Chapter 4

THE TECHNOLOGY-BASED FIRM: A GENERAL FRAMEWORK

Chapter contents:

4.1 Chapter outline

The preceding chapter described intellectual property in general and patents in particular and put IP and the patent system in the context of technology-based innovations and their diffusion on a market. This chapter will put IP in the context of a firm, its resources and its intellectual (or immaterial) capital (IC). A firm's IC not only incorporates its IPRs, but also its relations and competencies, including its technological capabilities. A special type of IC firm, the technology-based firm (TBF) is of particular interest here, and a general framework for such a firm is presented. The presentation is somewhat theoretical and compressed, and the reader interested in more empirical discussions can skip large parts of this chapter. However, it gives a framework for the following chapters regarding the resource structure of a company, the acquisition and exploitation of technology as a resource, and various corporate, technology and IP strategies. The term 'firm' will be used as it is commonly used in theories of the firm and it is synonymous with company, corporation and enterprise here.

Chapter 1 described the basic notion of IC and its growing importance in an increasingly knowledge-based society. The emergence of the IC firm, with the technology-based firm as a special but important case, is a reflection of this general long-run development, stretching over centuries. Many economic notions have centred around physical (land, capital) and manual (labour) human resources.[1] However, it may be argued that intellectual resources are becoming most important and will remain so in the future, both in terms of expenditure and as a source of returns and wealth. For example, in large as well as small technology-based firms ”soft” investments in IC (e.g. in R&D, education, training) nowadays often exceed ”hard” investments (machinery, buildings etc.). The growing value of firm-specific competencies, patents, trademarks, goodwill, etc. also often make the firm's intangible assets more valuable than its tangible assets, although the valuations are difficult to calculate and compare, as described in

[1] This does not mean that non-physical or intellectual resources and activities such as inventive work were ignored altogether by classical economists. Adam Smith, for example, dealt with the role of inventions and the division of inventive work. Nevertheless, such issues do not take up a major part of his works.

Chapter 1. The discrepancy between traditional physically oriented economic notions and the rise of IC creates problems, e.g. in accounting[2]. The IPR system then also serves an important role as a means to "tangibilize " and codify IC for purposes of economic analysis and accounting as well as for management. Intellectual property management in general assumes a much wider and more important role in the context of the rising IC firm (see further Chapter 8).

The TBFs as a group also become increasingly important as generators and accumulators of the world's technology and IC. The large TBFs typically become multi-national, multi-product and multi-technology as a result of diversification. The chapter also describes the nature and role of technology diversification and technology management.

4.2 Co-evolution of technology and the firm

In the history of institutions the modern business firm is a fairly recent innovation (emerging in 19th-century Europe), preceded by far by institutions like the church, the farm, the university (emerging in 12th-century Italy), the bank (emerging in medieval Italy as well), the patent system and also by the modern nation-state.[3] As an institutional species, the modern business firm in market economies has developed a remarkable viability and variety.[4] In the 20th century larger and more diversified multinational corporations (MNCs) and multiproduct corporations (MPCs) have emerged, typically internalizing their teaching, R&D, and banking functions while at the same time forging links with universities and banks. These latter institutions have in turn increasingly adopted organizational features from business firms in advanced countries.

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[2] This is also true for a country as Japan. See Fujita (1991) for the historical developments of accounting in Japan.

[3] Inserting a qualifier like 'modern' obviously opens the door for vagueness in dating. Here 'modern business firm' refers to a joint-stock limited-liability firm and 'modern nation-state' to the type emerging in connection with the American and French revolutions in the late 18th century.

[4] Despite the terms used here no biological analogies are intended. On the contrary, such analogies are often more misleading than helpful when applied to firms and technologies; see Penrose (1952) and Granstrand (1994a, Ch. 19). The (admittedly biology-inspired) terminology is used here as a language of general evolution, not necessarily confined to its application in biology (cf. von Bertalanffy 1968).

Super-markets

The viability of the firm as an institution partly stems from its possibility to recombine resources with other firm's on the stock market, i.e. the market for corporate control or the market for firms. This type of market is in fact a kind of ”super-market” since it works as a selection mechanism (‘selection mechanism’ in the sense of Nelson and Winter 1977, 1982) of a higher order, speeding up both variety generation and selection.

Standard markets

Secondly, the viability of a firm also stems from its ability to combine, cumulate, and recombine resources through markets for resources (inputs) and products (outputs) and the firm's ability to rapidly respond to business opportunities and threats. Such abilities are fostered by competition and the legal framework around a firm together with alerting signals provided by a system of accounting. This, however, may in turn produce monopolistic as well as myopic behaviour, both potential disfunctions of the firm as an economic institution.

Sub-markets

A third basis for the viability of the firm stems from the development of governance structures and managerial capabilities. From a transaction-cost perspective the emergence of increasingly large-sized, diversified and internationalized corporations could be interpreted as a sign of increasingly lower governance or management cost on average, compared to market transaction costs. However, the modern firm has also increasingly learned to utilize internal ”sub-markets” in order to reduce governance cost and/or raise innovativeness (e.g. through the divisionalized so called M-form of organization), as well as having learned to link up with external partners in networks. Thus, the modern firm has developed into a quasi-integrated hybrid form of organization, still possessing a considerable source of central power, however, thereby distinguishing it from a mere network.

Science and technology

A fourth part of the viability of the firm stems from the long-run evolution of S&T, including the scientific ”revolutions” during the Renaissance (introducing e.g. the method of systematic experimentation) and the Age of Enlightenment. The S&T evolution has continually generated new business opportunities and new types of consequential needs. At the same time, basic human needs related to a fundamentally different biological evolution have remained much the same.[5] An increasing range of business firms has then in one way or another (product- or process-wise) become reliant or based upon technology in exploiting business opportunities, thus giving rise to the technology-based firm (TBF) as a growing sub-species of the modern business firm.

There is no need to operationalize here, through some cut-off point, when a firm is technology-based and when it is not. However, it is important to spell out that the concept of technology is used here in the narrow sense of natural science and engineering or technical knowledge, thereby sticking to an old tradition according to Cantwell (1994). More specifically, this book will equate technology with a body of knowledge of techniques that falls into areas containing, in principle, patentable knowledge. Operationalization of technology, in this way, is immensely aided by the international patent system, which provides a method for classification that is in turn important for codification. In the same spirit, a technology could be defined as new if it is less than 20 years old (20 years being the maximal patent lifetime), and a unit of technological advance could be defined as the minimum level of invention required for patentability. Thus, the patent system also offers an operationalization of novelty as well as of the size of a novelty in the form of a simple metric norm. In general, the patent system is

[5] Humans have not, for example, developed three arms for cocktail parties, separate talking and eating organs or entirely new senses with new forms of stimulation and entertainment.

underutilized as a way to operationalize technology. It is far from error-free, but it is the best at hand, generally speaking.

As technology (engineering knowledge) has become an economic engine in technology-based firms, these firms have collectively become an increasingly important source of technology.[6] Thereby, firm-based technology has increased, absolutely as well as relatively. Thus, the increasing importance of technology-based firms and firm-based technologies is a perfect example of virtuous[7] co-evolution of an expansionary economic institution and S&T knowledge, concurrently independent of biological evolution in general.[8]

4.3 A general view of the firm

A firm is a multifaceted phenomenon which theoretically could be viewed in many ways – as a nexus of contracts, as a special type of network, as a substitute for market mechanisms, as a self-organizing system interacting with an environment, as an input/output production system (epitomized by the smoke-stack factory), as a bundle of resources and so on. These different views are complements rather than substitutes for each other, as they emphasize different aspects of a firm with its many forms – small/large, national/multinational, private/public, manufacturing/service etc.

In general, a business firm can be viewed as a legally identified, dynamic human system, consisting of a set of heterogeneous resources in an institutional setting (defining e.g. property rights). The firm has an interior and an exterior (or environment), and it has management and business ideas with a dynamic goal (or incentive) structure having commonalties for coordinating

[6] See e.g. Pavitt (1991).

[7] In some sense the Christian church as an institution on the one hand and S&T on the other hand would rather be an example of adversary co-evolution, at least in the Middle Ages.

