself should be a parallel process. At M-real the new product development process is parallel, but when the innovation process is considered, the customer end is not included in the early phases. This is not always necessary (fundamental research). Now customers are tried to get involved with the innovation process at an earlier stage. Also the aim is to get more ideas for innovations from the customers. Still, there are no structured channels or routines for this.

Everyone agreed that innovation is a corporate wide task, but the attitude inside the company is not always the same. That could be one reason for the difficulty in commercialising innovations: the innovation process is not understood as including profits from innovation. Too often the focus is on the technical aspects. This could come as the result of the history of the industry; technical side has traditionally been dominating. This is something that is difficult to change in the short run and the initiative and support for the change should come from top management in the first place.

The problem is to gain innovation rents. One way to approach this problem is to try to find the origin.

-Ideas for innovations may not be that good after all
-Commercialisation is not understood in the process – too much technology push
-The market environment is changing faster than M-real can react (or proact)
-Innovations can be copied too easily

Where new services are concerned, knowledge of the customer is even more important. The old saying ‘know thy customer’ is still valid and has a more important role in developing and commercialising service innovations. With big customers, services can be completely customised. Successful innovation is combining the customer needs to the firm’s technological knowledge and capabilities. Also incentives in the sales should be focused on finding new ideas for innovation and new sales methods. The latter is even more important in selling services. Map merchants have developed services for a longer period. Internal benchmarking could help other parts of the firm to develop and sell services.

These business areas had different kinds of value chains and different kinds of innovation management. Processes are seen in different ways. One reason can be that some of the business areas have more units from purchased companies. According to the path dependant nature of the firm and the fact that firms evolve in different kinds of environments, things are done differently and change is slow. Also the effects of an innovation to different units or business areas differ. This gives more reason to focus on the framework of the innovation process.

The real options approach can be used in strategic thinking in innovation strategy. They can help to start new projects, which do not offer instant

cash flows, but are needed to manage in the global competition. They make new technological paths available. There is still risk in starting projects and ending them before they are completed. Motivation of the people involved in the project can be reduced (Ståhle et al., 2002, 166). The project may be seen as a failure and the people involved are responsible for that. This could raise the barrier to innovate.

One important thing that did not come up in the interviews is technology transfer. This is because radical innovations are developed in technology centres and incremental innovations at business units. When incremental innovations follow radical innovations there should be absorptive capacity at the business units. That makes efficient improvements possible.

7 SUMMARY AND CONCLUSIONS

7.1 Summary of the study

This study has examined innovation in the literature in general and at M-real in particular. Innovation is the reason and response to changes in the market environment. Innovation can take the form of new products, new production processes or new organisational processes. The literature review has shown that by nature, innovative activities are uncertain, path dependant and multi technological. Uncertainty can come from technological or commercial features. Technological path dependency nature constrains firm's future choices in technology. Innovations are also a combination of different technologies. Systemic innovations need other innovations to be successful. Incremental innovations are important and they follow major innovations. Innovations can also affect the whole value chain of the firm and may have an effect on the customers and suppliers, the whole value network. These make the innovation process very collective. Different functions and managerial levels are required to successfully commercialise an idea or invention. It may also be necessary to involve customers and suppliers in the innovation process at early stages. After all, an innovation is an interaction of economic and technological factors. Dynamic capabilities detect changes in the market environment and are needed to implement the innovative activities, like innovation process, in a firm.

In capitalistic economies winners are separated ex post from losers. To develop an idea in such an economy is difficult. Consumer preferences, competitors' actions and technological advance change the markets. Also government regulation and laws may change during the innovation process. All these things should be considered in the innovation process planning and implementation. This makes it difficult to pick the winners between different projects. In some cases the value of the flexibility could raise the value of a project.

7.2 Conclusions

The real options approach can be used in innovation process planning. This can give flexibility to the project but also to resource allocation. Understanding the value of the knowledge gained from innovation helps to see where scarce resources should be invested.

Innovation at M-real has a strong technical focus. The customer end is often neglected in the innovation process. This makes gaining innovation rents more difficult. Innovation was not understood as a corporate wide task in the whole company. Also, service innovations are at central focus at M-real at the moment. Developing service innovations may prove to be difficult in an industry that has its roots in producing and selling volume products. It is also difficult to introduce radical innovations to the conservative customers.

This study of the innovation process at M-real is made in very general level. To get better understanding of the processes behind the innovations at M-real, case studies of different kinds of innovations are essential. By effects there are different kinds of innovation processes. Also the Penrosian resources required differs case by case. These differences make it difficult to make exact conclusions and generalise them to every project in the firm and they should be evaluated and followed case by case. Also discussions with customers and suppliers (equipment, raw material and advertising agencies) were excluded from this study. They could contribute new valuable information to the innovation studies.

