Corporate Innovation Systems

A Comparative Study of Multi-Technology Corporations in Japan, Sweden and the USA

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January 2000

Paper submitted to the Dynacom project

This paper is based in parts (sections 3–6) on research done within the framework of the research program 'Economics and Management of Technology' at the Department of Industrial Management and Economics at Chalmers University of Technology in collaboration with Dr. Sverker Alänge, Prof. Staffan Jacobsson, Prof. Sören Sjölander, Dr. Christer Oskarsson and Tekn.lic Niklas Sjöberg. Sections 7-9 are based in parts on research carried out under the auspices of the Royal Swedish Academy of Engineering Sciences in collaboration with Prof. Jon Sigurdson.

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ABSTRACT

This paper elaborates on the concept of 'corporate innovation system' and examines a number of technology and management issues, judged by industry to be highly prominent, e.g. technology acquisition, technology diversification, internationalization of R&D, IP management and commercialization of new technologies, based on samples of corporations in Japan, Sweden and USA. These issues constitute important features of corporate systems of innovation and form a basis for a comparative analysis. It is shown that external technology acquisition through various strategies increases in importance in general, as does technology diversification. As a result corporations become multi-technological ("mul-tech") and at the same time quasi-integrated corporate systems of innovation arise in which in-house R&D is managed together with a mix of external technology acquisition strategies with various contractual forms. Product case studies further show that external technology acquisition is associated with technology diversification into increasingly costly new technologies, technologies that are increasingly multi-firm led. This in turn spurs the formation of technology markets of various types. Data at corporate level further show a strong impact of technology diversification on R&D expenditures and corporate sales. A breakdown of corporations into strategic groups show that diversified "mul-tech" corporations grow faster than other corporations, while focused corporations had a second best strategy for growth. However, in order to realise growth through diversification it is of vital importance to gear technology management towards reaping economies of scale, scope and speed through coordination, conflict resolution and technology transfer. This presents new challenges to traditional in-house R&D management as well as to policy makers.

In comparing managerial capabilities and other features of corporate innovation systems there are clear nation-specific features, especially Japanese ones. To a considerable extent these have developed during a catch-up stage and could thus be interpreted as stage-specific. Some capabilities are likely to be conducive to innovation in a subsequent stage of forging ahead, while some will be dysfunctional. The paper finally discusses the

prospects for managerial evolution and convergence and the interplay between managerial and technological innovations.

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1 Introduction

1.1 Purpose

The purpose of this paper is to elaborate on the concept of corporate innovation system and then make a comparative study of such systems by examining a number of technology and management issues, judged by industry to be highly prominent. The issues include technology acquisition by various strategies, technology diversification, internationalization of R&D, IP management and commercialization of new technologies. Technology diversification (in contrast to corporate and product diversification) has only recently attracted interest among researchers, and then mostly outside the economic tradition, with early works such as Kodama (1986a,b, 1991), Pavitt (1985) and Pavitt et al. (1989). 'Technology diversification' in this paper is roughly defined as the expansion of a company's or a product's technology base into a broader range of technological areas. Such an expansion does not have to be concomitant with product diversification. Owing to increasing technological complexity and rising R&D costs of new products, the need for technology diversification might even tempt a firm to adopt a strategy (risky perhaps) of increased product specialization, i.e. decreasing its degree of product diversification, combined with increased external acquisition (sourcing) of technology. Technology acquisition and diversification also emphasize partly new responsibilities for technology managers, responsibilities that are normally not much recognized in traditional R&D and innovation management, with its main focus on in-house R&D, sometimes with an additional focus on hi-tech R&D.

The corporations studied are typically operating in many technologies – hence the notion of multi-technology corporation – MTC for short (see Granstrand and Sjölander 1990a for an elaboration on this conecpt). This feature, derived from diversifying into a broader range of technologies, actually shows a close relationship with external technology acquisition and the rise of quasi-integrated corporate systems of innovation, recurrently utilizing a mixture of various technology acquisition strategies. In fact technology diversification, especially into more generic technologies, could be regarded as a major factor behind external technology acquisition in combination with pressure to keep R&D costs and R&D times down. Based on corporate data, the paper also shows a strong impact of technology diversification upon R&D expenditures and corporate sales. However, in order to realize diversification based growth it is crucial to gear technology management towards reaping economies of scale, scope, and speed. Finally, since not very much systematic empirical research has been done yet on issues related to external technology acquisition and technology diversification, the results presented in this paper must be considered tentative and the conclusions treated with caution. For example, it is yet unclear what is the appropriate (optimal) level of diversification. Overdiversification may very well happen as it has done at times before, and studies of other corporate samples or with other observation periods may come up with other conclusions. Still, there is reason to believe that technology diversification is a fundamental variable for the understanding of corporate innovation systems and their development.

1.2 Method

The data reported upon here derives from several studies, including an interview and questionnaire study of 14 Japanese, 12 Swedish and 16 US large corporations. A similar interview and questionnaire study of other European corporations has also been done, but only partially and not reported here due to a low response rate. The general purpose of the project behind this paper was to compare best management practices regarding R&D, technology and innovation in Japan, the USA and Europe and try to assess the nature and role of technology management. Sections 3–6 in this paper is based on 91 interviews with top technology and business executives plus a questionnaire survey with a response rate of about 80%. The companies were selected by a handful of well-informed observers of Swedish, Japanese, and US industry respectively, who named those large, manufacturing companies they considered to be in the forefront regarding technology management. No specific industry selection was made but the companies selected came mainly but not exclusively from electrical and mechanical engineering industries. The firms in this study account for a large part of the entire industrial R&D expenditures in the corresponding countries; 38% for the 16 US companies, 21 % for the 14 Japanese companies and 68 % for the 12 Swedish companies. In addition to the study of corporations, a number of related product case studies are carried out.

Early on in the study (1988) technology acquisition and technology and product diversification was identified by interviewees as being (by then) the most prominent issues in technology management, see Table 3. Internationalisation of R&D was a third prominent issue, which is dealt with in Section 7. IP management was not ranked high enough in 1988 to be included in Table 3 but rapidly rose in importance in the early 1990s due to the emergence of the “pro-patent era” in the USA, which will be dealt with in Section 8 . Sections 7–9 are based on an interview and questionnaire study of 24 Japanese and 23 Swedish large corporations. Section 10 finally is based on a sample of 13 Japanese, 30 European and 14 US large corporations, again accounting for large parts of their nations R&D.

2 Corporate Innovation Systems

2.1 Review of systems concepts

A new and important strand of economics literature in the 1990s adopted an explicit systems approach to the studies of innovations. [1] As a result a number of concepts of innovation related systems were introduced, such as national, sectional and regional innovation systems. However, although mentioned in the literature there has been no focus so far specifically on corporate innovation systems. This is a gap in the literature, especially in light of the indication that companies, and large ones in particular, control a major share of the world's technology (Patel and Pavitt 1995).

The purpose of this section is to review some central concepts of innovation systems in order to define a concept of corporate innovation system (CIS) that is syntactically and semantically compatible with these received concepts. Table 1 gives an overview of some received definitions of innovation systems and related systems. Here is not the place to make a thorough discussion of the concepts but a few observations need to be pointed out.[2]

First, the general notion of a system is that it is composed of a set of components and a set of relations among these components.[3] As such systems are ubiquitous but still the general concept is useful, since it requires the systems components, the systems relationships and the systems boundary (criteria for inclusion and exclusion in the two sets) to be specified. The temptation to what can be called "catchallism" in defining a system is nevertheless there, that is to define a system too broad and/or vague which reduces the analytical usefulness of the concept and invites to circular reasoning. Catchallism is reduced by introducing qualifiers, i.e. subtypes, or specifying sub-systems.

The definitions by Edqvist and Lundvall are somewhat 'catchallistic', with the system being essentially composed of all causal factors of a certain type and their relations, i.e. the causal structure. This is of course feasible and also natural in a quest for a general definition as a starting point. Further qualifications then have the structure 'A B systems', with 'technological' or 'innovation' as B-qualifiers, and 'national' or 'sectoral' as A-qualifiers.[4] The definitions of national system of innovation

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[1] If one can speak of some kind of a breakthrough for the systems approach in innovation studies occurring in the 1990s, it might be due to the surge of studies of innovations in general, the quest for meso-level concepts (like industrial clusters, development blocks, regional complexes), the general appeal of the systems approach as used in engineering and the adoption of the systems approach by key opinion leaders in economics and policy analysis.

[2] For a good and thorough discussion, see Edquist (1997).

[3] More formally a general system is a pair (C, R) where C is a set of components and R is a set of relations defined on C (actually on some set product involving C). Systems analysis is essentially the exercise to characterize C and R. In the so-called state space approach each element of C is characterized by a vector of attributes in a state space.

[4] A number of additional, geographically oriented, A-qualifiers have been proposed, such as regional, local, continental and global, see further Edquist (1997).

are still catchallistic, since they all use the factor ’institutions’ as the components of the innovation system, with a catchallistic definition of ’institution’ (see further Edquist and Johnson 1997).[5]

The Breschi-Malerba definition of sectoral innovation system is on the other hand confined to certain actors, i.e. firms, some of which may not belong to (in an ordinary sense) the sector.

The causal structure is in most definitions made explicit by reference to activities or processes involving the objects innovations or technologies. Examples of terms used are development, diffusion, use, initiation, learning, marketing, mastering, getting into practice, generation, and utilization, and also innovation in itself, seen as a process rather than as a result of a process.

Thus, the syntactic structure of the received definitions of innovation systems is by and large:

A set (network, population) of factors/components/parts/aspects/institutions/firms/agents influencing (affecting, determining) the development/diffusion/use/etc. of innovations/(new) technologies/innovative performance.

[5] Cf. the textbook definition of institution in Table 2. Some authors, notably D. North distinguish between organizations (actors) and institutions, but that distinction does not enter into the definitions of national systems of innovation.

Table 1. Some systems concepts related to innovation

Term	Definition /characterization	Authors /reference	Comments
Innovation system	All important factors that influence the development, diffusion and use of innovations, as well as the relations between these factors.	Edquist (1997, p 14)	An adjustment of the text referred to has been made here in accordance with a later formulation by Edquist in Edquist et al. (1999, p. 5). The concept of innovation is not confined to technological innovations.
National innovation system	The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies	Freeman (1987, p.1)	The actor system is at the core of the definition. The nationality concept is unspecified, although there is a reference to the public sector. Innovations are confined to technological ones. 'New technologies' could be taken in the sense of 'new technology systems' defined in Freeman et al. (1982).
National innovation system	All parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as subsystems in which learning takes place.	Lundvall (1992, p. 12)	Focus on economic causal factors is implied. No explicit confinement to technological innovations, although the examples of subsystems given (incidentally leaving out the R&D system or subsuming it under the production system) indicates that the author has such technological innovations as prime examples. No reference to a nationality concept.
National innovation system	Set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process.	Metcalfe (1992, p. 82)	The definition closely resembles the one by Freeman, except the explicit alignment of the concept to the innovation policy framework of governments, thereby implying a national perspective.

(cont.)

Table 1. Some systems concepts related to innovation (cont.)

Term	Definition /characterization	Authors /reference	Comments
National innovation system	System: A set of institutions whose interactions determine the innovative performance of national firms. Innovation: Encompasses the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, if not to the universe or even to the nation.	Nelson and Rosenberg (1993, p. 4)	A definition of the joint term 'national system of innovation' is not given explicitly. The terms 'innovation', 'system' and 'national' are discussed separately and explicit definitions of 'innovation' and 'system' are given. As can be seen, the nationality of an innovation system is conceptually related to the nationality of firms. On p. 1 the authors make clear that technical innovations are focused in their work.
Sectoral innovation system	The population of firms which are active in the innovative activities of a sector. Such firms are engaged in the generation and utilization of new technologies and they are involved in processes of interaction, cooperation, competition and selection.	Breschi and Malerba (1995, p.2)	The actor system at the core of the systems concept is confined to firms. Technological innovations are primarily in focus. No explicit mentioning of institutions. Systems boundary is defined in sectoral terms. The definition resembles the one by Carlsson and Stankiewics (1991) of technological system in a specific industrial area, interpreted as sector.

Table 2. Some definitions of technological systems

Term	Definition /characterization	Authors /reference	Comments
New technology systems	Clusters of scientific discoveries, technically and socially interrelated families of innovations and the follow-up innovations made during the diffusion period.	Freeman, Clark and Soete (1982, p. 64)	A slight adjustment of the text referred to has been made here. The concept is strongly inspired by a Schumpeterian view of the world. The "family relations", being both technical and social, are not further specified, nor are the systems boundaries. Actors are not included in the system. On p. 201 the authors regard innovations as being new to a country (rather than new to the world), thereby assigning nationalities to otherwise technically similar innovations. The authors' definition of innovation is not confined to technical innovations (as with Schumpeter), although they have them primarily in mind (as had Schumpeter).
Techno-logical system	A network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology.	Carlsson and Stankiewics (1991, p. 111)	This definition focuses on the actor (agent) system (network). The systems boundary is specified in economic and/or industrial terms, which could be national or sectoral. Institutions (other than agents) as well as technologies belong to the systems environment. Thus, this definition includes actors and excludes technology and innovation in the system, while the definition by Freeman et al. does the reverse. The definition of Hughes includes both actors and technologies, plus the 'hard' technical system. In common terminology, as with Freeman (1974), 'technology' refers to a body of knowledge.
Techno-logical system	Systems including technical components, such as hardware and software, and organizational components, such as universities, industrial corporations, government agencies, and consortia made up of these.	Hughes (1994, p. 432)	Typical examples of technological systems Hughes has in mind are large area systems with heterogenous components bound together by a communication or transportation net-work, like electric power, railroad and telecommunications systems. Thus, in such examples there is a distinct technical system of technically related

			hardware components in a traditional engineering sense that is embedded in the technological system.
Economic system	A set of institutions involved in making and implementing economic decisions.	Gardner (1988, p. 4)	This is an economic textbook definition, included here as a contrast. Institution is further defined as “an organization, practice, convention, or custom that is material and persistent in the life and culture of a society” (ibid.). A standard textbook in social psychology has in turn the following definition of culture: ‘culture includes all institutionalized ways and the implicit cultural beliefs, norms, values and premises which underline and govern conduct)’ (Krech et al. 1962, p. 380).

Second, regarding semantics there are some differences in the definitions regarding 'innovation'. Most definitions in general of 'innovation', seen as an outcome of a process, rest in turn on two concepts, a degree of newness of a change and a degree of usefulness or success in application of something new. The concept of 'new' could be taken to mean new to world, new to a nation, new to a sector, or new to a firm, and in this respect several definitions differ. In addition, most definitions explicitly or implicitly refer to technological innovations. Edquist and to some extent Lundvall use a broader concept of innovation, including also organizational or managerial innovations, which in turn is in line with Schumpeter's classic, broad definition of innovation (Edquist 1997, p. 24). The concept of 'technology', which sometimes is taken very broadly, is apparently used more or less in the traditional engineering and industrial sense in the definitions reviewed here.