[8] Biology and genetic engineering develop as a S&T field and biotech-based firms increase in numbers. New evolutionary patterns in nature may take root as a result, desirable or not. Incidentally, this may open up possibilities for new analogies between biology, firms and S&T.

purposeful action. The interior interacts with the exterior in various ways, in particular through business transactions (economic exchange) on a market, which consists of a network of meetings between buyers and sellers. The business transactions are essentially exchanges of resources between the firm and its environment, typically production factors and products (in a wide sense, including any services) for money. A business is defined here as a set of business transactions, which is coherent in some sense in terms of resources, products and markets.

As the system evolves, resources are transformed as a result of interior operations or activities as well as through interaction with the exterior. In particular, resources are acquired and exploited through both interior operations and business transactions. To the extent that resources are acquired and exploited by the firm through business transactions, one can speak of them as inputs and outputs of the firm, respectively. However, resources could also be classified as inputs and outputs of a resource transformation process (production process in a wide sense) inside the firm, not necessarily directly linked to business transactions with the exterior.

The environment must be explicitly recognized since it provides business opportunities without which the firm would atrophy. At the same time, a firm faces environmental challenges or threats and may go bankrupt or disappear through merging, acquisition or liquidation. This normally results from interaction with the environment, which thereby provides not only opportunities but also threats. The opportunities and threats in the environment are changing, partly influenced by the firm, partly beyond its influence. The influence depends on the firm's management and (other) resources, which in turn are influenced by the environment and its past, current and anticipated interaction with the firm. The major strategic task for management is to position the firm in the stream of opportunities and threats, while creating a desired resource structure that generate adequate rents and that can also be transformed over time to meet new opportunities and threats.[9]

[9] This formulation does not imply that opportunities are fully exogenous to the firm. E.g. a firm that comes up with an innovation may create entirely new opportunities, some of which also spill over to other firms.

In an intellectual capital based firm (IC-firm), the resources and business transactions of the firm are oriented around some type(s) of intellectual capital to a decisive degree that could vary from ”pure” IC firms to hybrid IC firms. In particular for a technology-based firm (TBF), being a special case of an IC firm, the elements of the firm are technology-oriented. Thus, technologies constitute a vital part of such a firm’s resources. A substantial part of the technology-based firm’s interactions with the environment are moreover influenced by internal and external technical and technological changes, opportunities as well as threats, and the corresponding part of the environment is technology-oriented and constitutes the firm’s technological neighbourhood. Moreover, technology management is a vital part of management and technology-oriented ideas, and goals are a vital part of the technology-based firm’s business ideas and goal structure, although typically aligned to economic goals.

There is not much new about the general view of the firm as a system, which is dynamic, self-organizing, resource-transforming, interacting, human, purposeful etc.[10] It is when the structure of the resource set and its associated processes of acquisition and exploitation are specified that something new and useful can hopefully be achieved. The TBF is then a particularly interesting case for further analysis here. This analysis will be made next, or at least forwarded a bit.

4.4 The resources of a firm

4.4.1 General resource structure

The resource set is considered as the firm’s capital (or capitalized assets), and is decomposable into physical, financial and immaterial (or intangible or intellectual) capital (IC). Immaterial capital plays a key role and encompasses both disembodied IC (including business ideas) and embodied IC, the latter in the form of relational capital and competencies (or capabilities)

[10] This does not mean that there is nothing disputable about such a view.

possessed by humans. Disembodied IC is partly protectable by intellectual property rights (IPRs), including trade secret protection (whether weak or strong) of business ideas. Table 4.1 gives an overview of the resource categories used here, which in fact is one way (out of several) to present a categorical structure of assets on a balance-sheet.

The capital structure (resource structure) differs across companies and sectors and may be used for constructing taxonomies of companies, e.g. classifying them into raw material-based, IC-intensive, knowledge-based, technology-based etc. The capital structure of a company also is reflected in its culture and management style. Thus, organizational features and management skills are differentiated across sectors (forestry, banking, pharmaceuticals etc.), and management as an asset acquires a certain specificity to other assets, as well as to the local environment. Such adaptations of resources give rise to specific complementarities and concomitant difficulties in transferring and trading the resources separately.

Table 4.1 Resource categories of a firm[1)]

Material (Tangible)		Immaterial (Intangible) (IC) [2)]		
Physical capital	Financial capital	Intellectual property[3)] (Disembodied IC)	Good-will and power in internal/external relations[4)] among	Human (embodied) competence[5)] (capital)
Natural resources	Liquid capital	Patents	Employees	Managerial
Raw materials	Bonds	Data-bases	Customers	Technological
Buildings	Shares	Know-how	Suppliers	Commercial
Machinery	Securities	Licenses	Competitors	Financial
Work in progress	etc.	Trade secrets	Universities	Legal
Inventories		Trade names	Investors	Manual
etc.		Designs	Interest organizations	etc.
		Software	Societies	
		Copyrights	etc.	
		Concessions		
		etc.		

Notes:

1) At this level of analysis, concepts such as resource, asset and capital could be used interchangeably.

2) Exactly what IC should encompass is debatable, but it should definitely include IPRs as well as human competence (or capital or capability) and good-will. For simplicity, IC will here be taken to comprise all immaterial or intangible resources or assets, admittedly with some conceptual borderline problems. Thus ”intellectual” is used roughly synonymous with ”immaterial” meaning non-material. (As distinct from insignificant. Unfortunately, the term ”immaterial” in English means both non-material and non-significant.)

Needless to say, there are large problems in valuation of IC. This is a contemporary subject for accounting research. The problems are not insurmountable and there are several approaches being tried to take a fuller account of IC. The traditional balance sheet in double-entry accounting could be extended, of course, but it could also be complemented by separate IC balance sheets, essentially with non-consolidated multiple value concepts. The latter is probably a more viable approach. If nothing else, various balance sheets could be used continually in internal accounting, as well as for valuating the entire firm in connection with an acquisition on the stock market. See further e.g. Kaplan and Norton (1996) and Edvinsson and Malone (1997).

3) Intellectual property comprises exclusive as well as non-exclusive intellectual property rights (IPRs), which could be both registered and unregistered. The firm’s know-how in form of trade secrets (like business ideas and plans) is an important part of unregistered IPRs. Disembodied data bases, organizational routines and ”orgware” (called structural capital in Edvinsson and Malone, 1997) also belong to this category.

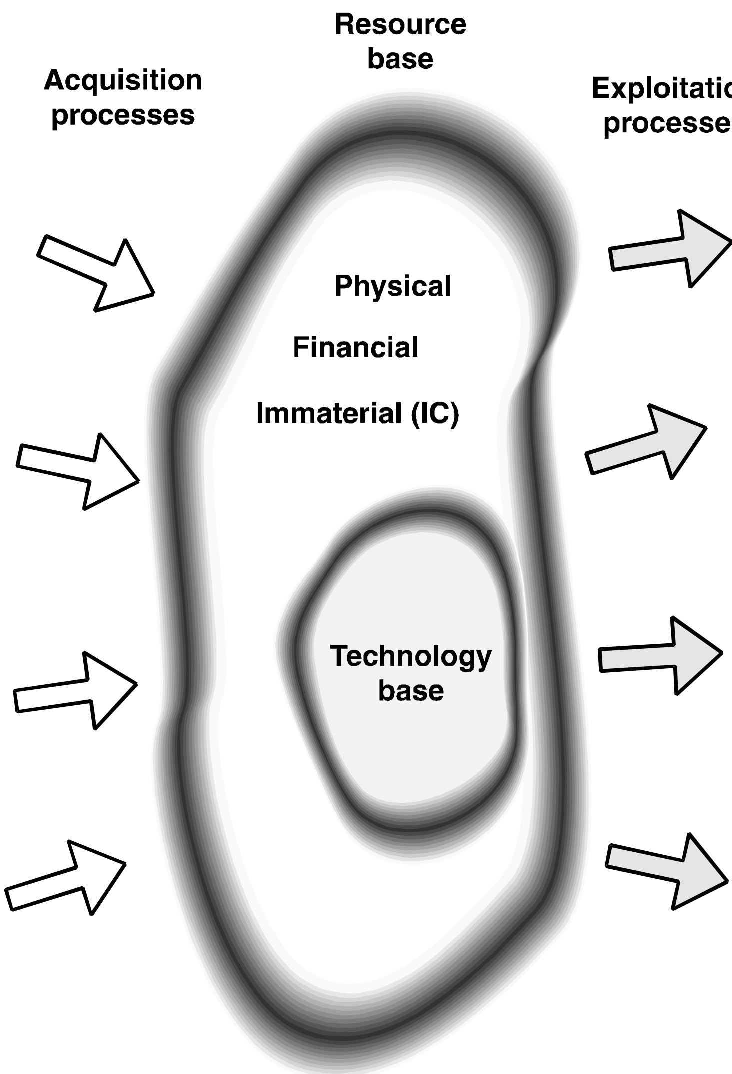
4) It is possible to distinguish the category ”relational capital” (including e.g. trust and internal motivation) as well as ”organizational capital” (or ”capability”) from IC. Here we rather use these categories as sub-categories of IC.