7.3 Further research

The real options approach seems to offer a good tool in innovation management as a common language. An interesting area to study further would be real options in practice. How can they be used in innovation process planning and implementation? And what benefits and problems compared to earlier methods arise? Real options may be useful also in examining the effects of an innovation and the need for new capabilities or paths in the firm.

Service innovations are in focus at M-real. This gives another area for a further study. How should services be developed at M-real and by whom? What kind of services should be developed at corporate level and what should be left to the business areas and units? Also the selling processes should be examined further. Developing new products or services are not much use if the selling is focused on volume products.

REFERENCES

Abernathy, W.; Clark, K. (1988). Innovation: mapping the winds of creative destruction. In: Tushman, M.; Moore, W. (eds.). Readings in the management of innovation (2nd ed.). Harper business, 55-78.

Abernathy, W; Utterback, J. (2001). Patterns of industrial innovation. In: Burgelman, R; Maideque, M; Wheelwright, S. (eds.). Strategic management of technology and innovation. (3rd ed.). McGraw-Hill Irvin, 149-155.

Amram, M.; Kulatilaka, N. (1999). Real options. Managing strategic investment in an uncertain world. Harvard business school press, Boston.

Autio, E.; Dietrichs, E.; Führer, K.; Smith, K. (1997). Innovation activities in pulp, paper and paper products in Europe. STEP report R-04, Oslo.

Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of management, vol. 17(1), 99-120.

Brady, T. (1995). Tools, management of innovation and complex product systems. Working paper, CoPS Publication No 3. Economic & social research council.

Brusoni, S.; Prencipe, A; Pavitt, K. (2000). Knowledge specialisation & the boundaries of the firm: why do firms know more than they do?. SPRU Electronic working paper no. 46, Brighton, University of Sussex.

Burgelman, R.; Maidique, M.; Wheelwright, S. (eds.) (2001). Strategic management of technology and innovation. (3rd ed.). McGraw-Hill Irvin.

Carlsson, B. (1994). Technological system and economic performance. In: Dodgson, M.; Rothwell, R. (eds.) The handbook of industrial innovation. Cornwall, Hartnolls Limited, 13-24.

Chesbrough, H.; Teece, D. (1996). When is virtual virtuous? Harvard business review, Jan-Feb, 65-73.

Cohen, W.; Levinthal, D. (1989). Innovation and learning: the two faces of R&D. The economic journal, 99, 569-596.

Coombs, R. (1994). Technology and business strategy. In: Dodgson, M.; Rothwell, R. (eds.) The handbook of industrial innovation. Cornwall, Hartnolls Limited, 348-392.

Cooper, R. (1990). Stage-gate system: a new tool for managing new products. Business horizons, vol. 33(3), 44-54.

Cooper, R. (1993).Winning at new products. Accelerating the process from idea to launch. (2nd ed.). Addison-Wesley publishing company.
Copeland, T.; Antikarov, V. (2001). Real options. A practioner's guide. New York, Texere LLC.

Dierickx, I.; Cool, K. (1989). Asset stock accumulation and sustainability of competitive advantage. Management science, vol. 35(12), 1504-1511.

Diesen, M. (1998). Economics of the pulp and paper industry. Jyväskylä, Gummerus Oy.

Dosi, G. (1984). Technological paradigms and technological trajectories. In: Freeman, C. (ed.). Long waves in the world economy. Guildford, Bibbles Ltd, 78-101.

Dosi, G. (1988). The nature of innovation process. In: Dosi, G.; Freeman, C.; Nelson, R.; Silverberg, G.; Soete, L. (eds.) Technical change and economic theory. Pinter publishers, 221-238.

Dosi, G.; Egidi, M. (1991). Substantive and procedural uncertainty. Journal of evolutionary economics, 1, 145-168.

Dosi, G.; Nelson, R.; Winter, S. (eds.) The nature and dynamics of organizational capabilities. New York, Oxford university press Inc.

Dosi, G.; Soete, L. (1988).Technical change and international trade. In: Dosi, G.; Freeman, C.; Nelson, R.; Silverberg, G.; Soete, L. (eds.) Technical change and economic theory. Pinter publishers, 401-431.

Foss, N. (1997). Equilibrium vs. evolution in the resource-based perspective: the conflicting legacies of Demsetz and Penrose. Working paper no. 97-10. Department of Industrial Economics and Strategy, Copenhagen Business School.

Freeman, C.; Perez, C. (1988). Structural crises of adjustment, business cycles and investment behaviour. In: Dosi, G.; Freeman, C.; Nelson, R.; Silverberg, G.; Soete, L. (eds.) Technical change and economic theory. Pinter publishers, 38-66.