The qualifier 'national' in itself is not specified by the authors to any extent that could reveal semantic differences. How to assess nationality is not treated as an issue. Nelson and Rosenberg discuss the concept 'national' but rather from the point of view whether it is too broad or narrow to serve as a useful qualifier.[6]

2.2 Corporate innovation system defined

We are now ready to tentatively at least propose the following definition. A 'corporate innovation system' is the set of actors, activities, resources and institutions and the causal interrelations that are in some sense important for the innovative performance of a corporation. Some comments are in order. Different groups of components are specified (actors, activities, resources and institutions) to indicate important subsystems like the actor system within and around the corporation involved in innovation, including R&D labs, R&D cooperative partners etc.; the R&D, production, marketing and outsourcing systems, where R&D, production etc. are activities; the resource structure with the system of technologies (seen as intellectual resources) in particular and the institutional structure (or system or infrastructure). The system of technologies or, in other words, the technological system is then taken in the literal sense in line with Freeman et al. (1982), i.e. as a set of interrelated bodies of technical knowledge, e.g. a set of complimentary or substituting product and process technologies. The technologies may be interrelated conceptually or causally, and in the latter case they are then interdependent.

A technological system in this sense is then distinguished from a technical system, which essentially is a set of physical parts of products or artefacts, i.e. a 'hard' system. The set of actors or agents (typically

[6] Thus it is not clear in their reference to national firms how multinational firms should be treated, which they referred to as an issue for further exploration. Usually, such firms have a single nationality, assigned with reference to location and/or management and control aspects (see e.g. Granstrand 1999b). A similar comment applies to the treatment of multi-product firms in a sectoral innovation system.

firms and other organizations) is referred to as the actor system or industrial system in case of industrial firms, typically then with input/output relations.

The importance criteria is unspecified to leave the concept flexible (in line with Lundvalls requirement, see Edquist 1997 p.8). The term innovative performance is in line with Nelson and Rosenberg's definition. This term is preferred to merely the term 'innovations' since it explicitly focuses on performance, and then primarily economic performance is understood. Merely generating innovations does not ensure economic performance since innovations are commercially successful, at least to some degree, but not necessarily economically successful in a RoI sense.

However, 'innovation' here is taken to mean any creation that is new to the world and useful to some extent, not only technological innovations although these constitute the most important category in general. By corporation, finally, is meant any company (firm, enterprise), not necessarily a large one. A company is often viewed as a system in itself (as in Granstrand 1998). A corporate innovation system then extends beyond the corporation viewed as a system but does not necessarily fully include the latter.

The definition proposed is by and large syntactically and semantically compatible with the ones in Tables 1 and 2. However, corporate systems of innovation are not necessarily sub-systems of national innovation systems or sectoral innovation systems or technological systems since there are multinational as well as multi-product and multi technology firms, as will be discussed in this paper. The significance of such firms in innovation is part of the motivation for introducing the concept of corporate innovation system.

3 Managerial Issues and Perceptions in Japan, Sweden and the USA

3.1 Technology Management Issues

In interviews with top technology managers, these were asked to enumerate the 3 to 5 most prominent technology management issues applying to their corporation. An aggregate selection and ranking was then made by the researchers, independently of each other, based on frequency of mention and emphasis in interviews (which were mostly taped). The results are shown in Table 3. A ranking or 'hit list' of issues like this one is obviously the outcome of a number of subjective judgments. The 'lifetime' of such a ranking is usually short and influenced by voguish thinking so common in management studies and practice. However, as items on top technology management agendas, the individual issues are much more long-lived.

Table 3. The Most Prominent Technology Management Issues in MTC's in Japan, the USA and Sweden 1988 (in rough order of prominence)[a)]

	Japanese MTCs (N=14)	Swedish MTCs (N=12)	US MTCs (N=16)
1.	Diversification	Technology acquisition	Technology acquisition
2.	Technology acquisition	Internationalisation of R&D	Organization and funding of R&D
3.	Internationalisation of R&D	R&D productivity	Government policy
4.	Investments in basic research	Shorter lead-times in product development	Quality and quantity of the labour force
5.	Internal ventures	Quality control	Shorter lead-times in product development

3.2 General environmental trends and important managerial issues[7]

Managerial perceptions are important when discussing and explaining corporate behavior. Perceptual differences reflect to some extent differences in the environments in which technology managers are working. The perceptions of what issues will affect the performance of the management teams, as perceived by technology executives in the questionnaire survey of MTCs, differ substantially between MTCs in the USA, Japan and Sweden, see Table 4.

[7] This section is a revised excerpt from Granstrand and Sjölander (1992b), pp. 184-187.

Table 4. Importance of managerial issues[a] and country differences as perceived by technology executives in MTCs in the USA, Japan and Sweden. N=26[b]

		Country diff.[c] 1988–1992			(Levels of significance)[d]		
		JPN N=11	SWE N=7	USA N=8	U/J	U/S	S/J
1	Keeping pace with new product technologies	2.82	2.33	2.75			.048
2	Fluctuating exchange rates	2.09	1.50	2.00			
3	Levels of exchange rates	2.18	1.50	1.75			
4	Acquiring managerial talent	2.09	2.33	162			
5	Low economic growth	1.27	1.67	1.88			
6	Government intervention	1.27	2.17	2.25	.013		.038
7	Coping with automation & computerization	2.64	1.67	1.88	.010		.019
8	Inflation	1.09	1.83	1.38			.032
9	Availability & cost of labor	2.09	2.00	2.00			
10	New competitors	2.00	1.50	2.38		.032	
11	Acquiring investment capital	1.60	0.67	1.50		.039	.029
12	Availability & cost of materials	2.27	1.50	1.50	.013		.026
13	Labor relations	1.54	1.17	1.88			
14	Trade barriers	2.18	1.17	2.00		.064	.008
15	Environmental pressure groups	1.18	2.33	1.38		.091	.005
16	Demand for shorter working week	1.64	1.33	0.50	.011	.039	
17	Escalating R&D spendings	2.27	1.17	2.12		.047	.006
18	Pressure for shorter innovation lead times	2.54	1.83	2.88		.016	.067
19	Shorter market lifetime of products	2.64	1.67	2.62		.041	.008
20	Pressure for more frequent introduction of new generation of products	2.45	2.00	2.50			
21	Pressure to acquire technology from outside company	2.09	1.17	2.12		.024	.023
22	Pressure for technological protectionism	1.82	0.83	1.88		.016	.035
23	Pressure for scientific protectionism	1.64	0.67	1.50			.033
24	Pressure to acquire technology from abroad	1.73	0.67	2.0		.008	.019
25	Increased complexity (fusion) of technology	2.70	1.67	2.50		.039	.006
26	Increased fusion between science and technologies	2.45	1.00	2.00		.022	.002
27	Demand for higher quality	2.82	3.00	2.88			
28	Level of interest rates	1.00	1.17	1.88		.048	

Scale: 0 = unimportant; 1 = of minor importance; 2 = important; 3 = of major importance

Notes:
a) Principal issues concerning one major product area of each firm.
b) Response rate = 62%.
c) Country averages.
d) Only significance levels below 10% are shown in the table.

Demand for higher quality emerges as the single most important issue. Keeping pace with technological progress also turns out to be of high priority. Issues associated with increased technological competition, such as shorter lead times and market lifetimes and more frequent introductions of new generations of existing products, turn out to be perceived as highly important by MTCs in the USA and Japan but not among managers in Swedish MTCs. Among Swedish MTCs, acquiring managerial talent, the influence of environmental pressure groups, and government intervention are perceived to be highly important for the performance of management teams. These findings are consistent with observations from interviews with these executives. Swedish technology executives seem to be less concerned with and worried by international competition, and to perceive government intervention and external non-industrial issues as much more important, compared with US and Japanese managers.

3.3 Discriminating issues

These country differences are even more evident if we examine the complete set of perceptual data. A stepwise discriminant analysis ($R^2= 0.74$) reveals that seven issues discriminate significantly among the three regions: Demand for shorter working week (16) is seen as much less of a problem among US managers than among Swedish and especially Japanese managers. Pressure for shorter innovation lead times (18) is viewed as an issue of less importance among Swedish managers while US and Japanese managers believe this is an issue of major importance. Pressure to acquire technology from abroad (24), and the pressure for scientific protectionism (23), are perceived as very minor managerial issues among Swedish executives compared with US and Japanese executives. The levels of exchange rates (3) and the availability and cost of materials (12) are seen as much more of a challenge among Japanese managers, while Swedish technology executives experience problems with environmental pressure groups (15).

The Swedish technology executives in the sample perceive the environment as much less competitive and less of a potential performance problem than US and especially Japanese executives. Trade barriers related to goods, science and technology, and problems of international sourcing of technology, are seen as less of a problem among Swedish technology executives than among Japanese and US executives. The interviews support this pattern. One can only speculate about explanations for these differences. The Swedish companies are much more internationalized than their counterparts in the USA and Japan, and hence they have more international experience. Another factor behind this pattern is probably that Swedish companies are much more niche-oriented, and often dominate or are among the dominating firms within their niches, and hence have a better control over their immediate commercial environment. The problem in the longer run with this niche orientation or product specialization might be that the niches will be threatened by substitute products or technologies, which might lead to a lock-in effect.

3.4 Trends in managerial perceptions

A trend analysis of changes in managerial perceptions between two time periods, 1983-87 and 1988-92, reveals expectations for a more challenging environment globally as perceived by managers in the three countries. The following issues have gained significantly (on the 5% level or below) in importance between the two time periods among executives in all three countries: shorter lead times and market lifetimes, increased external acquisition (sourcing) of technology, technological protectionism, increased fusion of technologies, science with technology, and lastly increased demand for higher quality.

For US technology executives shorter innovation lead times, and external and international acquisition of technology are becoming more important.

Demand for higher quality has increased in importance among Swedish executives more than any other issue. Among Swedish technology executives the availability of labor and managerial talent is also perceived to be increasingly important.

Japanese executives experience increased importance of such competitive issues as shorter innovation lead times and market lifetimes, along with technology-related issues, such as external sourcing, technology fusion and fusion of science and technology.

4 Corporate Development Strategies

In this section we will present some results of a survey regarding the importance of different corporate development strategies and technology acquisition strategies, as perceived in the companies in the sample for the 1980s. We have focused on generic corporate development strategies such as profitability, growth, product diversification, internationalisation and R&D investments, plus the taxonomy of generic technology acquisition strategies described in Granstrand and Sjölander (1990a). Table 5 shows the average perceptions for the sample of companies in each country and the level of significance (p) for differences between the years 1982 and 1987.

4.1 Country comparisons 1987

As noted in Table 5 there are 6 pair-wise country differences 1987 that are significant at the 5% level of significance. There are no significant strategy differences between Sweden and the USA, while Japan has several (but not all the same) significant strategy differences in relation to both Sweden and the USA. Internationalisation is the strategy with the highest similarity among the countries.

Some results in Table 5 are well in line with the common opinion that US companies generally are more profit-oriented than companies in the other countries. US companies also put more emphasis on profitability than on growth. The same tendency holds for Swedish firms. Swedish companies tend to put much less emphasis on product diversification than companies in the USA and Japan. These survey results are supported by the findings from our interviews.

However, US companies consider internationalisation of sales as one of the most important corporate development strategies, more important than the Japanese companies in the study. These rather emphasize internationalisation of production and R&D. In line with the move into more innovative R&D and more basic R (cf. Table 3) Japanese companies consider R&D investments as highly important for corporate development, and more so than especially Swedish companies. These results are also supported by the interviews.

4.2 Trends 1982 – 1987

Table 5 indicates that the importance of internationalisation as a strategy increased significantly between 1982 and 1987. Japanese and Swedish companies particular show a significant trend towards greater emphasis on internationalisation of R&D. It is interesting to note that there is no general or country specific trend towards greater emphasis on R&D investments. Finally, the companies in general have become more profit-oriented.

Table 5 Perceived Importance of Corporate Development Strategies 1982 and 1987[a)]

(p = significance level for the difference 1982-1987)
(Scale: 0 1 2 3 4 where 0 = of no importance and 4 = of major importance)

	General			Japan			USA			Sweden		
	82	87	p	82	87	p	82	87	p	82	87	p
	(N = 42)			(N = 14)			(N = 16)			(N = 12)		
Profit-ability	3.2	3.7	0.03	3.0	3.5[a]	0.17	3.5	4.0[a]	0.17	2.9	3.4	0.18
Growth	3.1	3.2	0.62	3.4	3.6[ab]	0.40	3.2	3.1[a]	0.83	2.6	2.7b	0.69
Product diversi-fication	2.8	2.5	0.21	2.9	2.9[b]	0.98	2.8	2.5	0.32	2.6	1.7	0.18
Internat. of sales	3.0	3.3	0.12	3.3	3.1[a]	0.41	2.9	3.6[a]	0.04	2.9	3.1	0.52
Internat. of produc-tion	2.4	2.9	0.05	2.4	3.1	0.13	2.6	2.7	0.84	2.1	3.0	0.09
Internat. of R&D	1.6	2.6	0.00	1.7	2.7	0.00	1.5	2.4	0.07	1.4	2.9	0.00
Investments in R&D	3.1	3.2	0.75	3.2	3.5	0.38	3.2	3.1	0.62	2.6	2.7	0.79

Notes:
a) Significant difference between Japan and the USA 1987 at 5% level
b) Significant difference between Japan and Sweden 1987 at 5% level

5

Technology Acquisition Strategies

5.1 Country comparisons

A first important observation is that there were no significant (at 5% level) country differences between the perceived importance of various technology acquisition strategies among companies in different countries, as shown in Table 6b. There is an indication, not very significant however, that Swedish companies possibly rely less on internal R&D in building up their technology base than do companies in the USA and Japan. Located in a small country, Swedish companies have a long tradition of international acquisition of technology, going back to the foundation of the large Swedish multinationals (cf. Gustavson 1986). In some Swedish companies it is a major strategic issue whether they are becoming too dependent on external technology acquisition. In the electronics industry, as an example, one company reported (in the interviews) that only 20-30% of their total cost of technology acquisition was associated with internal (in-house) R&D, while 70-80% was associated with external acquisition. Another indication, however, not significant at 5% level, is that the joint venture strategy was perceived to be of greater importance among US and Japanese companies than among companies in Sweden. In this case, however, there was no complementary support in the interviews.

A crucial issue for the management in large corporations is further how to allocate R&D resources. Careful consideration is needed to find a balance between centralised and decentralised R&D as well as between domestic R&D and R&D abroad.

The share of R&D centralized at corporate level was 40% for the Japanese corporations, while 8% for the Swedish and 21% for the USA. The country differences between Japan and Sweden was significant at 1% level, while the difference between Japan and the USA was significant at 10% level.

Thus, R&D is decentralised into various divisions and business units to a much larger extent in Swedish companies than in US companies and especially in Japanese companies. R&D in Japanese companies was internationalised to a much lower degree than in US and Swedish companies. Swedish companies perform R&D abroad to a very high extent in international comparison (see further section 7 on this).

A most crucial issue for technology management regards the quality of R&D personnel. The quality of R&D personnel is to some extent indicated by their level of formal education. Formal education sets certain limits for the R&D function, e.g. regarding its capability to access and absorb new technologies. Table 6a shows that a lower percentage of R&D personnel among Swedish companies holds a master degree than in US companies and especially compared with Japanese companies (1987). Among the Swedish companies in the sample, a significantly higher proportion of the R&D personnel does not hold any university degree compared with Japanese and US companies. PhDs are more common in US than in Swedish and Japanese companies.