5) Several terms are usable and distinctions could be introduced but, at this level of analysis, terms such as competencies, capabilities, abilities, kills, knowledge, information and so on can be used (roughly) interchangeably. For an overview of such terms, see EC (1997). The original concept of human capital, pioneered by Becker (1993), pertains to individuals. The results produced by the human capital typically become the property of the company when it is disembodied, however. For example, inventions made by R&D personnel and any associated patents may be stipulated in the employment contract to be the company’s property. The embodied human competence is part of the company’s IC, controlled through employment contracts. Thus, it has to be looked upon as rented human capital of IC rather than human capital owned by the company.

4.4.2 Acquisition and exploitation of resources

A firm's resources are continually being acquired, combined and exploited in various ways, as simply illustrated in Figure 4.1. The processes by which resources are acquired and exploited (including processes for generation, combination, transformation, regeneration and recombination of resources) vary widely across companies and sectors, of course, and give rise to variations in economic performance, in turn affecting further acquisition of resources. Resources by themselves, therefore, have different intrinsic economic properties that make their acquisition and exploitation processes different from each other, just as their transformations could be characterized in economic terms in various ways. We will distinguish between four general types of process related economies involved: static and dynamic economies of scale (in the ordinary sense of declining average cost), dynamic economies of scale (in a broad sense of learning and increasing returns), scope (in a broad sense of synergies), speed (advantages of absolute and relative pace of a process) and space (advantages of location). These different types of economies contribute to different extents to a firm's growth, diversification and internationalization.

Figure 4.1 Acquisition and exploitation of a firm's resources



4.4.3 Management as a meta-resource

It is not sufficient to view the firm simply as a set of resources without any reference to the way in which this set came into existence and evolved. In order to get a business firm started operationally (not only legally), there must be some business opportunity in the environment and a business idea in some person's mind of how to exploit this opportunity. The business idea, which may be treated as a piece of IC (e.g. a patent or a trade secret), and the person as an entrepreneur (manager) constitute the initial necessary resources.

Managerial competence is also part of the firm's IC and is a decisive resource for reaping different types of economies for the firm's formation, sustained existence and development. Management[11] acquires, combines and exploits resources in response to business opportunities in the firm's exterior, thereby performing a control function (in a wide sense) in the system. In this sense, management could be viewed as a meta-resource. As such, managerial competence is a unique resource that is not substitutable in its entirety. The use of this resource takes time and is associated with a cost, which we can call management cost.[12] Such a concept of management cost can then be used as an alternative to a transaction cost concept when only two governance structures are used, i.e. governance through markets and governance through hierarchies, and it can be used as a complementary analytical concept in a general case. What makes management so special as a resource is that it is a resource which is of unique decisiveness for any firm, as well as being ”self-sourcing” and ”self-allocating” in some sense. That is, management has to decide by itself (owners apart) how much effort to allocate to different tasks. This decision in turn requires some effort, and thus a theoretically difficult recursive problem of mental economy arises, usually resolved in practice by attending to time limits and corrective action rather than calculation.

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[11] No essential distinction is made at this level of the analysis between management, entrepreneurship, leadership, administration etc. Neither is a distinction made here between ownership and management. Ownership can rather be viewed as management at a higher managerial level, when need arises to make this admittedly important distinction.

[12] The occurrence of managerial evolution, managerial innovations and managerial learning serves to lower this cost, just as new technologies can, e.g. new information and communication technologies.

However, management cannot be viewed as a meta-resource, incurring a resource cost, solely in a traditional, rational economic perspective. Various behavioural characteristics at individual and organizational level have also to be considered, just as is done in transaction cost theory (with bounded rationality and opportunism). To illustrate, an important behavioural characteristic among entrepreneurs can be called their ”entrepreneurial hubris”, which gives them a bias towards overvaluing their IC, i.e. their business idea and managerial competence.[13] This behavioural bias tends to keep the firm together as well as tending, within limits, to develop the firm, giving it more ”animal spirits” and ”sweat equity” in the pursuit of entrepreneurial goals. This type of bias among entrepreneurs, which in this sense is to be regarded as a managerial deficiency (or ”management failure”), increases corporate coherence and sustainability. (Although within limits, often there is too much entrepreneurial hubris, which risks disaster and dissolution of the firm.) Additional influence from any market failure, e.g. regarding market under valuation of knowledge or complementarities, only serves to reinforce corporate coherence. Corporate coherence is thus explainable (at least partly) by reference to market failure or management failure (in the above sense) or both, each factor being in itself a favourable condition in principle for coherence, provided it is suitably biased.

Managerial competence is moreover to be regarded as a bounded, difficult to codify, non-protectable by patents, dynamically evolving, heterogeneous resource, especially in a large corporation with many sub-competencies pertaining to different managerial areas, tasks and functions (marketing management, financial management etc.). Technology management, then, is of particular concern in a TBF.

4.4.4 Knowledge properties in general

Since knowledge (competence, capability) plays a key role as an IC resource, its intrinsic economic properties need to be recognized. This is often done, and there are various ways to characterize these properties, the characterization below being just one. However, it is important

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[13] There are other dimensions of entrepreneurial characteristics of importance for the formation and existence of a firm, such as need for achievement, need for autonomy and need for power.

to make a fairly complete characterization of the properties of economic relevance in order to limit discussion of epistemological issues.

Thus, knowledge (competence) embodied in humans:

1) consumes much time and effort to acquire, especially at the individual level;

2) consumes little time and effort to use, once acquired;

3) improves and accumulates through use without deterioration (knowledge is limitlessly reusable or inexhaustible without wear, implying non-rivalry in consumption, and possibly with negative depreciation), but may deteriorate without use, creating a need for maintenance;

4) is irreversibly transferable to others, if it is suitably codified and adapted to the recipients' knowledge, while still being kept by the knowledge-holder (and possibly even improved through "learning by teaching"). Thus knowledge is cheaply cloned or reproduced if codified;

5) is impossible to be dispossessed of, for an individual, and difficult to dispose of, i.e. to unlearn or scrap. Machines are scrappable, but knowledge is not. Thus, knowledge advances are irreversible.

6) often has strong complementarities with other knowledge;

7) is easily rendered obsolete by new knowledge, appearing over time;

8) is possible for an individual to keep in (almost) perfect control in form of secrecy but control is rapidly lost once secret knowledge is disclosed;

9) is impossible to distribute equally among agents;

10) is generally more expensive to generate than to regenerate or imitate (e.g. knowing that something is possible, or exists, eases the search for it) and the generation of knowledge is uncertain and filled with surprises.

Compared to physical resources (capital), knowledge resources have some fundamentally different properties such as being inexhaustible, irreversibly producable and transferrable (due to their dispossession impossibility) and reusable and reproducible at no or low cost. Economic and legal concepts and 'laws' for physical resources thereby could be expected to apply fundamentally differently for knowledge resources in some respects.

Acquisition and exploitation of knowledge are characterized by a large fixed initial investment cost with a small variable cost in application. The variable cost may even be negative sometimes due to the effect of 'learning by using'. The 'technical' lifetime of knowledge is infinite and, through learning by using, its depreciation is negative as long as it is not rendered obsolete by other knowledge.