Fujimoto, T. (2002). Evolution of manufacturing systems and ex post dynamic capabilities: a case of Toyota's final assembly operations. In: Dosi, G.; Nelson, R.; Winter, S. (eds.) The nature and dynamics of organizational capabilities. New York, Oxford university press Inc., 244-280.

Granstrand, O. (1979). Technology management and markets. An investigation of R&D and innovation in industrial organizations. Chalmers university of technology.

Granstrand, O.; Patel, P.; Pavitt, K. (1997). Multi-technology corporations: why they have "distributed" rather than "distinctive core" competencies. California management review, vol. 39(4), 8-25.

Henderson, R.; Clark, K. (1990). Architectural innovation: the reconfiguration of existing product technologies and the failure of establihed firms. Administrative science quarterly, vol. 35(1), 9-30.

Howard, J; Moore, W. (1988). Changes in consumer behaviour over the product life cycle. In: Tushman, M.; Moore, W. (eds.). Readings in the management of innovation (2nd ed.). Harper business, 343-351.

Jantunen, A. (2002). Dynamic capabilities and real options. TBRC Working Papers, Lappeenranta.

Jägle, A. (1999). Shareholder value, real options, and innovation in technology-intensive companies. R&D management, vol. 29(3), 271-287.

Kivisaari, S. (1992). Management as a divided actor in product innovation. The case of a diversified Finnish corporation. Acta academiae oeconomicae Helsingiensis.

Kogut, B.; Kulatilaka, N. (1994). Options thinking and platform investments: investing in opportunity. California management review, winter 1994, 52-71.

Kogut, B.; Kulatilaka, N. (2001). Capabilities as real options. Organizational science, vol. 12(6), 744-758

Kyläheiko, K. (1995). Coping with technology: a study on economic methodology and strategic management of technology. LUT research papers 48, Lappeenranta, Lappeenranta university of technology.

Laurila, J. (1995). The thin line between ambitious and modest designs in new technology introduction. Case study evidence on the wood-containing printing paper industry. Helsinki school of economics and business administration working papers W-132.

Laurila, J. (1998). Managing technological discontinuities. The case of the Finnish paper industry. Routledge.

Lazonick, W. (2000). From innovative enterprise to national institutions: A theoretical perspective on the governance of economic development. The European institute of business and administration report.

Lazonick, W; O'Sullivan, M. (1988). Corporate governance and the innovative economy: policy implications. STEP report R-03.

Leifer, R; McDermott, C; O'Connor, G; Peters, L; Rice, M; Veryzer, R. (2000). Radical innovation: how mature companies can outsmart upstarts. Boston, Harvard business school press.

Leiponen, A., (2000). Essays in the economics of knowledge: Innovation, collaboration and organizational complementarities. Acta universitatis oeconomicae helsingiensis.

Lundvall, B.A. (1988). Innovation as a interactive process: from user-producer interaction to the national system of innovation. In: Dosi, G.; Freeman, C.; Nelson, R.; Silverberg, G.; Soete, L. (eds.) Technical change and economic theory. Pinter publishers, 349-369.

Madhok, A.; Osegowitsch, T. (2000). The international biotechnology industry: a dynamic capabilities perspective. Journal of international business studies, 31(2), 325-335.

Marquis, D. (1988). The anatomy of successful innovations. In: Tushman, M.; Moore, W. (eds.). Readings in the management of innovation (2nd ed.). Harper business, 79-87.

Mowery, D.; Rosenberg, N. (1989). Technology and the pursuit of economic growth. New York, Cambridge university press.

M-real Oyj. (2003). Vuosikertomus 2002.

Nelson, R. (1987). Understanding technical change as an evolutionary process. Amsterdam, Elsevier science publishers B.V.

Nelson, R.; Winter, S. (1982). An evolutionary theory of economic change. Cambridge, The Belknap press of Harvard university press.

OECD (1997). Proposed guidelines for collecting and interpreting technological innovation data-"the Oslo manual". OECD, Paris.

O'Sullivan, M. (1988). The innovative enterprise and corporate governance. The European institute of business and administration report.

Patel, P.; Pavitt, K. (1999a). The technological competencies of the world's larges firms: complex and path dependent, but not much variety. In: Pavitt, K. (ed.). Technology, management and system of innovation. Bodmin: MPG Books, 71-86.

Patel, P.; Pavitt, K. (1999b). Large firms in the production of the world's technology: an important case of "non-globalisation". In: Pavitt, K. (ed.). Technology, management and system of innovation. Bodmin: MPG Books, 125-145.

Patel, P.; Pavitt, K. (1999c). Uneven (and divergent) technological accumulation among advanced countries: evidence and a framework of explanation. In: Pavitt, K. (ed.). Technology, management and system of innovation. Bodmin: MPG Books, 193-317.

Pavitt, K. (1999a). Sectoral patterns of technical change: towards a taxonomy and theory. In: Pavitt, K. (ed.). Technology, management and system of innovation. Bodmin: MPG Books, 15-45.