Table 6a Formal Education of R&D Personnel 1987 (average percentage)

	Japan (N=14)	Sweden (N=12)	USA (N=16)
PhD	4[a)]	6	14
Master/ Bachelor	69[c)]	41[b)c)]	59[b)]
No university degree	27[c)]	53[b)c)]	27[b)]
Total	100	100	100

a) The Japan-US difference significant at 3% level.
b) The Sweden-US difference significant at 1% level.
c) The Japan-Sweden difference significant at 1% level.

5.2 Trends 1982 – 1987

Table 6b shows that internal R&D is still considered to be the most important source of technology for the companies, regardless of nationality. In general there is an increase in perceived importance of all strategies for external technology acquisition, except for purchase of licenses.

Technology scanning is perceived to be the second most important technology acquisition strategy in the total sample as well as in all country samples and has moreover grown significantly in importance. This is in turn connected to a growth in the use of patent information for technology and competitor scanning purposes (see below). The joint venture strategy has increased in importance in general and especially among the companies in the USA and Japan (see also Mowery 1992).

It is finally worth noting that 9 out of the 16 US companies in the interviews emphasised the importance of having a Japanese link, or a ’window’ in Japan. Through this ’window’ they have been able not only to gather information about Japanese competitors and technology but also in some instances it was used to acquire organisational capabilities related to the product development process and to manufacturing.

Table 6b. Perceived Importance of Technology Acquisition Strategies 1982 and 1987[a)]

(p = significance level for the difference 1982-87)

(Scale: 0 1 2 3 4 where 0 = of no importance and 4 = of major importance)

	General			Japan			USA			Sweden		
	82	87	p	82	87	p	82	87	p	82	87	p
	(N = 42)			(N = 14)			(N = 16)			(N = 12)		
Internal R&D	3.7	3.6	0.75	3.8	3.6	0.45	3.8	3.8	0.79	3.4	3.0	0.33
Acquis.of innov. firms	1.7	2.3	0.03	1.2	2.0	0.15	2.1	2.4	0.42	1.7	2.3	0.19
Joint ventures	1.9	2.7	0.00	2.1	2.9	0.03	1.8	2.8	0.01	1.7	2.1	0.29
Contract R&D	1.7	2.3	0.02	2.2	2.6	0.32	1.4	2.0	0.13	1.7	2.4	0.07
Purchase of licenses	1.9	2.1	0.24	2.3	2.3	1.00	1.6	2.1	0.14	1.9	2.0	0.73
Technology scanning	2.7	3.2	0.03	2.9	3.3	0.27	2.8	3.2	0.24	2.1	2.7	0.17
T-EXTA	6.2	7.7	0.00	7.1	8.3	0.12	6.1	7.7	0.04	5.4	7.0	0.06
T-EXTB	5.3	6.6	0.00	5.9	7.1	0.12	5.4	6.8	0.03	4.6	5.9	0.03

Note:

a) The various strategies have been selected in order to represent a falling order of organisational integration, or equivalently in increasing order of degree of external acquisition (sourcing), based on contractual considerations as elaborated in Granstrand et al. (1992b). Assuming, admittedly boldly, equi-distant strategies on a 0-1 scale of degree of external acquisition gives a cardinal scale. The degrees of the different strategies on this scale have been used as weights for weighing the different perceptions together into aggregate indices T-EXT of each company's degree of external technology acquisition, as described in the text. For the purpose of sensitivity analysis, two indices have been calculated – T-EXTA for the six strategies in the table considered as separate equi-distant categories and T-EXTB for five separate equi-distant categories, where the strategies contract R&D and purchase of licenses have been lumped together, since they have a similar degree of organisational integration.

5.3

Externalization of technology acquisition and use of technology markets

The strategies in Table 6b have been ranked in increasing order of externalisation (or falling order of organisational integration). The strategies and their corresponding contracts also correspond to different types of technology markets, except for technology scanning. For further analysis it is desirable to go beyond an ordinal ranking of the various technology acquisition strategies and try to measure on a metric scale the degree to which technology is acquired externally through technology market transactions or otherwise. A first idea that comes to mind (somewhat in the spirit of Professor Mansfield) is to attempt to assess for each strategy its corresponding percentage of total cost for technology acquisition. Also, it would be attractive to assess for each strategy the percentage of some technology related output (benefit) measure and combine this with the other measurements above. However, this turned out to be extremely difficult to extract systematically for each strategy at corporate level from accounting data and interviews. It was to some extent possible to use this approach using the crude dichotomy internal/external technology acquisition (as done in the product case studies). However, this dichotomy in turn cannot through light on the issue of quasi-integration, that is the use of intermediate contractual forms between hierarchical and market transactions. Besides, even if a percentage break-down could be obtained the percentages still have to be weighed together with weights that reflect the different degrees of organisational integration, in order to arrive at an aggregate metric measure.

Thus we have chosen to use a simple Likert-type scale of perceived importance at corporate level of each strategy and then in a boldly exploratory way assume that the weights for different strategies, reflecting their degree of externalisation of technology acquisition, are equidistant on a zero to one scale of weights, where the weight for internal R&D equals zero and the weight for technology scanning equals one. The equidistance assumption could be justified to some degree by viewing it as a first approximation, based on a kind of "principle of indifference". Note that the degree of externalisation is the reverse of degree of integration, which would have the weight for internal R&D equal to one and the weight for technology scanning equal to zero and the intermediate quasi-integrated forms dispersed in between. Obviously, sensitivity analysis is required, and we have in this paper used the following two indices for the degree of externalisation of technology acquisition, where PI(X) is the perceived importance of strategy X:

T-EXTA = 1.0 PI (Techn.scanning) + 0.8 x PI (Purch. of lic.) + 0.6 x PI (Contract R&D) + 0.4 PI (Joint ventures) + 0.2 x PI (Acq. of innovative firms)

T-EXTB = 1.0 PI (Techn. scanning) + 0.75 (1/2 x PI (Purch. of lic.) + 1/2 x PI (Contract R&D)) + 0.5 PI (Joint ventures + 0.25 PI (Acq. of innovative firms)

Thus the two indices differ in that purchase of license and contract R&D have been split up, respectively lumped together. This is due to the uncertainty about the difference in degree of integration for these two strategies, that are using traditional technology market strategies.

Using the T-EXT indices for weighing all strategies together, Table 6b further shows that the degree to which technology is acquired externally has increased significantly in general, and for the USA and Sweden in particular. Japanese companies have a similar but not significant increase, but they have a higher degree of external technology acquisition and use of technology markets than US and Swedish companies for both 1982 and 1987. However, no country differences were significant at 5% level.

Finally, the TEXT-indices were positively (but significantly only at 12% level) correlated with importance of internal R&D, indicating a weak complementary. On the other hand the TEXT-indices were positively correlated and significantly so with the importance of the corporate development strategies: growth, product diversification and R&D investments. A regression showed that technology externalisation was primarily explained by strategic emphasis on R&D investments while product diversification and growth only added about 5% to the explained variance. However, we are hesitant to stretch the quantitative analysis very far in this direction.

5.4 Follow-up study

In a follow-up questionnaire study of Japanese and Swedish corporations in the 1990s the same question about importance of various technology acquisition strategies (adding a university collaboration strategy) was asked to an extended sample of 24 Japanese and 23 Swedish large corporations, allowing a sectoral break-down. The results are shown in Table 7, and shows that:

1. Although in-house R&D definitely remained the main strategy regardless of country and sector, external technology sourcing or acquisition by various strategies was increasingly important and was seen as somewhat more important in Japan than in Sweden. Among the Japanese corporations, collaborative R&D and technology scanning was especially important on average.
2. University collaboration grew rapidly in importance for both Japanese and Swedish corporations. However, while the Swedish corporations by far preferred collaborations with domestic universities, the Japanese corporations regardless of sector preferred US universities, followed by Japanese universities. At a significantly lower level, Japanese corporations regarded various European universities as important but still at a significantly higher level compared to how Swedish corporations emphasized European universities.

To a considerable extent, external technology has come from foreign sources. Technology scanning has always had an international outlook. International technology licensing has a long history and international joint ventures and other forms of cooperative R&D has grown rapidly in recent decades (Mowery 1992). Less is known about how corporations view collaborations with universities at home and abroad. As Table 7a shows, Japanese corporations put the importance of collaborations with US universities next to in-house R&D, regardless of sector (although especially pronounced in chemical and mechanical corporations). Collaborations with their domestic universities had during 1987–1992 fallen behind US universities in importance (especially in chemicals, as perceived in 1992. Although this study only provides perceptual data as opposed to factual data on the foreign share of university collaborations in Japanese industry, it can be expected that this foreign share is quite high and increasing. Moreover, the country dispersion of importance attached to foreign university collaborations in Japanese corporations does not indicate any impact of psychic distance, related to cultural differences. Psychic distance has traditionally influenced the process of internationalization of various operations in many Western firms since it affects important cost component.[8] Table 7b shows that the choice of countries is consistent with the assumption that psychic distance has influenced the industry-university collaborations in the Swedish corporations. The dominant emphasis on domestic universities is one indication, but also the emphasis on UK and US universities among foreign ones. (Most Swedish MNCs have English as their corporate language and after World War II there has also been a certain cultural orientation in Swedish industry towards Anglo-Saxon countries.). Needless to say, the country dispersion of university-industry collaborations are also influenced by their benefits, in turn depending upon the quality and specializations of different universities and how these contribute to S&T advances relevant and valuable to the corporations.

[8] See e.g. Håkansson (1992, p. 109).

Table 7a. Perceived importance of technology acquisition stragegies 1987 and 1992.
(a) Japanese large corporations

Strategy[a)]	Chemical (n=9)	Electrical (n=10)	Mechanical (n=5)	Total (n=24)
In house R&D 1992	3.89	3.70	3.80	3.79
Growth ratio 1992/1987	0.97	0.98	0.95	0.97
Acquisition of innovative companies (or business units) 1992	1.88	1.40	2.40	1.78
Growth ratio 1992/1987	1.57	1.19	1.33	1.38
Joint venture and other forms of cooperative R&D, e.g. with subcontractors 1992	2.89	2.40	2.80	2.67
Growth ratio 1992/1987	1.26	1.42	1.07	1.27
Purchasing of licenses 1992	2.75	1.90	2.40	2.30
Growth ratio 1992/1987	1.13	1.04	1.10	1.09
Other forms of technology purchasing, e.g. contract R&D 1992	2.25	1.70	2.20	2.00
Growth ratio 1992/1987	1.06	1.13	1.10	1.10
University collaboration 1992	3.00	2.56	2.00	2.60
Growth ratio 1992/1987	1.26	1.23	1.25	1.25
University collaboration with universities in:				
Japan 1992	2.78	2.56	2.80	2.70
Growth ratio 1992/1987	1.04	1.11	1.20	1.10
USA 1992	3.13	2.67	3.20	2.95
Growth ratio 1992/1987	1.48	1.22	1.27	1.33
Sweden 1992	1.29	1.13	1.20	1.20
Growth ratio 1992/1987	1.00	1.00	1.13	1.03
UK 1992	2.13	1.63	2.00	1.90
Growth ratio 1992/1987	1.54	1.00	1.23	1.31
Germany 1992	1.88	1.75	1.80	1.81
Growth ratio 1992/1987	1.17	1.00	1.10	1.10
France 1992	1.38	1.63	1.20	1.43
Growth ratio 1992/1987	1.00	1.20	1.17	1.10
Rest of Europe 1992	1.00	1.13	1.20	1.10
Growth ratio 1992/1987	1.00	1.00	1.25	1.06
Asia 1992	0.43	1.38	1.20	1.00
Growth ratio 1992/1987	1.00	1.50	1.75	1.40
Technology scanning (incl. monitoring and intelligence) 1992	2.88	2.70	3.00	2.83
Growth ratio 1992/1987	1.04	1.00	1.17	1.05

Note:

[a)] The questions were asked for each variable for the years 1987 and 1992. The table gives the average answer for 1992 and then the average growth ratio 1992/1987, that is the average of the ratios of the answer for 1992 and the answer for 1987.

Table 7b. Perceived importance of technology acquisition stragegies 1987 and 1992. (cont.)
(b) Swedish large corporations

Strategy[a)]	Chemical (n=8)	Electrical (n=3)	Mechanical (n=12)	Total (n=23)
In house R&D 1992	3.63	4.00	3.58	3.65
Growth ratio 1992/1987	1.05	1.00	0.98	1.00
Acquisition of innovative companies (or business units) 1992	1.13	1.33	0.92	1.04
Growth ratio 1992/1987	0.58	0.83	0.95	0.84
Joint venture and other forms of cooperative R&D, e.g. with subcontractors 1992	2.38	2.33	1.83	2.09
Growth ratio 1992/1987	1.38	1.67	1.42	1.45
Purchasing of licenses 1992	1.14	1.33	1.08	1.14
Growth ratio 1992/1987	1.50	1.00	1.50	1.40
Other forms of technology purchasing, e.g. contract R&D 1992	1.75	1.67	2.25	2.00
Growth ratio 1992/1987	1.75	1.00	1.29	1.36
University collaboration 1992	2.17	1.33	2.17	2.00
Growth ratio 1992/1987	1.17	1.33	1.20	1.23
University collaboration with universities in:				
Japan 1992	0.29	0.00	0.67	0.44
Growth ratio 1992/1987	–	–	1.50	1.50
USA 1992	1.00	1.50	1.09	1.10
Growth ratio 1992/1987	1.50	1.50	1.23	1.35
Sweden 1992	2.75	2.00	2.42	2.48
Growth ratio 1992/1987	1.13	1.17	1.06	1.09
UK 1992	1.50	1.50	0.89	1.21
Growth ratio 1992/1987	1.00	1.00	1.00	1.00
Germany 1992	0.50	1.00	1.27	0.95
Growth ratio 1992/1987	–	–	1.00	1.00
France 1992	1.13	0.00	0.89	0.89
Growth ratio 1992/1987	1.00	–	1.00	1.00
Rest of Europe 1992	0.88	1.00	0.67	0.79
Growth ratio 1992/1987	1.00	1.00	1.00	1.00
Asia 1992	0.00	0.00	0.33	0.16
Growth ratio 1992/1987	–	–	1.00	1.00
Technology scanning (incl. monitoring and intelligence) 1992	2.25	2.00	2.42	2.30
Growth ratio 1992/1987	1.60	1.00	1.17	1.25

Note:

a) The questions were asked for each variable for the years 1987 and 1992. The table gives the average answer for 1992 and then the average growth ratio 1992/1987, that is the average of the ratios of the answer for 1992 and the answer for 1987.

An interesting question is whether the degree of external technology acquisition and the choice of strategies is different in different industries and technologies. For example, one may hypothesise (Granstrand 1982, p. 198) that more rapidly changing technologies would lead to higher externalisation (disintegration), especially if the sources of technological advances are outside the industry. The inclination to rely on technology markets for building up technological capabilities is especially strong if there are economies of speed since external technology acquisition tends to be time-saving, and also cost-saving if there is an adequate, competitively priced supply, as indicated in the product case studies (see below).