Knowledge has strong economies of scale, both static and dynamic, and has increasing returns in use as long as it is not obsolete. Because of the scope of complementarities among its parts, knowledge also often has strong economies of scope. Moreover, it is not time-consuming to use, once acquired, and it is highly mobile if codified (although there may be multiple, incompatible codes). The codification (or disembodiment) process may be time- and effort-consuming, however, and the less the knowledge is codified (into one language), the more time and effort are needed to transfer it among humans.[14] Science and R&D are important in order to improve the codification process, but are by no means the only ways to do so.

Codification is important not only for facilitating transfer of knowledge per se, but also to enable its accumulation. Accumulation takes place within an individual and a group (through use of memories), among humans (through transfer) and between human generations, and results in a

[14] Throughout the text here, both time and effort are emphasized. This is because there are very limited possibilities to make trade-offs between time and efforts (or costs). That is, in learning and teaching you can buy time through increased efforts only up to a point.

common pool or stock of knowledge.[15] This pool may partly be publicly available, and some knowledge may adopt a ”public good” characteristic.[16]

All in all, knowledge has properties that give it a great economic potential as a resource, even uniquely great in some respects. However, there are also properties that strongly limit the exploitation of this economic potential. As is well known, knowledge is difficult to value, price and sell. This is partly because knowledge is highly differentiated, which makes it difficult to match demand with a competitive supply, and partly because knowledge may easily be stolen with little chance of IPR enforcement (cf. Arrow’s information paradox, Arrow 1962). New ideas and knowledge, which may be difficult to partially codify and specify without risking full disclosure, are especially vulnerable to theft and inadvertent diffusion. New ideas and knowledge can be kept perfectly secret by an individual for a ’cost-free eternity’ (torture aside), but then the benefits from learning by using the new knowledge and complementarities from combining it with the knowledge of others are lost.

Thus, the intrinsic properties of knowledge create an economic potential, while at the same time creating limits to knowledge exploitation, especially to exploitation through market exchange mechanisms. This gives a natural rationale for having a system in an economy which stimulates knowledge exploitation without too many negative side-effects and costs. In fact, if a system could be designed that stimulates not only knowledge exploitation but also its acquisition, the system would be doubly effective. This is indeed what the IPR system is intended to accomplish regarding technical knowledge.

[15] The terms ‘pool or stock of knowledge’ are deceptive since they are often used together with the term ‘flow’ which indicates a physical transfer rather than diffusion or cloning of knowledge.

[16] This does not mean it is a free good in the sense that it is ”costless” to acquire and use (see Nelson 1992).

4.5 Technology as a resource

4.5.1 Special properties of technology

Technology is a special kind of knowledge and as such has, in addition to the general properties of knowledge above, special properties, not all of which are shared by other types of knowledge. These properties include:

1) An artefact link, i.e. technology is linked to artefacts (materials, products) or systems of artefacts and to the processes by which they are produced. These artefacts and their production processes are possible to characterize by physical design and performance parameters, which typically evolve over time as their underlying technologies develop. A certain technology may, moreover, be linked to many artefacts, i.e. having a wide applicability or being multi-purpose, just as a certain artefact may be linked to many specific technologies, i.e. being multitechnological.

2) A science link, i.e. technology is linked to natural sciences and their methodologies.

3) A relatively high degree of codifiability, partly stemming from the links to artefacts and the links to natural sciences, through the use of formulae in a formal language (mathematical, chemical, computational etc.), drawings, models, patent documents, textbooks, and a scientifically oriented language. Also the artefacts serve as codifiers of parts of technical knowledge, the embodied technology. However, in certain areas (e.g. new and/or less science-based) there is an important tacit knowledge component as well. The tacit component is not static, since codification is a dynamic process linked to R&D and scientification of technologies. On the other hand, R&D uncovers new technologies with, sometimes, a low degree of initial codification. High codifiability facilitates the specification and transfer of technical knowledge as well as its accumulation.

4) A ”practical purpose” link, i.e. technical knowledge is generated largely with the intention to have something working in practice or to achieve some level of technical performance.

5) Links to common globally oriented systems for its operationalization (specification) and assessment, especially the patent system and the educational system but also systems for standardization, testing, regulation, classification etc.

An implication of these idiosyncrasies of technical knowledge is that it is easier to have a system for registering technical knowledge, due to its higher codifiability and its artefact link. The patent system is such a system, and it also stimulates the codification of technology. At the same time, as its main purpose, it stimulates technology generation, diffusion (cloning) and technology cumulation.[17] The patent system thus reinforces some of the knowledge properties of technology, giving rise to economies of scale, scope and mobility (speed and space) of technology, although at the possible cost of some R&D and output market distortion plus the cost of administering the patent system. Thus there is still another special and unique property of technology, namely that it is:

6) Possible to protect by patent rights.

The heterogeneity of technology must be emphasized, although this property is not unique to technology as a body of knowledge. Technology being heterogeneous means that different fields of technology and types of technology may be identified (not without difficulties) and combined, and that their economic properties typically differ. The economic properties of a specific technology, or combination of technologies, pertain to a) its genericness or degree of applicability; b) its impact on customer utility and/or production cost impacts which are mediated through the corresponding technical performance parameters; c) cost of acquisition; d) its complementarities and/or substitution effects upon other technologies; e) potential for advancement; f) the excludability or appropriability (e.g. through patents) of its related benefits or returns; and g) the state and rate of diffusion on the market.

[17] Sometimes, however, complementarities are not gained since technology exploitation may also be hindered rather than fostered by a fragmentation of IPRs among agents that raise transaction costs to the point of hindering exchange through market transactions. One example of this is the digital audio tape (DAT) technology; another may occur in what is now termed multimedia, in which numerous interests in media, telecom and computing industries converge and conflict.

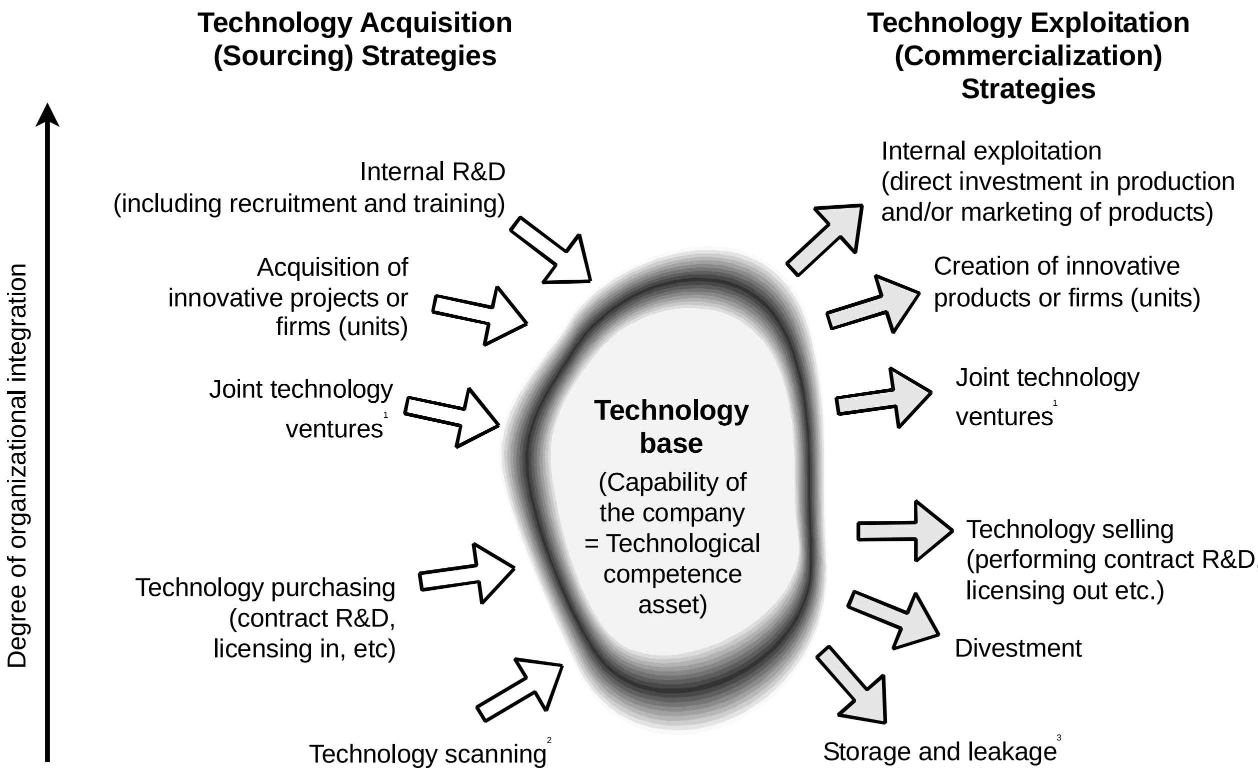
Needless to say, new technologies are dynamically evolving in a cumulative and interactive manner. Technological changes that give rise to innovations, at a closer look, typically involve new combinations of partly old technologies, and partly new technologies, some of which render some other old technologies obsolete. An empirically important phenomenon is the increase in the range of relevant technologies, i.e. technology diversification, at the business level, giving rise to multitechnology products and processes, which in turn gives rise to multitechnology corporations as the typical TBFs. At the same time, fundamental breakthroughs in S&T give rise to generic, multipurpose or multiproduct technologies. Altogether, these two phenomena of multitechnology products and multipurpose technologies create more and more technology/business couplings with associated economies of scale and scope. These economies are potential, however, and must be realized by an active and innovative management.