Pavitt, K. (1999b). What we know about the strategic management of technology. In: Pavitt, K. (ed.). Technology, management and system of innovation. Bodmin: MPG Books, 61-70.

Pavitt, K. (2002a). Knowledge about knowledge since Nelson & Winter: a mixed record. SPRU Electronic working paper no. 83, Brighton, University of Sussex.

Pavitt, K. (2002b). Innovation routines in the business firm: what matters, what's staying the same, and what's changing. SPRU Electronic working paper no. 45, Brighton, University of Sussex.

Pavitt, K.; Steinmueller, E. (1999). Technology in corporate strategy; change, continuity and the information revolution. SPRU Electronic working paper no. 38, Brighton, University of Sussex.

Pavitt, K; Robson, M; Townsend, J. (1989). Technological accumulation, diversification and organisation in UK companies, 1945-1983. Management science, 35, 81-99.

Penrose, E. (1995). The theory of the growth of the firm. Third edition. New York, Oxford university press.

Petit-Gras, S. (1997). The dynamics of the innovation process in the Finnish paper industry. The mill point of view. Espoo, Helsinki university of technology.

Porter, Michael, E. (1985). Competitive advantage: creating and sustaining superior performance. With a new introduction. New York, Free Press.

Porter, Michael, E. (1990). The competitive advantage of nations. Hong Kong, The Macmillan press.

Rosenberg, N. (1994). Exploring the black box. Cambridge University Press

Rosenberg, N. (1995). Why technology forecasts often fail. The futurist, Jul-Aug, 16-21.

Rosenbloom, R; Christiansen, C. (1998). Technological discontinuities, organizational capabilities and strategic commitments. In: Dosi, G; Teece, D; Chytry, J. (eds.). Technology, organization and competitiveness. Oxford university press, 215-245.

Rothwell, Roy. (1994). Towards fifth generation innovation process. International marketing review, 11(1), 7-31.

Roussel, P.; Saad, K.; Erickson, T. (1991). Third generation R&D. Boston: Harvard Business School Press

Sanchez, R. (1993). Strategic flexibility, firm organization and managerial work in dynamic markets: a strategic options perspective. In: Shrivastava, P.; Huff, A.; Dutton, J. (eds.) Advances in strategic management, vol. 9, 251-291.

Schumpeter, J. (1939). Business cycles. Vol. 1. McGraw-Hill book company Inc.

Schumpeter, J. (1943). Capitalism, socialism and democracy. London, George Allen & Unwin Ltd.

Shapiro, C.; Varian, H. (1999). Information Rules. Boston, Harvard Business School Press.

Sthåle, P.; Kyläheiko, K.; Sandström, J.; Virkkunen, V. (2002). Epävarmuus hallintaan – yrityksen uudistumiskyky ja vaihtoehdot. Jyväskylä, Gummerus kirjapaino.

Stora Enso press releases. Available URL: http://www.storaenso.com/CDAvgn/main/0,,1_-3039-2944-en,00.html 3.7.2003

Tanayama, T. (2002). Empirical analysis of processes underlying various technological innovations. Vtt publications 463.

Teece, D. (1980). The diffusion of an administrative innovation. Management Science 26(5), 464-470.

Teece, D. (1988). Technological change and the nature of the firm. In: Dosi, G.; Freeman, C.; Nelson, R.; Silverberg, G.; Soete, L. (eds.) Technical change and economic theory. Pinter publishers, 256-281.

Teece, D. (1998). Capturing value from knowledge assets: the new economy, markets for know-how and intangible assets. California management review, vol. 40(3), 55-79.

Teece, D. (2003). Explicating dynamic capabilities: asset selection, coordination, and entrepreneurship in strategic management theory. Presentation at Lappeenranta University of Technology.

Teece, D.; Pisano, G.; Shuen, A. (2002). Dynamic capabilities and strategic management. In: Dosi, G.; Nelson, R.; Winter, S. (eds.) The nature and dynamics of organizational capabilities. New York, Oxford university press Inc., 334-362.

Tidd, J.; Bessant, J.; Pavitt, K. (2001). Managing Innovation: Integrating technological, market and organizational change. 2nd ed. Chichester, John Wiley & sons.

Trigeorgis, L. (1993). The nature of option interactions and the valuation of investments with multiple real options. Journal of financial and quantitative analysis, vol. 28(1), 1-19.

Utterback, J. (1994). Mastering the dynamics of innovation. Boston, Harvard business school press.

Wheelwright, S.; Clark, K. (2001). Accelerating the design-build-test cycle for effective new product development. In: Burgelman, R; Maideque, M; Wheelwright, S. (eds.). Strategic management of technology and innovation. (3rd ed.). McGraw-Hill Irvin, 900-910.