6 Technology Diversification

6.1 Measuring Technology Diversification

As to the measuring of technology diversification, there is no generally accepted method and a number of options have yet to be explored. Thus we have to elaborate a little on the method used here. In principle, counts of patents, personnel and publications of various types could serve as inputs to a technology diversification index. This index in turn could be constructed similarly to a product diversification index (or its reverse, a concentration or specialisation index), of which there are several options with no superior axiomatisation, see, for example, Nelson et al. (1967), Scherer (1984, p. 236), and Kodama (1986b). In this paper counts of qualified engineers of various types employed by the firm will be used, on the assumptions that a) these people are the prime carriers of the firm's technological competence and that b) in general they work close to their area of professional education. These assumptions are admittedly contestable but may serve as a first approximation. Better approximations could naturally be achieved if different qualities of scientists, engineers, technicians etc., had been distinguished and each employee's know-how and work content had been assessed.[9] In addition to engineer counts, patent analysis has been used here to assess the degree of technology diversification for given product areas. This obviously requires a great deal of technical knowledge, and in-depth interviews have been used in this study.

6.2 Technology Diversification in Japan[10]

The interviews indicated that at least thirty-five of the forty-two companies in the sample had diversified their technology base significantly during the 1980s. The interviews also indicated a significantly higher level of technology diversification in Japanese companies than in Swedish and US companies.

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[9] The validity of engineer counting as a methodology has been elaborated in Jacobsson and Oskarsson (1995).

[10] This section is excerpted from Granstrand et al. (1989).

Some common managerial motives for technology diversification in Japan also appeared in the interviews. First, Japanese companies responded to staggering exports (due to the yen appreciation and trade frictions) by diversifying into more product areas, rather than by internationalising. Thus, product diversification drives technology diversification (and also vice versa). Second, there was a tendency among Japanese companies to go into new areas as a result of a mixture of curiosity, visions (business and technological) and a willingness to learn in a piecemeal fashion without a clear time/cost-bound business plan, and in this way to prepare themselves to grasp opportunities when they came.

Third, there was a bandwagon effect in the sense that Japanese companies tended to converge in their product and technology diversification. There are a few generic technologies, such as information technology, automation technology, biotechnology and materials technology, which attract a large number of companies' R&D efforts. A contributing factor to this pattern is the common belief in Japan in the life cycles of industries and that Japan is under pressure from both horizontal (industrialised countries) and vertical (newly industrialised countries, NICs) forces in international competition and has to move into certain generic technologies that form the technology base for future business. It may also be noted that product diversification may be more or less natural as technological advances open up such possibilities. For example, digitalisation of audio and video signals makes it possible to move more easily between audio, video and computer areas. Technology diversification also leads to an expanding set of opportunities when these technologies are combined or 'fused' into new technological areas (cf. mechatronics, optronics, bioelectronics, biochemistry).

Fourth, there was a consensus among the Japanese companies that, even in cases of no product diversification, companies diversify their technology base to a certain degree and that this degree would increase. One reason behind this is the increasing technological complexity of the products and the related increasing specialisation among qualified scientists and engineers.

In comparison, Swedish and to some extent US companies have undergone a phase of product specialisation simultaneously with technology diversification in the 1980s. This suggests that the companies in the different countries make different trade-offs between economies of scope versus economies of scale. While static as well as dynamic economies of scale (i.e. average and marginal cost reductions from increased production capacity and accumulated production respectively) favour product specialisation, economies of scope favour product diversification, as well as technology diversification, everything else being equal (cf. Teece 1980, 1982).

The question then arises whether Japanese companies are more suited and willing to reap economies of scope in R&D, production and marketing than Western companies. Certainly Japanese companies in the past have paid much attention to economies of scale, and learning-curve effects in particular. But there seems also to be a shift in the 1980s towards putting more emphasis on economies of scope. This may be partly due to technological advances, such as FMS and factory automation which may diminish both static and dynamic economies of scale, and partly due to managerial learning how to manage R&D and multi-technology R&D in particular, taking advantage of specific features of the Japanese corporate society. Our preliminary observations suggest several such features. Without going into any depth here it seems that such features as lifetime (or rather long-time) employment, low inter-firm engineer mobility, high intra-firm engineer mobility, rich communication behaviour, substantial technology management efforts at corporate level, agglomerate economies in the Tokyo and Osaka areas, government interventionism in pre-competitive stages, weak territorial instincts among engineers and several other institutional and culture-bound features, make Japanese companies generally comparatively well suited to reap technology-related economies of scope.

6.3 Technology Diversification at Corporate Level in Sweden

This section analyses the patterns of technology diversification in an extended sample of 21 Swedish companies. The measure used here as a technology diversification index, is equal to (1-H), where H is Herfindahl's concentration index applied to the set of broad engineering categories in the companies.[11] The database used is the roster of the Swedish Association of Graduate Engineers. The database covers 85 per cent of all Swedish Masters of Science. It includes engineers from all Master Programs at Swedish Universities. In 1990 there were nine categories of master of science programs in Sweden: Mining and Metallurgy (B), Electrical Engineering (E), Engineering Physics (F), Chemical Engineering (K), Civil Engineering (V), Mechanical Engineering (M), Computer Engineering (D), Physics and Electricity (Y) and Industrial Management (I). The last three categories of master programs were introduced in the 1970s. To test the sensitivity of our findings by the increase in master of science categories, we modified the number of master categories in a way which is unfavourable for our hypothesis of an increasing degree of technology diversification. We therefore merged the groups Electrical Engineering (E), Computer Engineering (D), Physics and Electricity (Y) into one group and also merged the groups Mechanical Engineering (M) and Industrial Management (I) into one group. Thus, two indexes of technology diversification will appear in the following tables, one unmodified index and one modified index, both showing the degree of technology diversification. The 21 companies accounted for more than 90 percent of the Swedish industrial R&D expenditure in 1987.[12]

The data showed that there was a tendency towards increased technology diversification in 18 out of the 21 companies. Also with the modified index, giving a conservative estimate of increases in technology diversification, there was a tendency towards increased technology diversification in 11 of

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[11] $H = \sum_{i=1}^{m} (n_i/N)^2$, where m is the number of engineering categories, n_i the number of engineers in category i and N the total number of engineers.

[12] The number of engineers allocated to these companies in 1980 was 5,945, which was about 40 per cent of all Swedish masters of science in the corporate sector in 1980. In 1989, 12,052 engineers were allocated to these firms (which is about 37 per cent of all Swedish masters of science in the company sector).

the 21 firms. To shed some further light on the question of which factors can be associated with increased technology diversification, we studied the patterns of R&D expenditure, R&D intensity, sales growth and the change in diversification of the technology base in 16 of the firms.[13] A stepwise multiple regression analysis was performed for all combinations of sales growth, R&D growth and growth in technology diversification for the time periods 1980-1984, 1985-1988 and 1980-1988. The following models turned out to present the most significant and important results:[14]

1) SALESGROWTH 1980-88 = CONST + (TDIVGROWTH 1980-89, R&DINTENSGROWTH 1980-88)
2) SALESGROWTH 1985-88 = CONST + (R&DGROWTH 1980-84, TDIVGROWTH 1980-84)
3) R&DGROWTH 1980-88 = CONST + (TDIVGROWTH 1980-89, SALESGROWTH 1980-88)
4) R&DGROWTH 1985-88 = CONST + (TDIVGROWTH 1980-84, TDIVGROWTH 1985-89, SALESGROWTH 1980-84)
5) TDIVGROWTH 1985-89 = CONST + (R&DGROWTH 1980-84, R&DGROWTH 1985-88, SALESGROWTH 1980-84, SALESGROWTH 1985-88)

The results are presented in Table 8 below.

[13] The number of firms was reduced to 16 because of missing data in three cases and international mergers and acquisitions in two cases; hence comparable figures for 1980 and 1988 were not available.

[14] The following variables were included in the analysis:

(TDIVGROWTH A-B) = The relative growth in technology diversification index (1-H) between years A and B, operationalised as the percentage growth of the technology diversification index between A and B.

(R&DGROWTH A-B) = The relative growth in R&D spending between years A and B, measured as the percentage growth of inflation-adjusted R&D spending between A and B.

(R&DINTENSGROWTH A-B) = The relative growth in R&D intensity between years A and B, operationalised as the percentage growth in inflation-adjusted R&D intensity between A and B.

(SALESGROWTH A-B) = The relative growth in sales between years A and B, operationalized as the percentage growth of inflation-adjusted sales between A and B.

Table 8. Summary of Stepwise Multiple Regressions

Dependent Variable	Variable Entered	Coefficient	Number in	Partial R2	Model R2	Significance (2 tail)
SALESGROWTH 1980-88	TDIVGROWTH 1980-89	1.517	1	0.561	0.561	0.002
	R&DINTENSGROWTH 1980-88	-0.012	2	0.221	0.782	0.032
SALESGROWTH 1985-88	TDIVGROWTH 1980-84	0.508	1	0.516	0.516	0.048
R&D GROWTH 1980-88	TDIVGROWTH 1980-89	0.711	1	0.805	0.805	0.013
R&D GROWTH 1985-88	TDIVGROWTH 1980-84	0.862	1	0.705	0.705	0.022
TDIVGROWTH 1985-89	R&DGROWTH 1985-88	0.423	1	0.350	0.703	0.029
	SALESGROWTH 1985-88	-0.335	2	0.353	0.703	0.048

The results showed that sales growth between 1980 and 1988 was explained by growth in technology diversification (R2=0.561) and a decrease (negative coefficient) in R&D intensity (R2=0.221). Growth in sales and R&D costs in the early 1980s was not associated with growth in technology diversification in the late 1980s. Instead, the result showed that growth in technology diversification in the early 1980s was associated with growth in sales and R&D costs in the late 1980s.

These results indicate that the changing nature of R&D (caused by technology diversification) is associated with increased R&D spending. Hence, the results in Table 8 suggest that increased technology diversification might be a major explanation of the more or less global increase in R&D expenditure in recent years. Further, the results in Table 8 imply that increased technology diversification might be a significant explanatory factor influencing corporate growth in the 1980s in Swedish firms.

Concerning acquisitions and product diversification as possible causes of increased technology diversification, Oskarsson (1990) found that acquisitions and product diversification played no major role for increased technology diversification in these firms between 1980 and 1989. Indeed, average levels and growth rates of both technology diversification and product diversification were all uncorrelated at the 5% significance level.

6.4 Technology Diversification at Product Level

Table 9 summarises the findings regarding technology diversification and technology acquisition for three product areas studied in depth in the Swedish companies. As seen, technology diversification has increased as well as external technology acquisition over different product generations for all three product areas, by various measures. It is also notable that technological coexistence is more predominant than technological substitution, as seen from the larger number of old technologies in a current product generation compared to the number of obsoleted technologies.

The main factors behind the increases in the number of sub-technologies seem to be technological transitions from analogue to digital technologies (in all three cases), a rapid development in man-made materials (all three cases) and the combination of electronics and physics (optronics) in optical fiber systems. The major driving force behind the transitions in all three product cases is dramatically increased technological opportunities that, realised in the products, boost performance (which increases customer utility) and/or decrease the cost of the products. For both cellular phones and telecommunication cables we have seen a very rapid increase in key product performance as well as rapidly increased R&D costs during a short time period – from the end of the 1970s to the end of the 1980s. The performance/price ratios have also increased rapidly and there has been an enormous market growth in the 1980s for both cellular phones and optical fibers.

It is worthwhile to note in passing that some technologies both boost product performance and decrease product cost. That means that the classification from a company's point of view of technologies into product and process technologies so often used conceptually is not empirically always a good dichotomy. Moreover, it might be misleading, if not dangerous, to use this imperfect classification as a basis for formulating R&D and competitive strategies in apparently mutually exclusive categories, e.g. in terms of product R&D versus process R&D or product differentiation versus cost leadership (cf. Porter 1980). Technologies that both affect product performance and cost might then be misjudged and competitiveness might be lost.

Furthermore, the conditions for R&D work have changed. One effect of the technology transitions and the resulting increase in technology diversification and R&D costs found at the product area level is increased external technology acquisition and use of technology markets. In all three product cases, the majority of new technologies were acquired externally, mainly from Japan and the USA. Therefore, despite the increased R&D activity within firms, both as increased width and depth of the technology base, firms still have to externalise their technology acquisition to a significant degree. These may be several reasons for these patterns. First, increased technology diversification naturally demands a larger set of different technological competence. In the product studies, external technology acquisition mainly applied to new (to the firm) technologies that were so technologically complicated that they required a significant, and in some cases very large, amount of R&D efforts – including time – if developed internally. Second, even if the firms had decided to develop all new technologies internally, it would have been a critical problem finding sufficient R&D competence within reasonable time and cost. Third, the supply of externally available technology was stimulated by product specialisation among component supplying firms, many of which were highly specialised suppliers of a single, very complicated technology in the products.

Table 9. Number of Sub-Technologies and Technology Acquisition Patterns for Different Product Generations in
(Source: Interviews as reported in Oskarsson 1990)

Product	Number of important sub-technologies: Old[a)]	New[b)]	Tot	Obsoleted[c)]	R&D costs (index with generation 1=100)	Number of technologies acquired externally[d)]		Main engi cate for I
1. Cellular phones								
- Generation 1 – NMT 450	-	-	5	-	100	0.6	(12%)	E
- Generation 2 – NMT 900	5	5	10	0	200	2.8	(28%)	E,F,
- Generation 3 – GSM	9	5	14	1	500	4.0	(29%)	E,F,
2. Telecommunication cables								
- Generation 1								
– Coaxial cables	-	-	5	-	100	1.5	(30%)	E,K,
- Generation 2								
– Optical cables	4	6	10	1	500	4.7	(47%)	E,F,
3. Refrigerators								
- Current generation	-	-	5[e)]	-	n.a.	0.1	(2%)	n.a.
- Next generation	3	4	7[e)]	2	n.a.	1.7f)	(24%)	n.a.

Notes:
a) No. of technologies that also existed in the preceeding generation.
b) No. of technologies that did not exist in the preceeding generation.
c) No. of technologies in the preceeding generation not existing in the current generation.
d) Average value for the ten largest competitors (per cent of total number of technologies)
e) Estimates by experts.
f) This figure is preliminary.
g) 'Main' meaning more than 15% of total engineer stock. The categories are: Electrical (E), physics (F), chemistry (K), mechan engineering categories respectively.
h) Modified to only six categories of engineers.
i) Number of IPC-classes at 4-digit level.

7 Internationalization of R&D[15]

7.1 Background

As Table 3 shows, internationalization of (in-house) R&D was considered an important issue in Japanese as well as Swedish corporations. Internationalization of R&D and innovation in corporate innovation systems is also a common phenomenon among large corporations in general, and increasingly among small, technology-based firms as well.

However, internationalization of corporate R&D is not a new phenomenon, especially not in Europe. By and large the internationalization of corporate R&D was a marginal phenomenon, however, until almost a century later, when more than just a handful of MNCs started to build up international R&D organizations. In some old MNCs such as Philips (Holland) and SKF (Sweden), some R&D operations had developed in subsidiaries for market and production support already long before World War II. The war then seriously diminished the coordination of foreign subsidiaries in these old European MNCs, which could be seen as an unmanaged step towards multi-domestication. (Their US subsidiaries often became especially independent.)