Finally, it is important to distinguish technology from management. Both technology and management are knowledge resources and as such are bounded, heterogeneous and dynamically evolving and, via their embodiments, both affect the transformation of other resources. However, management primarily has links to human resources, behavioural characteristics and social sciences. Compared to technology, managerial knowledge is less codifiable, more localized and non-protectable by patents.

4.5.2 Acquisition and exploitation of technology

From the point of view of a company, technology as a resource or asset can be acquired and exploited in various ways; see Figure 4.2. This asset or technology base is embedded in the general resource base of the company, as depicted earlier in Figure 4.1. At the same time the firm's technology base is embedded in the collective technical knowledge in the firm's industry and in society in general, as illustrated in Figure 4.3. It should also be noted that acquisition and exploitation of technology using various strategies or modes give rise to corresponding markets. In particular, external acquisition of technology gives rise to technology markets, which is a particular form of IC markets. There are various types of such technology markets, corresponding to company acquisitions, licensing, contracts etc.

Figure 4.2 Generic strategies for acquisition and exploitation of technology



Notes:

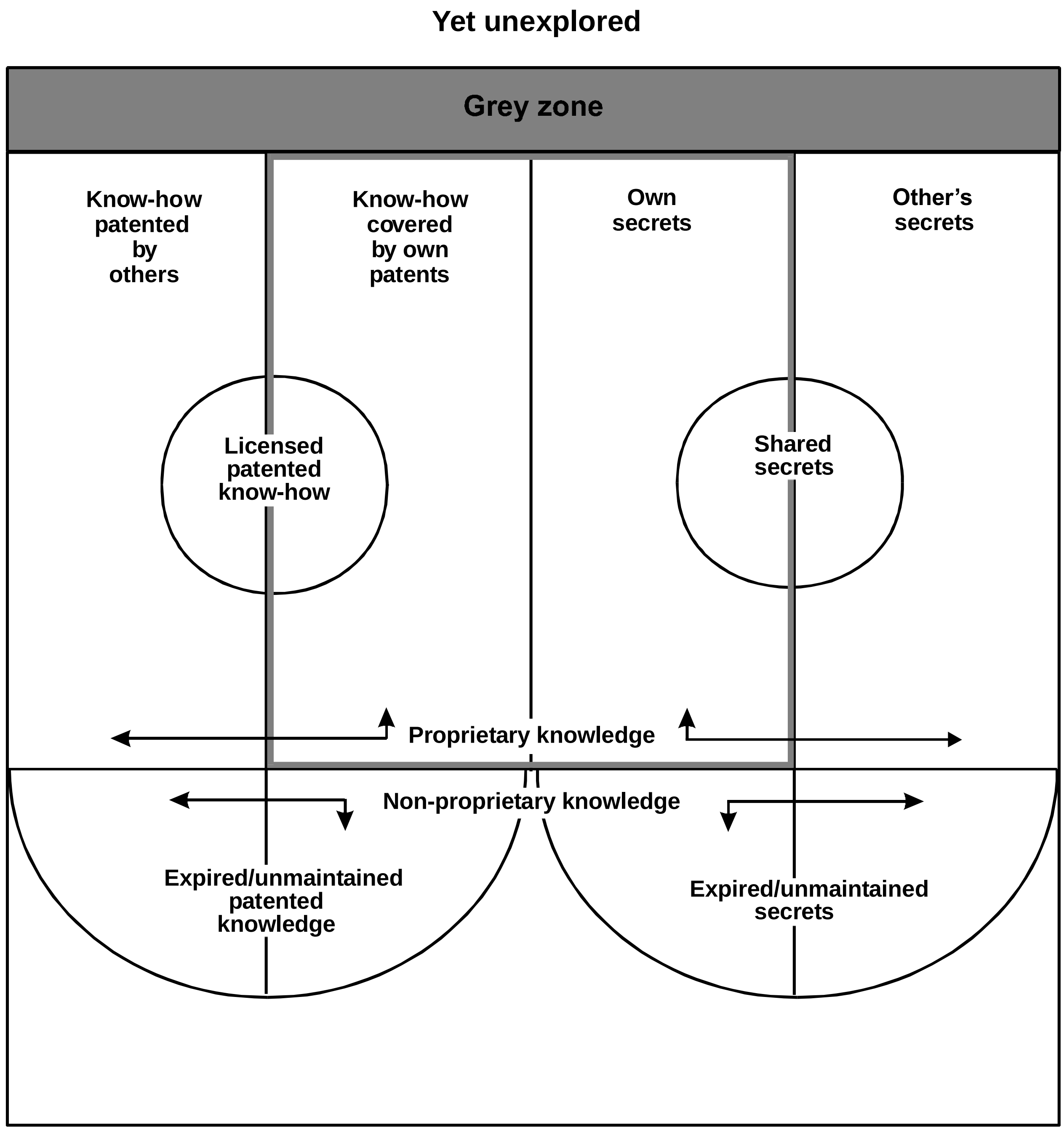
1) Joint technology ventures refer to ventures involving some form of technology related external cooperation in general, for example joint R&D with subcontractors.

2) Scanning includes legal and illegal forms of acquiring technological know-how from the outside without any direct purchasing from its original source.

3) This is not a strategy for exploitation but a kind of residual of unappropriated technology, possibly leaking to competitors through their technology scanning efforts.

Source: Adapted from Granstrand and Sjölander (1990)

Figure 4.3 IPR status in various parts of a new technology or research field



4.6 Diversification

4.6.1 Types of diversification

A firm can be viewed as being composed of one set of businesses (or product/market combinations), constituting its business base, and one set of resources, constituting its resource base. Between these two bases there is a many-to-many correspondence between resources and businesses (with a standard production function as a very special case), subjected to environmental changes and management and organizational behaviour. A firm may engage in two fundamental types of diversification - business diversification, i.e. increasing its range of business types (with product, service and market diversification as special cases), and resource diversification, i.e. increasing its range of resource types (with e.g. technology diversification as a special case).[18] Resource and business diversification corresponds to input and output diversification, from the point of view of the firm as a whole. Note that 'business diversification' here typically refers to business on the firm's output markets, while diversification on the firm's input markets is subsumed under resource diversification. This is an essential distinction in the argument below, saying that the interaction between these two diversification processes is one important source of dynamics in the evolution of the firm.

Each business of a firm has in turn a resource base, and each type of resource may be exploited in several businesses. These links can be summarized in a resource/business matrix (see below), analogous to the product/market matrix commonly used in describing diversification.[19]

As the firm evolves over time, its resource base and business base may shift, with some resources R_i, businesses B_i, and mutual BR-couplings scrapped (or substituted), and some kept

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[18] Such a firm could be labeled multi-business, multi-resource and corresponds to the multiproduct, multifactor firm in neo-classical theory.

[19] In fact, a key contribution by Wernerfelt (1984) was to emphasize the resource perspective in strategy-making, which previously had commonly focused only on product/market diversification (with internationalization as a special case).

(conserved) and some added. See Figures 4.4 and 4.5 for two graphic representations of this phenomenon.

Strictly speaking, the concept of diversification refers to the ”added part” in these shifts. We can then distinguish between the processes of substitution or exit, conservation, and diversification or entry, pertaining to both businesses and resources. Any change in the business base as well as in the resource base then involves some or all of these three processes, which gives a number of possible types. For example, over long periods of time the resource and/or business base may shift entirely and become disjoint from what it originally was. This may particularly happen to raw material-based firms and chemical firms, while invention-based firms in mechanical and electrical engineering sectors rather display ”rooted” diversification, with the original business and product area remaining at least for a long period of time before it is scrapped. Sometimes a stage of resource diversification, driven by ”demand pull” and economies of scope, is followed by a stage of business diversification, driven by ”resource push” and economies of scale, which is then followed by a stage of business and resource scrapping. However, different types of diversification in a firm do not necessarily have to evolve in a stage-wise or sequential manner but can instead be conducted concurrently. Concurrent diversification puts larger demands on managerial resources, though, and sequential diversification has historically been more common.[20]

An innovation typically leads to changes in the resource and/or business base, and to the extent that resources and businesses are kept compared to those that are scrapped and added due to the innovation, the change is gradual rather than radical. Tushman and Andersson (1986) make the distinction between competence-destroying (i.e. scrapping) and competence-enhancing (i.e. adding) technological innovations. Many, if not most, technological innovations shift the competence base (including the technology base) into a new base which overlaps the old one to

[20] Cantwell and Piscitello (1996) argue that, for the largest European and US firms, technological diversification and internationalization of technological activity have historically occurred sequentially, while a new contemporary complementarity between them has been emerging since the 1980s.

some extent. Typically there is then an enhancement (diversification) bias, i.e. with more adding than scrapping of competencies (see Granstrand 1994, Ch. 7). In addition, several technologies in the technology base are usually retained or conserved. Thus, to the extent that technology conservation and diversification dominate over technology substitution, the resulting change becomes more gradual than radical, which is in line with the cumulation and continuity view of the firm.

Generally speaking, then, the size and rate of change in the resource and business base implied by any diversification provide a basis for distinguishing between different types of related and incremental diversification as opposed to unrelated diversification.[21]

[21] This latter type is also referred to as conglomerate diversification. As is well known, most studies show the poor economic performance of such diversification, although it could be argued that perfect capital markets should lead to neither economies nor diseconomies. However, conglomerate or unrelated diversification is in practice related to some extent through the use of common managerial resources. Management failure in the form of managerial or entrepreneurial hubris mentioned earlier can easily come into play, as does the principal agent problem arising from management seeking job security in corporate diversification.

Figure 4.4 Shifts in the resource and business bases over time

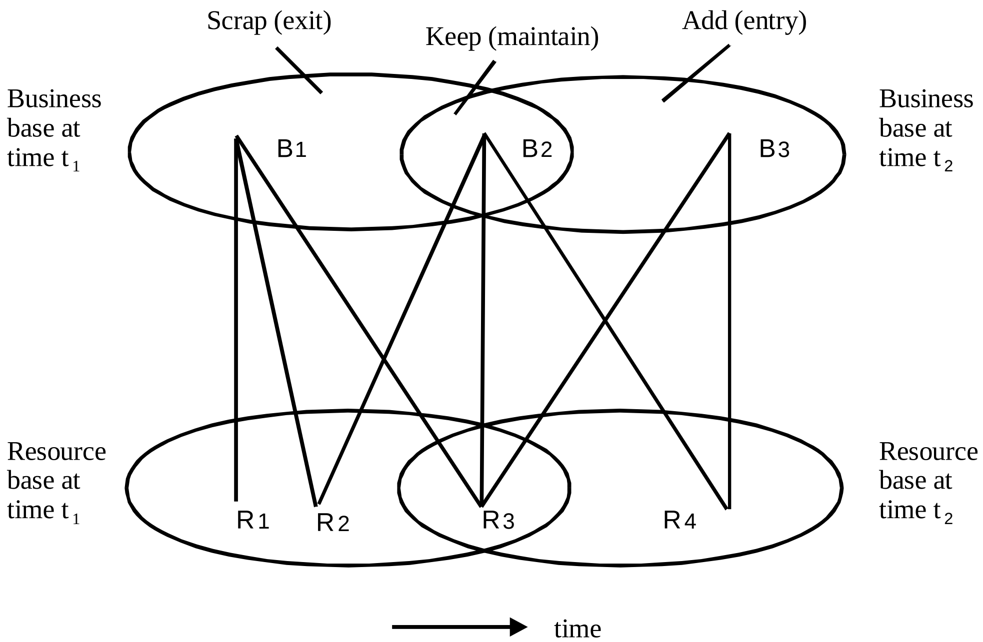
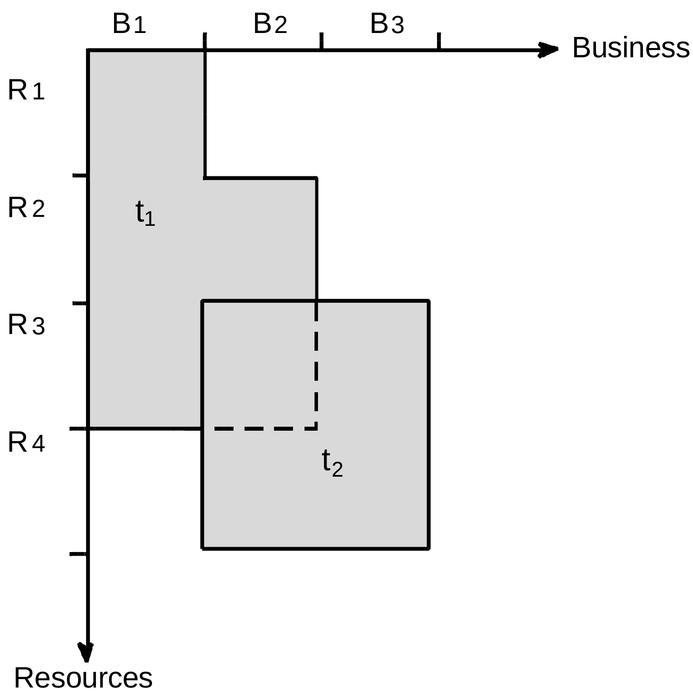


Figure 4.5 Shifts in the resource/business matrix over time



4.6.2 Diversification dynamics

As commonly perceived, a firm derives its dynamic features primarily through interaction with its environment. There are other sources of dynamism as well, which are fairly well recognized. One is management (in a broad sense, including entrepreneurial acts in the organization as a whole) to the extent that it is not entirely adaptive to environmental changes. Another is endogenous innovations, rather than adaptations. However, two additional sources of dynamism need to be recognized as well.

The first is the increasing returns that accrue in the resource acquisition and exploitation processes per se, in particular learning (in a broad sense, including learning in recurrent contracting, leading to reduced transaction costs). The second source is the interaction between resource and business base shifts, diversification in particular. As resources are acquired to support a specific business, some of these resources may have multiple uses with properties that improve the economic prospects of going into a new business, e.g. through the provision of economies of scale and scope.[22] This in turn may require that new resources are acquired as well. Moreover, resources already acquired for a business that are later scrapped may be difficult to dispose of in the market in the short term, possibly leading to sunk fixed costs, which in turn creates an incentive to use surplus resources for business diversification.[23]

A resource may also be lost or scrapped for other reasons (e.g. loss of key people or concessions), leading to the scrapping of a business, thereby possibly releasing other resources with alternative uses and so on. These dynamics in scrapping/keeping/adding businesses and resources with alternative uses are in reality influenced by the firm’s interaction with its environment, of course, but it is important to note that external dynamics is a sufficient (at least in the long run) but not a necessary condition for internal dynamics. That is, a firm could in

[22] This case has been well recognized in literature. Penrose (1959) is definitely a pioneering work, followed by Teece (1982) and Chandler (1990) and others. Normally, reference is made to resource slack, indivisibility and under-utilization.