After the war it became of primary concern in the MNCs to build-up production capability and meet the booming post-war demand in various countries, while R&D for new products and multinational coordination on the whole became a secondary concern. As international competition became more fierce in the 1970s after the post-war demand-led growth of the 1950s and 60s, corporate multinational coordination did become a strategic concern in many MNCs. However, regaining control is costly and recentralization is more demanding than decentralization. A good example is SKF which felt it had to create a fairly large corporate R&D lab in Holland in the early 1970s (away from corporate headquarters in Sweden) as a vehicle for coordinating its domestic and other foreign labs, especially in Europe.[16] Other vehicles for coordination began to be used as well in these old and highly internationalized MNCs, e.g. creating different development centers locally in some subsidiaries and assigning continental or global responsibilities for development work to these centers. This type of local development for global markets, or ”local for global” development, came to substitute, at least partially, for the traditional ”local for local” development and ”central for global” development. These multinational development responsibilities for a certain new product area assigned to a subsidiary could also be transferred to another subsidiary within the MNC, e.g. at a later stage in the innovation

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[15] This section builds on Granstrand (1999b).

[16] See Granstrand and Fernlund (1978).

process (not without conflicts as a rule).[17] Thus, some MNCs in advanced stages of their internationalization, started in the 1960s and 70s to use a kind of multicentred ”local for global” approach to conducting multinational R&D.[18] This approach deviated from a pure, single centre approach with a central R&D lab for corporate-wide R&D, transferring technology forth and back to subsidiaries, the latter being in turn responsible only for ”local for local” development.[19] In recent years attempts towards rationalization and recentralization of overly multicentred and decentralized R&D can be observed in many MNCs.[20]

In contrast to European MNCs, Japanese MNCs internationalized more recently in the post-war period and were able to build up globally coordinated organizations more rapidly, especially during the 1980s. Internationalization of corporate R&D remained marginal, however, but became a top management issue in Japan in the 1980s, as did the issue of build-up of corporate research in general. Industry in Japan increasingly began to rely on indigenous S&T and innovation after having caught up with the West.[21] Access to foreign technology, mostly through technology intelligence and licensing in, had always been a primary concern, with indigenous R&D (mostly D and with much process D) focussing on further improvements. For this it was important to build up domestic R&D under close control and with close links to key production facilities. In the 1980s supply of more basic S&T advances and innovative ideas, through in-house R&D, external R&D cooperation and intelligence became increasingly important. This created a perception of a need to internationalize R&D, although a certain loss thereby of management control and coordination was perceived as a problem.

Thus Japanese MNCs have in general had another process of internationalization than their Western counterparts, especially compared to MNCs from small European countries with a small domestic market.

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[17] Tension and conflicts among subsidiaries in an MNC and between subsidiaries and the parent company are common in multinational R&D. Such conflicts sometimes foster new ideas and products, but probably more often give rise to delays and duplications. A telling case of the latter is ITT's development in the 1970s of the public telephone switch system called System 12, with different European subsidiaries developing their own local for local version (1210, 1220 etc.), which resulted in delays and ultimately in market loss. As one R&D manager at the time expressed it: ”The only thing that unites the ITT subsidiaries in Europe is their common despise of the parent company in the US.”

[18] See Granstrand (1982), pp. 51-52.

[19] For thorough empirical studies of technology transfers in Swedish MNCs, see Zander (1991) and Fors (1996). For further readings (in English) on the history of internationalization of Swedish MNCs, see Carlsson (1979), Granstrand (1982), Håkansson (1981) and especially Zander (1994).

[20] Technological interdependencies, increasing R&D costs and enabling new infocom technologies motivate such attempts, among others. See also Gerybadze and Reger (1997) and Kuemmerle (1997).

[21] See Granstrand el al. (1989, 1991); Sigurdson (1995); Asakawa (1996).

7.2 Method

Data were collected through a questionnaire survey with 24 and 23 responding large corporations in Japan and Sweden respectively, representing chemical, electric and mechanical engineering sectors. (The 23 Swedish corporations were consolidated into 14 for the analysis of factual data, see below). The sample was composed so the largest R&D spenders in each of the three sectors in each country were included, except for the Swedish-Swiss corporation ABB, which was excluded from the survey data since it is bi-national. To some extent the sample was then extended to include pairs of Japanese and Swedish corporations, competing in at least one business area. All in all, the resulting samples of responding corporations by and large include the largest R&D spenders and represent over 50% of total Japanese industrial R&D and around 80% of total Swedish industrial R&D. The respondents have been corporate technology managers and staff. The response rate to the questionnaire survey was 78% for the Japanese corporations, and 86% for the Swedish corporations. Dollar or yen estimates were asked for, and the exchange rate 133 yen per US dollar was used.

Since foreign R&D is skewly distributed in large corporations, some having no foreign R&D at all, any sample average of foreign share of R&D is highly sensitive to the composition of the sample. This should be kept in mind when comparing results from different studies. The samples and sampling criteria may not appear as very different, but the results may differ, depending upon whether, e.g. some corporations with no foreign R&D have been included or not or whether some corporation (like ABB and SKF) with highly internationalized R&D is included or not. Some studies (like Forsgren et al. 1995) have sampled only from large corporations qualifying as MNCs, while this study has sampled from large corporations qualifying as large R&D spenders, which makes a difference since there are a few of the latter (like the state teleservice corporations Telia in Sweden and NTT in Japan) with much R&D but with very little foreign R&D.

7.3 Growth of foreign R&D

Table 8 first shows the domestic/foreign composition of sales, employees and R&D in the two samples. As can be seen from the data, the foreign shares of sales, employees and R&D were larger for the Swedish corporations than the corresponding shares for the Japanese corporations (which were larger on average and had a larger domestic market), regardless of sector. By and large the foreign share of sales, employees and R&D increased from 1987 to 1991. The foreign share of sales, employees and R&D grew faster in Japanese corporations across sectors, except for sales in electrical corporations. Between 1987 and 1991, R&D internationalized faster than employees (except for Japan), which in turn internationalized faster than sales, regardless of country. Especially chemical R&D,

including pharmaceutical R&D, internationalized very fast. Global R&D expenditures grew on average with an annual compounded rate of 11% between 1987 and 1991 for both Japanese and Swedish corporations, while foreign R&D grew on average 48% annually compounded for Japanese corporations and 32% annually compounded for Swedish ones.

Thus, foreign R&D grew significantly between 1987 and 1991 both in absolute numbers and relative to total R&D world-wide in the corporations studied, regardless of country and sector. Since the samples cover a substantial amount of total industrial R&D in Japan and Sweden, it is fair to claim that Japanese and Swedish R&D has become more internationalized in the period studied. This is in contrast to the period 1982 to 1987 for which no significant increase was found for the similar but smaller sample of 14 Japanese and 12 Swedish large corporations reported upon in earlier sections of this paper.

Table 10a. Internationalization of sales and R&D in Japanese large corporations.

Variable[a)]	Chemical (n=9)	Electrical (n=10)	Mechanical (n=5)	Total (n=24)
Sales globally in 1991 (MUSD)	6 341	33 096	30 791	22 582
Growth ratio 1991/1987	1.31	1.43	1.45	1.42
Sales abroad in percent (%) of total sales in 1991(MUSD) [b)]	16	32	46	28
Growth ratio 1991/1987	1.45	1.08	1.09	1.22
Number of employees globally in 1991[c)]	13906	153056	60771	81649
Growth ratio 1991/1987	1.23	1.15	1.03	1.14
Number of employees abroad in % of the total number in 1991[c)]	17	24	21	21
Growth ratio 1991/1987	13.08	1.39	1.75	5.67
R&D expenditures globally in 1991 (MUSD)	255	1 984	1 285	1 190
Growth ratio 1991/1987	1.38	1.56	1.50	1.53
Percentage of R&D conducted abroad in 1987	0.71	1.14	3.40	1.58
Percentage of R&D conducted abroad in 1991	5.57	3.86	5.80	5.00
Growth ratio for B2, i.e. foreign share of R&D 1991/1987	7.85[d)]	3.39	1.71	3.16

Notes:

a) The questions were asked for each variable for the years 1987 and 1991. The table gives the average answer for 1991 and then the average growth ratio 1991/1987, that is the average of the ratios of the answer for 1991 and the answer for 1987.

b) Although all sales data are consolidated, some corporations recorded the percentage of sales abroad based on non-consolidated figures. Assuming that the missing consolidation data are represented by mainly domestic firms, this creates an upward bias on the data. The growth ratio is presumably marginally affected by this bias.

c) Some corporations have reported non-consolidated employee data, although consolidated data were asked for. In general, this creates a downward bias on the number of global employees and an upward bias on the percentage of employees abroad. (The latter assumes that the missing corporate data are represented by mainly domestic firms.) The growth ratios are presumably marginally affected by these biases.

d) The growth ratio for the chemical corporations with the pharmaceutical corporations excluded was 17.3.

Table 10b. Internationalization of sales and R&D in Swedish large corporations.

Variable[a)]	Chemical (n=4)	Electrical (n=2)	Mechanical (n=8)	Total (n=14)
Sales globally in 1991 (MUSD)	3 711	5 771	3 384	3 818
Growth ratio 1991/1987	2.37	1.53	0.95	1.26
Sales abroad in percent (%) of total sales in 1991(MUSD)	80	44	69	68
Growth ratio 1991/1987	1.13	1.13	0.97	1.03
Number of employees globally in 1991	25 625	59 600	26 173	30 791
Growth ratio 1991/1987	1.93	0.99	0.87	1.04
Number of employees abroad in % of the total number in 1991	59	28	56	52[2)]
Growth ratio 1991/1987	1.48	1.17	1.12	1.24
R&D expenditures globally in 1991 (MUSD)	110	604	245	271
Growth ratio 1991/1987	1.83	2.16	1.24	1.53
Percentage of R&D conducted abroad in 1987	3.3	8.5	23.6	15.0
Percentage of R&D conducted abroad in 1991	15.3	17.0	29.1	23.0[3)]
Growth ratio for foreign share of R&D 1991/1987	4.64[4)]	2.00	1.23	1.53

Notes:

a) The questions were asked for each variable for the years 1987 and 1991. The table gives the average answer for 1991 and then the growth ratio 1991/1987, that is the average of the ratios of the answer for 1991 and the answer for 1987.

b) For a sample of 19 of the largest Swedish manufacturing MNCs, Forsgren et al. (1995, p. 483) reported a corresponding figure of 53% for (as it seems) the year 1988.

c) For a sample of 20 large Swedish MNCs Håkansson (1992, p. 98) reports a corresponding figure of 23% in 1988. It should be noted, however, that the distribution of percentages like these is fairly skew, which make averages of them sensitive to the composition of the sample. The sample in this study includes a few large R&D spenders with little foreign R&D, which explains the lower figures here. A later governmental study showed that the 20 largest Swedish corporations in 1995 had an average foreign R&D share of 22% (Swedish National Board for Industrial and Technical Development). Braunerhjelm et al. (1996) reports an average foreign R&D share of 24.7% in 1994 for a sample of around 170 Swedish MNCs having established foreign affiliates.

d) Excluding the pharmaceutical company in the sample, the other chemical companies studied grew from no foreign R&D in 1987 to an average of 14.7% in 1991.

7.4

Driving and inhibiting forces

Now, what are the driving and inhibiting forces behind the increased internationalization of corporate R&D? Table 9 shows the corporations' perceptions of such forces. Although the measurements do not readily permit aggregating and averaging, a few observations can be made. Let us first look at the Japanese situation. Table 11a then shows that:

1. The strongest driving forces were perceived as more important than the strongest inhibiting forces, with generally increasing tendencies, in contrast to the tendencies for the inhibiting forces. This is of course consistent with the actual increase in the internationalization of R&D, which then could be expected to continue to increase.

2. Creating access to foreign S&T was the strongest driving force (and had the strongest tendency to increase further) across sectors. However, it was not a primary motive to create access to a cost-effective supply of R&D personnel, which is a narrower motive (Reddy and Sigurdson 1994 makes a similar observation).

3. The driving forces on the demand side (i.e. to support local production and markets) were still important, although less so among chemical corporations for which foreign acquisitions were a stronger driving force. At the same time, the need to have R&D close to the domestic market was about equally important.

4. The strongest inhibiting factor across sectors was the need for close supervision and control of R&D and thereafter the costs of coordination and communication. These were management-oriented factors.

5. Government policies and regulations appeared not to be very important on average, although more driving than inhibiting, especially among electrical corporations.

6. The risk of leakage was not a strong inhibiting force in any sector.

Turning to the Swedish situation, the picture is quite different. Thus Table 11b shows that:

1. The driving forces did not dominate in the same way as for Japanese corporations.

2. Foreign acquisitions and the need for local market support were the most important driving forces on average, while economies of scale and management-oriented factors were the most inhibiting forces on average. Creating access to foreign S&T was only important among electrical corporations, although the tendency for this factor is strongest across sectors for both Swedish and Japanese corporations. The strongest driving force among chemical corporations was foreign acquisitions.

3. Government policies and regulations had little importance, regardless of sector.

Thus it appears as if Japanese corporations employed a mode of internationalization of R&D with stronger driving forces and more emphasis on supply side factors, while Swedish corporations had more of a balance between driving and inhibiting forces and more emphasis on demand side factors and acquisitions. Government policies didn't play much of a role in both Japanese and Swedish corporations and neither did the risk of leakage. The mode of internationalization of R&D in terms of the mix of driving and inhibiting forces appears to be more nation-specific than sector-specific.

International alliances and mergers is an important feature of contemporary business, a feature which significantly affects the internationalization of R&D. In contrast to Japanese corporations, several large Swedish corporations have engaged in international mergers - the Swedish - Swiss ABB (formed 1987), the Dutch-Swedish Akzo Nobel (formed 1994) and the Swedish-US Pharmacia-Upjohn (formed 1995). [22] These mergers were partly motivated by the need to rationalize R&D in the face of rising R&D costs. However, in the case of ABB, R&D has not been reduced after the merger but has roughly doubled over a 7-year period in the 1990s, amounting to about a 10% annually compounded growth and corresponding to about 8% of total sales. In 1996 the Swedish (=Sweden-located) share of ABB's total R&D costs was approximately 25% (equalling about 33% of the total R&D manhours), and the Swiss share was approximately 26%. One way then to assess the foreign share of ABB's R&D cost is to interpret 'foreign' as 'non-Swedish and non-Swiss', which gives a foreign share of 49%.[23] Similarly the foreign share of Pharmacia-Upjohn's R&D for 1996 was very roughly 20%. Naturally, international mergers will result in an immediate decrease in the foreign share of R&D, when calculated this way, everything else equal. [24] Finally, it could be added here, based on reported experiences outside the survey, that the costs of coordination and communication in R&D in international mergers are substantial when seen over a long time and are easily underestimated. Additional costs may also occur due to stalemates and damages caused by destructive internal competition and conflicts, not at all uncommon in international mergers.

[22] The attempted Swedish-French merger between Volvo and Renault was close to being completed but the merger process was dramatically stopped in the last minute and the alliance broken up in 1994.

[23] For an overview of ABB's R&D organizations, see Sigurdson and Tallwing (1997).

[24] To avoid this kind of discontinuity in the foreign share calculation in case of an international merger, a weighted average calculation is preferable. Since ABB has been excluded from the survey and the other mergers have occurred after the survey, the reported figures in the tables are not affected.