[23] One example being diversification induced by life (or long) time employment, e.g. in Japan.

principle go on scrapping (substituting) and adding (diversifying) even in a static (let alone stable) environment.[24]

The internal diversification dynamics is driven by the economic properties of resources and their transformation, notably of the four types considered here: economies of scale, scope, speed and space. These economies derive from the physical or intrinsic properties of resources in conjunction with the many-to-many transformation or production (in a wide sense) correspondence between resources and businesses. Different diversification patterns put different requirements on management in reaping the relevant economies involved. Too much unrelated resource and business diversification, as in conglomerate diversification, as well as too much diversification in a short period of time may then overtax management as well as other resources. Commonly observed sequences of corporate evolution such as internationalization (market diversification) followed by resource diversification, spurring subsequent product diversification, can then be explained by dynamically changing mixes of economies of scale, scope, speed and space. Concurrent diversification, e.g. more or less simultaneous internationalization and product diversification, may then be achieved through (1) complementarities, giving rise to economies of scope; (2) resource sharing, giving rise to economies of scale; (3) managerial learning, removing certain diseconomies of scale; (4) a premium on time to certain markets; (5) locational economies (economies of space). Knowledge resources in general and technology in particular have properties, many of which are unique, that form a strong dynamic interaction between the different diversification processes within the firm.

4.6.3 Technology and product diversification

Technology diversification can lead to growth in the technology-based firm, while at the same time leading to growth in the firm's R&D expenditures. Theoretically, in the process of taking

[24] Of course, there are environments that would not allow this to happen, but the point is that, if there are admissible environments, they do not need to be dynamic.

advantage of technological opportunities, technology diversification at the corporate level may lead to increased sales in five different and partly complementary ways.

Static economies of scale

There are static economies of scale to the extent that the same, or close to the same, technologies could be used in several different products with minor adaptation costs. Because exploiting knowledge in various applications is characterized by relatively smaller variable costs per additional application in relation to the fixed cost of acquiring the knowledge, the static economies of scale are significant when a technology has a wide applicability to many different product areas in a corporation. This is the case for generic technologies by definition.

Dynamic economies of scale

Knowledge is not consumed or worn out when applied, but is typically improved by the learning process when applied repeatedly, which allows for dynamic economies of scale.

Cross-fertilization (economies of scope)

Different technologies have a potential to cross-fertilize with other technologies, yielding new inventions, new functionalities and increased product and/or process performances when combined, regardless of whether the technologies in question have a wide applicability to many product areas or not. This cross-fertilization then yields what could be called true economies of scope, which are not the kind of economies of scope that arise from shared inputs, and are considered special cases of economies of scale. This third type of economy, potentially associated with technology diversification, depends on specific technologies which could be combined or integrated. The economics of this type also vary over time, depending upon the intra-technology advancements.

Economies of speed

Combining technologies most often requires some technology transfer, and (under certain conditions) intra-firm technology transfer is faster and more effective than inter-firm, giving rise to speed and timing advantages, that can be labelled as economies of speed.

Economies of space

A technologically diversified company with diversified absorptive capacities can reap economies of space by locating operations in regions with a concentration and high diversity of technologies that yield spill-overs (that is, ”multi-technology” regions).

The growth of R&D expenditures resulting from technology diversification derive from the cost of new technologies plus the cost of overcoming difficulties in combining various technologies. Increasingly expensive R&D needed to support existing businesses thus gives an incentive for technology-related business diversification to economize upon the (quasi-fixed) R&D investments, be it through product diversification or market diversification or both. The relative failure of MPCs vs MNCs observed in literature could then be hypothesized to result from a higher degree of technology-relatedness (implying scale, scope as well as speed economies) in MNCs, everything else being equal. In addition, internationalization may provide locational economies[25] (or ”economies of space”) in relation to R&D. Since diverse S&T activities tend to agglomerate in various regions of the world (Cantwell 1989, 1994) a MTC gains further locational advantages by locating R&D and technology-sourcing activities in such ”multitechnology regions”, as mentioned above.

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[25] This corresponds to the L factor in Dunning’s OLI-paradigm (see e.g. Dunning 1988).

Sceptics of business diversification, of whom there are many, might submit that technology diversification does not necessarily have to lead to technology-related business diversification. The need for technology diversification is largely generated by forces exogenous to the firm. As empirical studies have shown, many firms also grow through technology diversification without engaging in business diversification. However, as R&D expenditures grow through technology diversification, a need arises to recover those expenses through expanding the business base. Many firms have in the past responded to this through market diversification, especially internationalization, thereby becoming MNCs.

Technology-related product diversification

An alternative, sometimes complementary, depending on the limits of managerial capabilities, is to engage in technology-related product diversification and spread R&D costs over several product areas. Compared to internationalization, however, this puts other and seemingly larger demands on management.

Division of R&D labour

Another general response to rising R&D costs in TBFs is the development of markets for technology with increasing division of R&D labour among TBFs. Rising R&D costs, in conjunction with the genericness of new technologies, increase both supply and demand on a technology market. Empirical studies have shown an increase in external sourcing of new technologies in TBFs. More general rationalization of R&D work is also possible, e.g. through cost-reducing innovations in the R&D process itself (e.g. in software development).

Technology-related partnering

Still another possibility for mitigating the rise in R&D costs so common to TBFs is to engage in technology-related partnering, either pure R&D partnering or technology-related business partnering. In fact the growth of partnering among TBFs of all sizes is to a considerable extent motivated by rising R&D costs, influenced by technology diversification. Again technology-related partnering puts special demand on management, general management as well as technology management, but in this case, it relates to management links among several firms, which requires a quite different type of quasi-integrated governance structure.

In summary, the economic properties of technology as a resource create, through technology diversification and technology-related business diversification, an economic potential for the firm. Other physical and intellectual resources may also provide an economic potential in similar ways, of course, but it is argued here that technology has some unique and particularly strong properties in these respects, including the associated tendencies toward costly (and risky) R&D. The fact that physical capital and intellectual capital have some fundamentally differing economic properties is clear, but how then does technology differ from other IC resources? Don't other competencies or knowledge resources provide economies of scale and scope much as technology does? Yes, they do, but as described above, technology has some unique properties which lead to particularly strong economic potentials. For example, it is possible to embody ("productify") technology in artefacts to decrease transactional hazards, and more so than in the case of pure knowledge-based services. The possibilities to codify can be argued to be larger on average for technology than for other competencies, which improves the prospects of accumulation and transfer, which in turn improves the prospects of reaping economies of scale, scope, speed and space.[26]

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[26] The whole issue of codifiability could be elaborated at length, but must be omitted here (see above and also Arrow 1974 and Nelson 1992). Suffice it to say that codification is a dynamic (evolutionary) process, driven partly by R&D (cf. the importance in this respect of contributions by Lavoisier and Mendelejev in chemistry). As a technology

S&T discoveries and inventions (e.g. radio waves, photoconductivity, the laser) have a feature of indivisibility, in the sense that the magnitude with which they are made is far from fully determined by the need for them in a particular situation of resource utilization. This property they share with discoveries in other knowledge areas in general (cf. the discovery of the American continent by explorers and exploiters). Mother Nature simply has a way of revealing herself in bits and pieces, not always proportional to the effort or need of her explorer. The patent system is directed to technology and technical inventions (not science), and by design gives indivisibilities in form of a unique economic potential to technical advances beyond a certain technical (as opposed to economic) size or level of invention. The indivisibilities induced by the patent system yield possible slack and economies of scale. This may, however, be a minor consideration compared to the role of the patent system in providing potential economies for the patent holder relative to competitors, through the temporary, restricted input monopoly protection associated with patent rights.[27, 28]

The role of patents in firms (and economic development in general) is an issue which could be elaborated at great length. Most authors do not regard the role of patents as very important, however. E.g. Chandler (1990) attributes a secondary role to them in firm formation historically. On the other hand, there are not many studies with this focus. At the same time things are changing. A ”pro-patent” era has emerged in the 1980s as IC has become generally more important.

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matures, it becomes more codified - in fact the level of codification could even be taken as a defining characteristic of maturing, until new discoveries challenge the accepted code, thereby temporarily disrupting cumulation (cf. Kuhn 1970, Lakatos and Musgrave 1970, Popper 1968).

[27] If the indivisibilities are small they could be taken to ”convexify”. The number of patents related to a product is often large and also tend to increase with new product generations. At the same time, it may be claimed that the genericness or range of application of many patents increases.

[28] The timing properties induced by the patent system are notable. First, there is a ”winner takes all” race to get a patent granted; second, (single) patent protection expires fully after a fixed time interval.

4.7 The management factor

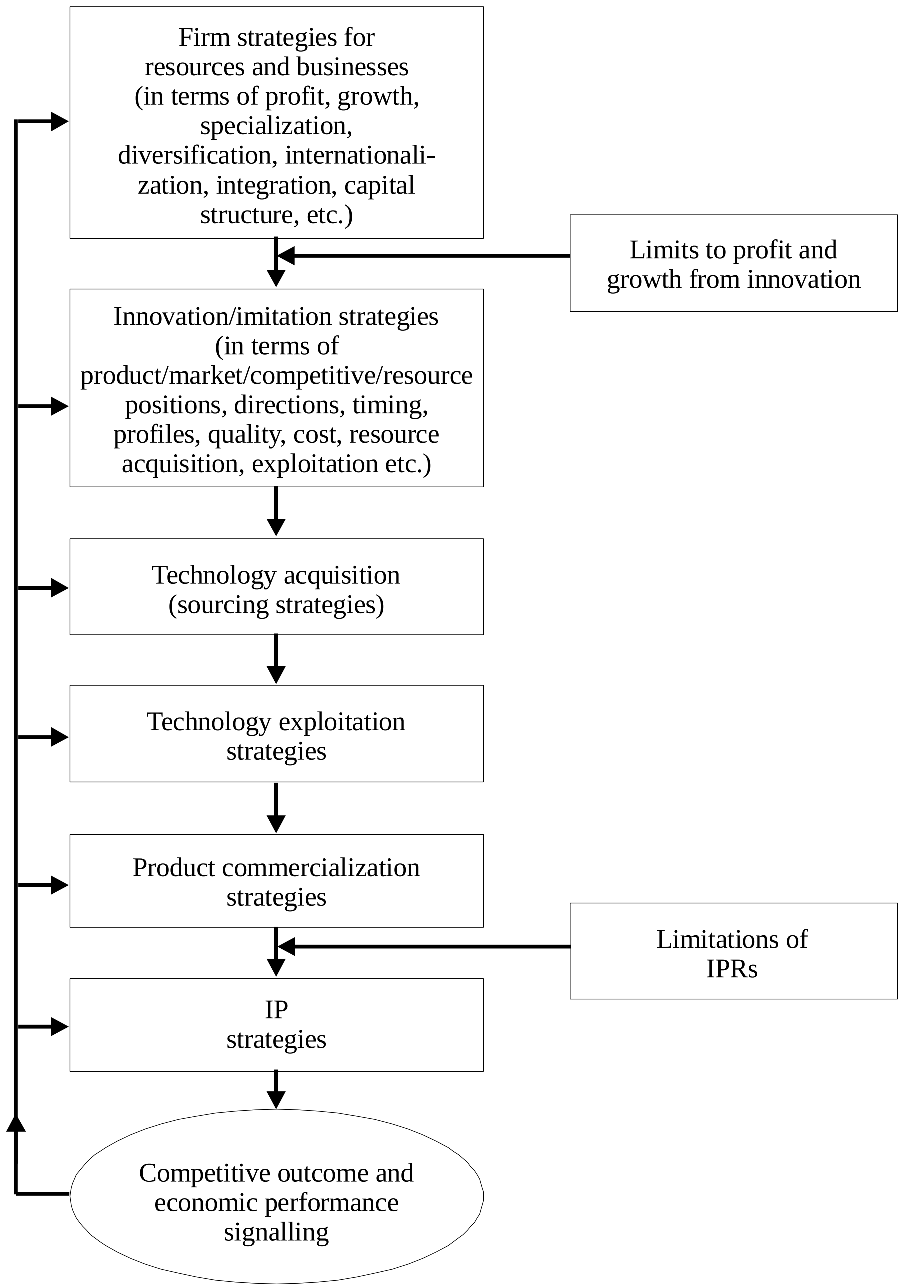
Abstaining from further elaboration here, we may infer that technology has properties of an enormously strong economic potential. Some of these properties are shared with other resources, in particular with other competencies, while some properties are unique. Some properties are intrinsic of technology; some are man-made. The IPR system in particular is part of the institutional setting that by design endows technology with unique economic properties, although it is debatable how strong they are.

However, the general economic potential of technology is not realized automatically, nor are its returns automatically appropriated, not even by a firm which has invested in acquiring it. In order to accomplish that, management (in a broad sense, including organizational capabilities) is a necessary but not sufficient competence. This is not the proper place to elaborate upon how it can be achieved, more than to indicate a few challenges to current managerial thinking based on the analysis above. First, a specialization strategy of ”sticking to the knitting” could be severely criticized on the above grounds (see Granstrand et al. 1992). Second, in order to reap technological economies of scale, scope, speed and space, technology transfer and technology integration are of decisive importance in acquiring and exploiting technology, often with in-house R&D as a dominant mode of acquisition. This challenges to some extent the current approach (at least in the West) that favours one-sided decentralization of R&D and technology management. Moreover, down-sizing middle technology management in that connection may jeopardize critical integrative functions for reaping the economic benefits of technology diversification.

The management factor must explicitly enter into a theory of the technology-based firm and its diversification processes as a variable intermediate between technological and economic changes at the firm level. Management should not only be represented by its embodiment in humans, expressing itself in managerial strategies and performance (of which the yardsticks are much poorer than for technical performance), but should also be represented by a knowledge area, subjected to evolution through learning, accumulation and innovations just as for technological evolution. At the same time, managerial knowledge and practices co-evolve with new technologies (e.g. new computer and communication technologies) with an interplay between technological and managerial innovations. Management serves as an explanatory factor together with the technology factor not only behind the formation, sustained existence and diversification of the technology-based firm, but also behind differences in economic performance of firms (exogenous factors apart). In an even wider perspective the management factor could be seen as a partial explanation of the strength in the co-evolution of S&T and the firm as an institution.

Unfortunately for many economic theorists, management has paradoxically been somewhat of a big, dark box, perhaps even bigger than the black box of technology. An important way to explore this box is to represent the management factor by the formulation and execution of management strategies in a broad sense of target-related controlled courses of organizational action. Strategies can be formulated at various managerial levels for various sets of activities, and needless to say there are many general typologies of strategies. Figure 4.6 gives an overview of some general types of strategies for a TBF. These strategy typologies also serve as a frame of reference for the empirical chapters to follow.

Figure 4.6 Types of strategies for the technology based firm



4.8 Summary and conclusions

The modern firm is a very viable economic institution, drawing strength from several layers of competitive markets, as well as from the development of management capabilities and a powerful co-evolution with science and technology. As a result of this co-evolution, technology-based firms have grown so as to altogether control most of the world's technologies, thereby also increasingly giving rise to proprietary firm based technologies. TBFs are a special but important case of intellectual capital based firms. The IC base of a company can be decomposed into various types of IPRs, inter- and intra firm relational capital and competencies, which can be acquired and exploited on various types of IC markets. The function of management is a defining characteristic of a firm and therefore could be viewed as a meta-resource. For a TBF technology is also a defining characteristic. Technology has a number of specific properties in addition to the general properties of knowledge. In particular, technology is possible to codify and protect by patents.

Through notably strong economies of scale, scope, speed and space associated with the combination of different technologies and other resources, the TBF is subjected to specific dynamics in its growth and diversification and shifts in businesses and resources. In particular, a TBF tends to engage in technology diversification, thereby becoming multi-technological. As such the TBF has incentives to economize on increasingly expensive new technologies by pursuing strategies of internationalization on both input and output markets, technology-related business diversification, external technology sale and sourcing, R&D rationalization and technology-related partnering.

In order to realize the potential economies associated with new technologies, management is crucial. An important function of management is then to formulate and execute strategies at corporate, technology, product and IP levels, for which there are a number of general types and options. These options are explored in subsequent chapters in more empirical detail.