Table 11a. Driving and inhibiting forces behind internationalization of R&D in Japanese large corporations.
(Scale: Of no importance = 0,1, 2, 3, 4 = of major importance.
Within parenthesis future tendency: Decreasing = -1, 0, +1 = increasing)

Question	Chemical (n=9)	Electrical (n=10)	Mechanical (n=5)	Total (n=24)
Driving forces:				
Supporting local production, importance	1.40 (0.60)	2.67 (0.67)	2.60 (0.80)	2.32 (0.68)
Supporting local customers and markets, importance	1.60 (0.40)	2.78 (0.67)	2.00 (0.80)	2.26 (0.63)
Creating access to foreign science and technology, importance	3.20 (0.80)	3.11 (0.89)	3.20 (0.80)	3.16 (0.84)
Creating better access to cost effective supply of R&D personnel, importance	1.60 (0.60)	2.00 (0.33)	1.20 (0.40)	1.68 (0.42)
Local ambitions among subsidiaries, importance	1.60 (0.40)	2.00 (0.38)	1.80 (0.40)	1.83 (0.39)
Local government regulations, importance	1.80 (0.20)	2.00 (0.13)	1.60 (0.60)	1.83 (0.28)
Foreign acquisitions, importance	2.20 (0.00)	1.00 (0.13)	2.00 (0.40)	1.61 (0.17)
Inhibiting forces:				
Need for close supervision and control of R&D, importance	2.83 (-0.14)	2.11 (0.00)	3.40 (-0.20)	2.65 (-0.10)
Risk of leakage of information, importance	1.29 (0.14)	1.33 (0.22)	1.40 (0.20)	1.33 (0.19)
Need to have R&D close to domestic market, importance	2.14 (0.29)	1.89 (-0.22)	2.60 (0.40)	2.14 (0.10)
Economies of scale in R&D, importance	2.14 (0.29)	1.78 (-0.11)	1.80 (-0.25)	1.90 (0.00)
Costs of coordination and communication, importance	2.29 (0.14)	2.00 (-0.22)	2.40 (0.00)	2.19 (-0.05)
Government policies, importance	1.14 (0.29)	0.67 (0.11)	1.00 (-0.20)	0.90 (0.10)

Table 11b. Driving and inhibiting forces behind internationalization of R&D in Swedish large corporations.
(Scale: Of no importance = 0,1, 2, 3, 4 = of major importance.
Within parenthesis future tendency: Decreasing = –1, 0, +1 = increasing)

Question	Chemical (n=8)	Electrical (n=3)	Mechanical (n=12)	Total (n=23)
Driving forces:				
Supporting local production, importance	2.20 (0.25)	0.50 (0.00)	2.00 (0.20)	1.87 (0.18)
Supporting local customers and markets, importance	2.40 (0.00)	3.00 (1.00)	2.13 (0.00)	2.33 (0.18)
Creating access to foreign science and technology, importance	1.50 (0.80)	3.00 (1.00)	1.63 (0.75)	1.75 (0.82)
Creating better access to cost effective supply of R&D personnel, importance	1.33 (0.60)	1.00 (0.50)	1.25 (0.00)	1.25 (0.36)
Local ambitions among subsidiaries, importance	2.60 (0.75)	0.50 (0.00)	1.13 (0.00)	1.53 (0.27)
Local government regulations, importance	1.20 (0.25)	1.00 (0.00)	1.13 (0.20)	1.13 (0.18)
Foreign acquisitions, importance	3.33 (0.50)	3.00 (1.00)	1.50 (0.75)	2.38 (0.67)
Inhibiting forces:				
Need for close supervision and control of R&D, importance	2.00 (0.50)	2.00 (0.00)	2.30 (0.14)	2.16 (0.21)
Risk of leakage of information, importance	1.33 (0.00)	1.33 (0.67)	1.80 (-0.14)	1.58 (0.07)
Need to have R&D close to domestic market, importance	1.33 (0.00)	2.33 (-0.33)	1.30 (-0.17)	1.47 (-0.15)
Economies of scale in R&D, importance	2.67 (1.00)	2.33 (0.00)	2.80 (0.43)	2.68 (0.50)
Costs of coordination and communication, importance	2.50 (0.50)	2.67 (0.00)	2.10 (0.29)	2.32 (0.29)
Government policies, importance	0.67 (0.00)	0.00 (0.00)	1.40 (0.00)	0.95 (0.00)

7.5

National modes of internationalization of R&D

Apart from a faster pace although from lower levels, internationalization of R&D in the Japanese corporations was more supply-led with no indication that the choice of foreign countries was influenced by psychic distance. The high importance attached to collaborations with US universities seems to be a unique feature of Japanese corporations.

The factual as well as perceptual data show more clear differences between Japan and Sweden than between any pair of sectors.[25] Thus, there are indications that there is a Japanese mode of internationalization of R&D, a mode which in some regards is unique.[26] However, there were many similarities as well between Japanese and Swedish large corporations. Some features of internationalization of R&D could very well be more universal than nationally dependent, as well as the possibility of some kind of convergence of nation-specific modes of internationalization of R&D. For example, if – or rather when – English becomes a more or less globally adopted language in S&T as well as in business, the home country language differences will become less important. Similarly, when costs of international communication and management decreases, home country locations will become less important. Costs derivable from psychic distance would then decrease in importance for the internationalization of R&D.

Regarding the role of psychic distance as an explanatory concept for internationalization in general, the whole concept needs to be challenged on both empirical and conceptual grounds. Psychic distance has been found to influence historic patterns of internationalization of sales. production and also R&D. However, the relative strength of the influence has often not been assessed empirically, so other factors could have had stronger explanatory power. Moreover, psychic distance seems to have limited influence on patterns of internationalization at divisional level (Forsgren et al. 1995, p. 486), at the level of research rather than development (Håkansson 1992, p.113) and for R&D in Japanese corporations (this study). The process of denationalization may further decrease the empirical validity of psychic distance, as would improvements in multi-cultural management. Almost all MNCs have a fairly clear nationality (or in a few cases two) in some sense, even in cases where they have been highly internationalized since long ago. Japanese MNCs have a strong national corporate identity, and so have many US MNCs and – perhaps to a lesser extent – many Swedish MNCs. Nevertheless, the national features of most MNCs slowly

[25] The sector variations were larger for Swedish corporations than for Japanese ones. This is difficult to explain based on the data presented here, but it is conceivable that it is due to (1) the relatively long history of advanced internationalization of Swedish MNCs, which has allowed them to differentiate; (2) random company variations in the smaller Swedish sector samples; and (3) the relative homogeneity of Japanese industry.

[26] Studies of internationalization of R&D of other nations also indicate the existence of nation-specific modes, see e.g. Niosi (1997) for a comparison of Canadian and Swedish modes.

fade away, be they features linked to owners, managers or employees or to locations of key functions. However, the nature and pace of this denationalization may differ, depending upon the nationality and sector. The fact that certain nationalities present a stronger ”resistance” to denationalization than others is quite reasonable, while it is less clear that denationalization might be sector-dependent. However, denationalization is fostered by a number of conceivably sector-specific factors, including the relative domestic scarcity of key inputs (such as finance, top managers and key professionals), international mergers, and foreign agglomerations and mobility of sector-specific resources and business opportunities.

On conceptual grounds, the concept of psychic distance can be criticized as compounding different types of costs of communication and coordination, related to geographical as well as cultural differences, in an imprecise and context-specific way. Not only that general cultural differences between countries are many-faceted and vary over time, in the context of internationalization of R&D they are probably of lesser importance than for internationalization of sales and production, and probably of decreasing importance over time.[27] As long as foreign R&D is demand led and more or less a consequence of foreign sales and production this circumstance is disguised, however. Moreover, psychic distance is thought of as an indicator of management costs of communication, coordination and control, being positively correlated with cultural differences. However, cultural differences may also provide benefits, something that was stressed in interviews in several Japanese corporations. R&D people with different cultural backgrounds and styles of thought were perceived as beneficial for creativity and speedier problem solving. Thus, the concept of psychic distance has several deficiencies as an aggregate indicator of costs of managing foreign operations. That does not imply that the different cost components related to geographical distance and cultural differences of various kinds are of minor importance, rather that they should be treated separately.

7.6 Increasingly supply-led internationalization of R&D

What could conceivably explain the emphasis Japanese corporations put on supply side factors as forces driving internationalization of R&D? Is it a feature unique to a Japanese mode of internationalization or is it an indication that internationalization of R&D is in general becoming increasingly supply-led? Some brief arguments for the latter, and thus for

[27] There are in fact indications that sub-cultural differences between different S&T areas may be stronger than cultural differences between different countries. E.g. a Swedish pharmacologist may find it easier to communicate with an Indian pharmacologist than with a Swedish chemist. Thus, one could speak as well of a “technological distance” as influencing the costs of communication. This notwithstanding the S&T community and its common professional culture is likely to be conductive to international communication in R&D work.

the standpoint that Japanese corporations are precursors in this respect, will be given here. Increasing R&D investments and increasing need for companies to diversify into a wider range of new technologies for new product generations are fairly general phenomena.[28] Domestic factor markets for R&D may then become too small, and local excess demand for people trained in certain technologies may more easily arise.[29] Moreover, sources of R&D inputs and new technologies are proliferating on an international scale, although with tendencies to concentrate in certain regions and around certain centers of excellence.[30] Externalities thereby arise, which are localized, especially in new technologies with an important tacit and human embodied component. Together with the need for "speed to technology", these factors give supply-oriented incentives for having a company presence in the region with sufficient absorptive capacities. For this a fairly small (say 3 to 10 people) but high quality unit for R&D and technology intelligence may be adequate. Finally the management cost of running foreign R&D without piggy-backing on marketing and production FDIs, has probably decreased and will decrease, due to managerial learning. Thus, there are several general phenomena that are likely to foster an increased demand for R&D inputs with an increasingly internationalized cost-effective supply, leading to an increasingly supply-led internationalization of corporate R&D, everything else equal.

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[28] See e.g. Granstrand et al. (1992).

[29] Note that the time for a domestic university training system to respond to industry needs is quite long.

[30] See Cantwell (1992) and Dunning (1992).

IP Management[31]

8.1 Background

Japan's industry has an outstanding post-war record of patent growth, abroad (especially in the USA) as well as at home. This is corroborated by data over several indicators, such as patent numbers (number of patent applications and patents granted in Japan, USA, Europe etc. over the last few decades); patent shares (regarding both applications and patents granted); patent intensities (e.g. number of patents per R&D worker or R&D dollar); and patent citations. At the same time the growth of patenting in many countries declined until recent years and in some cases even turned negative (see Griliches 1984).

Japan had already taken the worldwide lead already in 1958 in the number of patent and utility model applications. The dramatic increase in patent application filings in Japan even before the 1980s has to a large extent been attributed to efforts by leading electrical and electronics firms. In the early 1980s, Hitachi, Toshiba, Matsushita, Mitsubishi Electric, NEC and Fujitsu were reported to account for about 25 per cent of all applications filed with JPO (Rahn 1983, p. 485).

In the USA in 1982 a court specialized in – and favorable to – patent legislation was created, the Court of Appeals for the Federal Circuit. Independent of this, but shortly thereafter, a new director of the Antitrust Division in the US government initiated a change in antitrust policy, implying an upgrading of patent rights visavi traditional antitrust concerns. These legal developments were seemingly minor events on the world scene, but nevertheless happened to trigger the emergence of a pro-patent era, subsequently fuelled by political and industrial concern in the USA over its declining international competitiveness, especially visavi Japan, and the free-riding of other nations, especially Japan, upon US investments in new technologies. As a result, the economic value of patents increased, as did the resources and attention devoted to patenting and the amount of patent disputes, the latter escalating at times to what has been popularly called patent wars, especially between the USA and Japan.

8.2 Purpose

This section will describe developments in the organization and management of patent and IP (intellectual property) resources and activities especially in large Japanese corporations. Special attention will be paid to what can be called a patent culture in these corporations. The latter has developed during a long period of time, but was strengthened considerably from the 1980s onwards, through developments in IP organization and management,

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[31] Most of this section builds on Granstrand (1999).

spurred by the outbreak in the 1980s of “patent wars”, notably with large US corporations. Accordingly, IP resources have increased substantially and the IP organization has become upgraded, more centralized, more comprehensive, and more attended to by top management, technology management and business management. It appears as if Japan, partly as a result of the pro-patent era, has developed still another area of management in which Western companies have much to learn.

The quantitative data in this section derives from the same study of 24 Japanese and 23 Swedish large corporations as reported upon in the previous section.[32]

8.3 Volume and width of patenting

Pairs of actually or potentially competing Japanese and Swedish corporations will be compared here. The sole criterion for pairing the corporations is that they have at least one major product area in common, regardless of size of the corporations in terms of sales or R&D budgets. Since the corporations are already large by any standard, and mostly multinational, a common product area is the major factor determining the likelihood that they have met or will meet in the marketplace in Europe and/or the USA. Table 12 gives a comparison of the patent volume and patent width indicators for the pairs of competitors. It is immediately apparent that there is, with a few exceptions, a consistent pattern of larger absolute volume and width of Japanese corporate patenting activities in both Europe and the USA. However, apart from the general caveats and possible sources of statistical errors in using patent statistics, there are a number of additional considerations with regard to possible objections to this type of comparison.

First, Sweden belongs to Europe while Japan does not. To the extent that a company’s propensity to patent on its home market and its neighbouring markets might be expected to be higher than on other markets, European patenting statistics give a positive bias to Swedish companies compared to their Japanese counterparts. From this point of view, US patenting statistics should give a more unbiased comparison between Japanese and Swedish companies. Moreover, the US patent statistics cover all patents in the USA with no specific transient effects as those arising from the start-up of European Patent Office, EPO, in 1978. Moreover, the various ways or routes to receive patents in Europe are not fully covered by EPO statistics.

[32] An interview study of IP organizations and management in 10 large US corporations was conducted in the 1980s, however with little comparable quantitative data.

Table 12. Comparison of corporate patenting activities in Europe and the USA

Corporate pair[1)]	Sector	Sales ratio (1991)	Patent volume ratio EP[2)]	Patent volume ratio US[3)]	Patent width ratio EP[4)]	Patent width ratio US[5)]
Hitachi/ABB	Electrical	5.5	2.2	5.2	1.3	1.4
Toshiba/ABB	Electrical	6.7	2.1	4.2	1.0	1.2
Takeda/Astra	Chemical	2.4	2.8	3.9	1.4	1.7
Sanyo/Electrolux	Mechanical	0.9	0.7	3.3	0.6	1.8
NEC/Ericsson	Electrical	3.7	5.1	9.0	2.6	1.6
Shimizu/Skanska	Construction	2.7	17.2	27.0	10.5	10.7
Nippon Steel/SSAB	Mechanical	11.8	14.8	46.2	3.4	7.5
Nissan/Volvo	Mechanical	3.4	9.1	16.6	2.6	2.6
Toyota/Volvo	Mechanical	4.5	7.8	14.3	2.1	2.6

Notes:

1) The corporations paired have at least one major product area in common.

2) Ratio of number of EPO patents with priority 1977–1989 for the two corporations in the pair.

3) Ratio of number of US patents published 1979-1991.

4) Ratio of number of EPO patent classes with more than one patent with priority 1977–1989.

5) Ratio of number of US patent classes with more than one patent published 1979-1991.

Secondly, a general caveat when comparing Japanese and Swedish patenting statistics concerns differences in the respective patent systems. Until 1987 the Japanese patent system did not allow more than a single claim in a patent application while the European, including the Swedish, patent system allowed multiple claims. In the latter system, companies have had the possibility to file a broad patent application with many claims while the corresponding application in the Japanese system would have to be split up in many applications, one for each claim. Despite the adoption of the multiple-claim system in Japanese patent law, it might be expected that it would take time until the companies adopt the new system in practice. Furthermore, nothing prevents companies from filing single-claim applications, either in Japan or in Europe. Companies could moreover lower their patent filing and maintenance cost through using multiple claims. This is what many Japanese companies often have done when patenting in Europe and the USA. Thus, as a first step the Japanese and Swedish companies can by and large be compared regarding their number of patents in Europe and the USA and increasingly so after 1987.

Still, it may be objected that Japanese company patents in Europe have a more narrow scope on an average than Swedish company patents and, indeed, Western company patents as a whole. Interviews with Japanese and Swedish companies indicate that this has been and still is in fact the case, although the difference might decrease in the future. However, this matter pertains to the quality of patents, apart from the mere quantity.

When discussing quality of patents, several distinctions must be made. First there is the *legal quality* of the application in terms of formulating its wording, supporting it with evidence of novelty and aligning it with the legal framework. Second, there is the *technical quality,* roughly expressible in terms of level of invention. Third, there is the *economic quality* in terms of potential economic value for the rights holder. Unfortunately, the correlation between legal, technical, and economic qualities of patent applications and patents are not strong. Minor technical inventions may have major economic value and vice versa. The common attitude among Western engineers of frowning on minor ”junk patents” or ”petty patents” is often economically questionable from a corporate point of view. Just as questionable is the behaviour, also common among Western engineers, of seeking technically major patents and then neglecting to support them with subsequent patents, minor as well as major. Many companies can certify that it is costly to have an engineering culture that gives priority to technical qualities with little regard to economic values.

Regarding the technical quality of Japanese patents, several studies have shown, based on number of citations, that Japanese patents in general in the 1980s were not inferior. (See e.g. Narin et al. (1992). There were significant sector differences, however. The number of citations of Japanese patents in pharmaceuticals was low while it was high in electronics.

The technical and legal quality of patent applications reflects on their approval rate. There is reason to believe that this approval rate is increasing at least among large, leading companies in Japan. The technical and economic quality of patents is also indicated by the share of commercially exploited patents and share of patents supporting economically successful products, as well as by the maintenance profile (or vintage structure) of the company’s patents, i.e. how long patents are kept in force by the company. Table 13 gives an overview of these indicators.

All in all, there is insufficient reason to believe in consistently low quality levels of Japan’s patents as a dominant explanation behind its large quantity of patents.

Table 13. Quality indicators of Japanese and Swedish patents[1)]

	Share of commercially exploited patents[2)]	Share of patents leading to economic success	Share of patents licensed commer-cially[3)]	Number of years of patents in force	Share of patents kept maximally[4)]
Japanese companies	26.1	14.7	11.3	10.5	16.1
Swedish companies	60.5	38.1	4.9	11.4	21.6

Notes:

1) Estimated by the 24 Japanese and 23 Swedish large corporations in 1992.

2) Through own production.

3) This figure is biased upwards due to block licensing and broad cross-licensing agreements.

4) More detailed data in maintenance profile were collected as well, but are not shown here.

8.4 IP Organization and Management

Traditionally in Western companies, IP matters have not attracted a great deal of resources and attention concerning their organization. Usually, IP activities have been split into patenting and other activities and attached in a subsidiary manner as staff or service functions to other functions in the corporation. A traditional large Western corporation has typically had some kind of patent department attached to R&D or a legal department at corporate level with some liaison engineers decentralized. Trademark-related activities have mostly been attached to marketing. Sometimes, there has also been a separate licensing department.[33]

The IP organizations in large Japanese corporations in the 1990s have a number of common features that clearly distinguish them from the traditional patent organization in large Western corporations.

[33] There have been few, systematic studies across companies, industries and countries of IP organization and management. A classic study is Taylor and Silberston (1973), which contains a sub-study of patent and licensing departments in approximately 30 UK companies in the chemical and engineering industries. Several of the findings in the Taylor- Silberston study may well represent the traditional situation in many other Western companies.

IP resources

The resources devoted to IP activities are not just slightly larger, they are often larger by a magnitude, with several hundred patent employees in the largest IP departments. The top companies in this respect in 1991 were Toshiba with 370 patent employees, Canon with 350, Matsushita Electric with 340 and Hitachi with 330.[34]

Centralized IP department

Responsibilities for patenting and other IP matters have been integrated and centralized into a comprehensive IP department at corporate level. In fact, all 24 corporations in the sample had a centralized patent department with corporate-wide responsibilities for patent coordination, headed by one central corporate patent manager. Usually, this department had similar responsibilities for other IP matters as well; there was an organizational trend showing evolution from a patent department to an IP department and from a patent manager to an IP manager.

Status of the IP department

The status and power of the patent and IP department has risen. Questions about patents and related matters were regularly discussed at company board meetings in most of the corporations, and often the IP manager reported directly to the CEO. The career paths to top management positions often have resided substantially in R&D with involvement in IP matters, and several Japanese CEOs were strongly IP-oriented. The IP department was thus of strategic concern under pro-active management, not just a reactive service department. Consequently, there was a need for sustainable in-house competence on a substantial level and scale. Still, much patent work was outsourced.

Clearing-house

Substantial emphasis and resources were devoted to having the patent department serve as an active clearing-house for technical information, with activities for technology scanning internally and externally, patent mapping, patent clearance, dissemination etc. Sometimes, technology intelligence was conducted in special subsidiaries as well. Such information-related activities are clearly important but in Western companies they have been difficult to

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[34] Comprehensive IP departments of this size can also be found in some leading Western firms. For example, IBM reportedly in 1989 had 240 professional employees linked to its Intellectual Property Law Department. However, in contrast to large Japanese IP departments, IBM's was much more internationalized (with about 30 locations globally and about 10% of the patent professionals located in Japan) and decentralized (with only about 5% working in corporate headquarters) and lawyer intensive (with about 60% being US lawyers).

maintain, coordinate and link to decision-making. Often the Western patent department has scanned and disseminated patent information without adding much value for the user, and without much follow-up and feedback. Japanese firms also experience difficulties like these, but they tackle them in more determined and systematic ways.

Integration of IP and R&D

Good working relations between the patent department and R&D were emphasized. This is a natural concern in Western firms as well, however the Japanese patent department was usually more powerful than a reactive service department purely under the aegis of R&D. Patenting people were regularly involved in the early stages of R&D, not casually called in at too late a stage as has often been the case in Western companies. Patent management operated pro-actively rather than reactively responding to requests from business and R&D operations and was expected to take sufficient initiative in order to secure viable patent positions in various business and technology areas. Needless to say, that is not an easy task as business divisions become increasingly independent. In general, corporate patent management in Japan had more power than their Western counterparts.
To illustrate, in one corporation a review of patent positions was regularly undertaken at an early stage of entering a business and/or technology area. If the review showed an unfavourable ”jungle” of patents, the IP manager had the clout to hold up the project until some kind of patent clearance (through e.g. licensing) had been undertaken. However, more common than vetoing, an IP manager had the possibility to bring such a situation to the attention of higher management.

Patent (IP) culture

The Japanese patent organization was immersed in what can be called a patent culture in the corporation. This is an important feature that will be dealt with separately next.

8.5 Patent management and patent culture

Japanese industry, and large corporations in particular, have developed a general orientation concerning patenting. That could best be described as a patent culture residing within and between companies.[35] The patent culture did not develop as a result of a grand design but

[35] The concept of culture has come into popular use – and misuse – in management in the last few decades. Despite a certain vagueness and tendency to use culture as a catch-all concept, it will be used here since it captures some important, if yet evasive, features in organizations. A standard textbook in social psychology has the following definition: ”Culture includes all institutionalized ways and the implicit cultural beliefs, norms, values and premises which underline and govern conduct” (Krech et al. 1962, p. 380).

was instead part and parcel of a catch-up process that started after World War II and was further strengthened after the emergence of the pro-patent era in the 1980s. That is not to say that managerial action cannot influence the formation of a culture in business, such as a patent culture.

The question is to what extent can a patent culture be fostered by managerial action in a corporation. A more general question is how a corporate culture in general could be formed. Japanese corporations are renowned for having built strong corporate cultures by various means. Needless to say, a well-functioning culture of some sort could be an effective vehicle for coordinated, purposeful action, and as such, could work as an efficiency-enhancing control mechanism. At the same time a culture could become a barrier to change. Moreover, in society as well as in large corporations, there is a fair amount of cultural diversity with several subcultures that may clash with one another.[36]
Thus there is a need for management to consider how to influence cultural formation and change. General managerial instruments that are mentioned in the management literature as useful in bringing about cultural formation and change are: strategy and policy formation, recruitment, promotion, restructuring of communications through organization and location, and campaigns of various sorts. There are also less tangible managerial actions representing elements at a fundamental level within a culture, such as actions that influence language and values, create symbols and rituals, integrate company life with social life and leisure activities, take on social responsibilities, strengthen ideologies, nurture common myths, and create implicit incentive and penalty structures. The importance of company leaders as role models who live as they preach is also extremely important.
These are all general elements in fostering a culture in a corporation, and it is in the nature of things that an exhaustive listing of elements cannot be made and that many elements are intangible, requiring much managerial sophistication. When it comes to building a corporate patent culture that was found in the large Japanese corporations studied, the elements become more specific. Some of these elements, as observed, are dealt with below, in no particular order.

1. Top management involvement in patenting and IP Top management involvement is indeed a necessary but insufficient condition. It is typical for most Japanese corporations to have top management involved in technology and R&D. Many corporations, too, have had a preference for technologists as CEOs, although there are corporations such as Hitachi and Toshiba that prefer a succession of technologists and commercialists as CEOs. In either case they are almost always members of top management with an appreciation of patenting matters, often having direct personal experience. Some top managers make it a habit to ask

[36] A subculture is simply ”a culture within a culture”.

questions about the patent situation during business presentations, and some also make it a habit to visit labs and discuss, among other things, patenting in more casual ways. It is important to show concern and at the same time refrain from letting obsolete or otherwise insufficient technical knowledge or one's own pet ideas misguide R&D.

2. Patenting and IP as a common concern for all engineers Although specialists are always needed for patent work, it is considered important not to consider patenting primarily a specialist function but to make patenting a common concern for all engineers. Training courses, job rotation and career paths with at least an early stint in a patent department are valuable, together with the other measures described below.

3. Patent policies and strategies integrated in business plans Without a requirement that makes patenting and IP a regular and specified item on the agenda of business plans, business managers will easily neglect the IP situation or let IP strategies become too generalized and watered down. Integration of business and IP aspects is not only a matter of thinking hard and coming up with cunning ideas but is also a matter of two-way communication with some integration of business language and IP language. "What is our unique competence in this business?" is a common question in business analysis. The equally important, but less commonly used IP–related question is "How can we protect our unique competence in this business?"

4. Clear patent objectives Clear, quantified objectives for patenting were common among the Japanese corporations in the study. There are many arguments against quantifying objectives, and often patenting people produces such arguments. One argument is that quantified objectives are said to stimulate quantity rather than quality of patents and foster unfruitful competition. On the other hand, quantification focuses attention and provides clear yardsticks for rewards and penalties, as well as for improvements. The arguments for quantifying objectives appear to be stronger when building a patent culture. Such objectives then function as symbols and provide a basis for habitual behaviour, even rituals, such as "Kamikaze research", which describes the patenting frenzy in Japanese companies at the end of the budget year in order to meet quotas. Such behaviour could be seen as going too far, but nevertheless is part of the patent culture.

5. Clear patenting incentives for R&D personnel and organizational units The issue of how to reward inventive work by individuals, teams and units is a very important and fundamental question in both Japanese and Western firms. This is a complex issue that could be elaborated at great length. Without doing so here, one can just point to the clear and fairly strong reward schemes employed by Japanese firms, often developed without the adversarial relationship between the firm and the inventor that easily develops in Western firms. The following citation is in contrast with the top management view, not uncommon in Western firms, that R&D people basically are salaried for doing inventive work.

> We try to encourage the view that the company's value to society lies in developing new technology. We also try to provide a corporate environment where thought and originality are rewarded.
>
> We give annual cash awards to the employee who has applied for the most patents that year and to those who have developed patents or software of an outstanding nature.
>
> Keizo Yamaji
> Former CEO, Canon Group

6. Fostering of behavioural attitudes and norms Fostering of behavioural attitudes, norms, habits and standards conducive both to technology protection by patents and secrecy and to technology intelligence can be done in various ways. For example, certain reading and writing habits of engineers can be encouraged, as in Canon. A citation by Dr. Yamaji may again illustrate:

> I encourage our researchers to read patent specifications rather than academic theses and to write patent applications rather than technical reports. I also tell them to make virtual experiments ("Gedanken" experiments) in order to have them apply for more and more patents, so that we can be prepared for the era to come when only some companies, strong in patents, will cooperate with each other and survive.
>
> Keizo Yamaji
> Former CEO, Canon Group

Canon, as well as other companies, also tries to encourage writing habits by aligning the reporting on R&D work to the norms and standards used in patent documents. In this way, patent application work is facilitated while thinking in patent terms is encouraged. Speaking, listening and observation habits of engineers, salesmen, managers etc. could also be influenced for protection and intelligence purposes, although extreme behaviour in this regard may be counter-productive in other respects.

7. Visible organizational means Tangible and intangible means for building a patent culture have to complement each other. Examples of visible organizational means besides the ordinary patent organization are patent promotion centres, patent liaison officers distributed in the organization, corporate-wide patent campaigns, patenting prizes, and patent strategy seminars.

8. Language, methodology and philosophy A common language is central to any culture. One way to foster a professional language for a patent culture is to develop concepts and tools and employ them in a methodology for analysis and in communication, which could be further turned into a philosophy. The patent-mapping methodology was developed in Japan by JPO initially and then improved over time by large corporations (see Granstrand 1999b, Ch. 9). It has been a useful methodology for several purposes in itself, but at the same time it has contributed to building a patent culture through its influences on language, analytical perspective, conceptualization and communication.

Finally, it must be emphasized that corporate patent cultures are embedded in and reinforced by an overarching industrial and national culture, conducive to patenting, inventions, intelligence, and so on. There is a wide range of institutional arrangements for this with government agencies and initiatives, legislation, associations, institutes etc. The large Japanese corporations as a whole play an increasingly important role. The corporate IP managers know each other well and are part of various ”old boy networks” (to use a Western term). The Japan Patent Association (JPA) is a good example of an organization primarily catering to the interests of large corporations since long ago.[37]

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[37] JPA was formed in 1938 by patent attorneys employed in some large corporations including Toshiba and Hitachi. It was originally named Chrysanthemum Feast Club (Choyo Kai) and was renamed Japan Patent Association (Nihon Tokkyo Kyokai) in 1959 (Rahn 1983, p. 473).

Commercialization of new technologies

9.1 Background

There is an old saying, that stated roughly says Europe makes science, the USA innovates and Japan commercializes. This is obviously a sweeping statement, which is no longer true, but to a certain extent it has been true in the past. Europe has been providing an essential scientific base for the spur of US technological innovations from the late 19th century on, and the USA in turn has been providing much of the technological base for Japan's commercial achievements after World War II. Scholars have also pointed to the numerous innovative skills in the USA coupled with a certain lack of imitative and commercialization skills compared to Japan (see e.g. Mowery and Rosenberg 1989, Rosenberg and Steinmueller 1988).

A number of reasons behind Japan's skills in commercializing new technologies can be found at the macro and policy levels. For example, a strong pragmatic technology orientation in government and industry, a low level of government spending on military R&D, a high level of privately financed industrial R&D under conducive macro policies (e.g. technology, fiscal and trade policies providing e.g. low cost of capital and instrumental protectionism) and fierce domestic competition have created a technology-driven economy with a strong market orientation.

The process of catching up generates dynamic advantages relative to the process of sustaining a lead (see Abramowitz 1986). Table 14 gives an overview of the pros and cons for a country's industry when operating as an early or late mover in a market. Japan has certainly been able to develop late-mover advantages. The catch-up process has also created a culture and a momentum conducive to further progress, based on skills or competence cumulated in the catch-up process. These skills are also highly useful in the process of sustaining a lead as well, at least for a time. Important examples of such skills are the ones acquired in connection with patenting and the use of patent information. At the same time, attitudes and competencies acquired by innovators and early market leaders often seem to threaten the sustenance of their leading positions, e.g. through the NIH syndrome, which could be seen as part of a larger ”success breeds failure syndrome” common among innovators. A successful catch-up also tends to build in risks associated with rapid but unbalanced growth, allowing progressive and backward parts to co-exist in the economy, possibly to the point where the backward parts become bottlenecks seriously limiting further aggregate growth.

Of course, it is also possible that some attitudes and competencies nurtured by a catch-up process are not conducive to reaching and sustaining an innovative position. One example is what can be called the FIB syndrome (”foreign is better”), which deters companies from venturing into a technological lead. To overcome this syndrome, MITI has played an important role through its collective R&D projects, such as the VLSI project. Much has been written about the importance of MITI in engineering these collective R&D projects in ”pre-competitive” stages as an instrument for catching up (see e.g. Fransman 1994, 1995, Sigurdson 1995, 1996). However, forging ahead in addition to catching up also requires overcoming the FIB syndrome and the setting of actual R&D targets for the purpose of taking a technological lead in a dynamic race. When MITI proposed such targets, there was a large degree of initial hesitation among Japanese companies who were sceptical that such targets could be met, creating responses such as ”IBM will always be ahead”.[38] Naturally, collective R&D with government support has been instrumental in smoothing financial risks, but in addition, MITI, along with some progressive companies and industrialists, has been instrumental in overcoming the FIB syndrome in more and more parts of Japanese industry.

[38]At the same time IBM accelerated its pace when observing Japanese initiatives and advances.

Table 14. Advantages and disadvantages of early and late movers on markets[1)]

Early mover	Late mover
Advantages:	
• Economies of scale and learning and increasing returns in general • Firstcomers have first crack at emerging technologies and markets and the opportunity to establish unchallenged, dominant market share • Possibility to use pre-emptive and foreclosing strategies or otherwise build up barriers to entry • Reputational advantages • Possibility to build up exclusive IP positions • Possibility to set standards	• Economies of speed and timing • Reduction of basic R&D costs compared to firstcomers • Lower initial start-up costs • Reduction of aimless groping • Technological leapfrogging is possible • Learning from early movers • Reduction of NIH effects • Aggregate growth rates tend to be faster • Cumulation of catch-up competencies
Disadvantages:	
• Build-up of physical and intellectual capital which becomes obsolete • Build-up of inertia, rigidities and hubris • Build-up of the NIH syndrome and the success breeds failure syndrome	• Lag in technology • Resource scarcity due to early mover preemption • Forced to concentrate on low value-added products • Lacking economies of scale in production • Threat by foreign imports from firstcomers • Competition from foreign subsidiaries operating in home markets • Threat of being overwhelmed (the FIB syndrome) • Lack of large companies which can invest in product improvements, appropriate innovations and pursue second-to-market strategies • Tendency towards unbalanced growth and a polarized economy

Note:

1) In principle, categories diagonal to each other in the table would be logical negations of each other if the table had contained exhaustive lists of relative advantages and disadvantages. However, as a matter of emphasis the table shows mainly different factors in all four early/late pro/con categories without being exhaustive.

Source: Compiled and selected from Abramowitz (1986), Ames and Rosenberg (1963), Conrad (1984), Gerschenkron (1962), Kerin et al. (1993), Leonard-Barton (1995), Lieberman and Montgomery (1988), Okimoto (1983), Schnaars (1994), Utterback (1994) and the author. The works represent a mixture of country and company perspectives.

A number of reasons behind Japan's success in commercializing new technologies can also be found at micro levels and in the fine structure of society and corporate life. A particularly important factor is the management skill developed in large parts of industry, especially for managing large corporations. Since technology has been the engine of Japan's developments, skilful technology management has been crucial. As is well known, Japanese management has drawn considerably upon Western management but has at the same time developed unique features and a considerable range of managerial innovations (TQM, JIT, Kanban, concurrent engineering and so on), which in turn has been emulated in the West.[39]

9.2 Common features of technology exploitation in Japan

At the company level, the interviews in the study suggest that the features in Table 15 are characteristic for the sample of Japanese companies in their commercialization (exploitation) of new technologies.

Table 15. Common features of technology exploitation in Japan

1.	Synergetic product/technology diversification (reaping economies of scale, scope and speed)
2.	”Speed to market” through
	• Exploratory R&D
	• Incremental development and learning
	• Concurrent engineering, coordination and communication
	• Sense of urgency (stimulated by domestic competition)
	• Global marketing
	”Speed to technology” through
	• Technology scanning
	• Will to explore and experiment (often early on and with patience)
	• Technology acquisition (e.g. from Western firms and universities and through internal and external technology supply and llicensing networks)
	• Large central R&D
	• Technology transfer and communication internally and externally
3.	Dynamic application orientation and user cooperation
4.	IP protection, licensing and monitoring

[39] This, by the way, illustrates two things. First, how innovation and imitation processes occur in management just as in technology. Second, how the roles of innovators and imitators may shift back and forth over time among actors (countries, companies, individuals), thereby inducing them to play a mixture of innovator/imitator roles over time in intertwined processes of catching up, forging ahead, falling behind, recatching up, etc. (to use the terminology in Abramovitz 1986).

9.2.1 Synergetic diversification

Japanese companies at large have long been engaged in product diversification processes, usually resulting in a considerable diversity of product businesses (see previous sections). As is well known, many Western companies also engaged in product diversification as a strategy for balanced growth and risk dispersion, especially when this strategy came en vogue in the 1960s and 1970s in the USA. Product diversification in the West often resulted in economic failure, as in ITT, although there have been some striking successes too, as in General Electric. As is also well known, diversification failures in the West have then resulted in a pendulum swing towards product specialization, under labels such as ”back to basics,” ”stick to the knitting,” ”do what you do best” etc.

In contrast, Japanese companies have on average been successful in product diversification. They also engage, not in unrelated or conglomerate diversification as was often the case in the West, but in related diversification and especially in technology-related diversification. Most companies interviewed in this study and related studies judged that most of their successful diversifications have been ”technology-driven” (Canon, Toshiba, Hitachi, Teijin, Toray, Yamaha, Seiko, NEC etc.).

As a rule, Japanese companies have diversified through internal development, while US companies have typically diversified through mergers and acquisitions. In Japanese companies, there is in fact an ever-ongoing evolutionary process of diversifying the technology base together with diversifying the product base of the company. This is a process comprising several sub-processes in parallel: refinement of existing technologies, refinement of existing products, technology diversification related to the company’s existing products, and finally product diversification related to the company’s existing technologies. The company’s existing technologies are refined at the same time as technologies new to the company, but possibly relevant to its existing product areas, are incorporated in the company by various means and are then tested and further improved upon. Ultimately, the new technologies may be incorporated in a new product or in an existing product area with increased performance-to-cost ratios or new functionalities for the customer. This product and its technologies, including its production technologies, are then further improved upon etc.

As in-house competence in new technologies is built up, a search for new applications of these technologies is initiated, which after some time – occasionally a considerable time – may result in a venture into a new product area. Thereby, the product base of the company is expanded but in a way that is related to the existing technologies in the company. This *technology-related product diversification*, in interaction with *product-related technology* *diversification*, takes advantage of economies of scale, since the same technology may be utilized in several products, possibly with an adaptation cost, which is sometimes considerable but more often is minor (see Chapter 4). It must be noted that these types of economies of scale derive from the commonly held fact that technical competence in an area is built up at a considerable fixed cost but with a low variable cost when applied over a number of applications. That is, as with any body of knowledge, the cost of technology is not very dependent upon the scale of its use. In addition adapting the technology to different applications further enhances competence, which usually gives some kind of learning revenue.

When new technologies are complementary to old ones in the technology base of a product – which they often are – technological economies of scope or technology related synergies arise from cross-fertilization. However, incorporating more technologies in a new product or process also leads to progressively increased R&D costs, since integrating more technologies requires more coordination and communication.

A diversified company with a broad technology base, which involves a new technology needed for a new product, also has what can be called speed advantages in addition to scale and scope advantages. The company can then incorporate this technology not only cheaper but also faster, by transferring it internally (possibly with some modification). Usually technology transfer is slower for a company which has to acquire the new technology through in-house R&D instead of external sourcing, although barriers to intra-firm technology transfer (such as NIH-barriers) may sometimes be significant.

9.2.2 Economies of speed

Characteristic of technology exploitation is the well-known speed-to-market behaviour in the Japanese commercialization of new technologies. Exploratory efforts in new technologies may start very early in industry, and proceed for many years in parallel in many Japanese companies operating in various product areas, but once their commercial feasibility is established, the final pace of commercialization is very rapid, spurred on by domestic competitors. To have R&D resources for basic technology development and exploratory work is therefore a prerequisite for reducing time-to-market in product development. Concurrent management and concurrent engineering with strong integration of simultaneous or overlapping, rather than sequential, activities for product development, production and marketing are then used for reducing time-to-market, as is well known. Japanese firms also appear to be quicker than US firms to reach the market with new products, at least in case the products are largely based on external technology rather than in-house R&D.[40]

Concurrent management may further be applied not only to different functions in developing a new product, but also to the development of different product generations, whose development phases may overlap. That is, R&D for the second (or even third) generation is started before the first product generation is launched on the market. Of course, trade-offs must then be made between time and costs, and also between lost and gained sales through internal 'cannibalization' among the different product generations of the company. Moreover, customers may be lost entirely to the company if two generations are spaced too far apart in time, thus creating a need for an intermediate generation (or version or model) that serves as a "gap-filler", although it cannibalizes on the preceding generation.

As is also well known, Japan has in the past extensively acquired technology from abroad through various means, not least through licensing in, and used this technology for commercialization on the domestic market in the first place but also increasingly on international markets. As Japan has reached, and in a number of cases surpassed, the technological levels of the West, the possibilities of sourcing suitable technology from abroad have decreased.

This is a tendency that has been reinforced by an increased control of technology transfer to Japan by Western companies. Japan has also built up an impressive indigenous R&D as she tries to access technology increasingly through other means, such as joint ventures, research cooperation and technology exchanges. In accessing new technologies in these ways, patenting plays an important role. Moreover, one source of technology, which is increasingly utilized by Japanese industry, is Western universities. At the same time, Japanese R&D is becoming increasingly internationalized (see previous section).

These patterns of behaviour also contribute to a kind of economies of speed, which arise from what can be called "speed to technology". This is actually a type of speed to input markets or factors, rather than speed to output markets, which is what is commonly meant by the phrase "speed to market". Speed to technology then contributes to speed to market.

In this context one can note that concurrent management may also be applied to the different phases of entering new business areas. However, the prevailing feature so far in Japanese companies is that technology-related product diversification has proceeded more

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[40] As shown in a study of about 200 Japanese and US firms by Mansfield (1988a, b). Actually, both innovation times and innovation costs were shown to be lower for Japanese firms, but not in case the new products were based on internal technology.

stepwise in an evolutionary fashion, as described above. Thus, in the commercialization of new technologies there are races in several directions – speed to technology (input market) and speed to (output) market. The outcomes of these races determine market lead time. Patent races, in which the winner gets all, are part of these races, making ”speed to patent” important. In general there are multiple patent races in connection with developing and sustaining a new product. Speed to patent and speed to market and technology should then be seen as complementary races, rather than substitutes. Winning a strategic patent is one very effective way to create substantial market lead time since such a patent not only slows down but blocks the competitors in their race to the market. Monitoring patenting activities of others is an important means for speed to technology. Sometimes in Western companies, patenting is seen as slowing down speed to market; in this case, insufficient patenting resources may be the actual impediment.

9.2.3 Dynamic application orientation and user cooperation

It is almost a truism to say that application and user orientation are key features of technology exploitation. Still there are some important points that are not self-evident, some of which are more specific to Japan.

Weak science and research culture

First, Japan has had a weak science and research culture in the catch-up process, which has focused on technology – acquisition, adaption and deployment. Scarce resources for industrial R&D in the 1950s and 60s led industry to economize on dearly acquired technologies from abroad.[41] In fact, in S&T and R&D work, a strong and prestige-focused science and research culture often fosters counterproductive attitudes towards the commercialization of new technologies, with its need for less glamorous development and application engineering work. To build up a science and research base avoiding such attitudes is a current and future challenge for Japan, especially since a science culture can easily become stronger than the national and corporate cultures. It may then be useful to recognize that honoured features of science like creativity and pioneering are critical features in engineering as well. History of technology abounds with cases where creativity in applying existing technologies to new applications has made a big difference.

[41] The policy in Japan at the time to acquire technology through licensing in rather than through joint ventures with foreign partners for the domestic market (although such ventures occurred as well) also put pressure on indigenous companies and their R&D personnel to learn how to exploit the acquired technology in all respects, without being able to resort to a joint venture partner.

Application visions
Second, the application orientation is often dynamic or sequential in the sense that a series of applications can be envisioned as feasible over time, in contrast to a single application. Such a stepwise application vision can be developed through curious and persistent exploratory work and experimentation with new technologies already at an early stage. The different applications may correspond to different business areas as part of a stepwise (rather than concurrent) technology-related diversification as described above. The applications may also correspond to different market segments in the same business area, segments that require increasingly high technical performance. Usually, Japanese companies have climbed up the quality ladder, while several Western companies, at least in the military-industrial complex, have climbed down or ignored mass-market applications altogether. Kodama (1995), referring to the Japanese approach of ”trickle-down”, describes this circumstance very well.

Broad market orientation
Application orientation is different from a narrow market orientation that only focuses on existing customers and their needs. Applications are characterized by physical attributes of a product or a technology in a certain usage context. Identifying those technical performance variables that give extra value added per R&D dollar to users in potentially large user groups gives guidance to R&D. A company that has maintained an innovative position for a long time thus has developed an R&D logic with preferences that have lost some of their economic relevance. For example, a company having developed centrifugal separators for years for applications in liquid food processing (milk, juice, etc.), oil purification etc., may have its R&D focused on the degree of separation as the primary technical performance variable, while for most users the reliability of separators in terms of its mean time between failures is the performance variable that primarily improves the user’s economy. Users often do not have this kind of knowledge either, and it may not be readily available or perhaps even given much thought.

User cooperation
This leads to the fourth point, which is the conduciveness of user cooperation to innovation. Such cooperation has generally increased, not only in Japan, and much has been written about it. An excellent work on the importance of user cooperation is von Hippel (1988).

9.2.4 IP protection, licensing and monitoring

As is evident both in the questionnaire responses and in the case studies, IP protection, licensing and monitoring is an important feature of technology exploitation in Japan.

From a company's point of view the main function of a patent should be to help the company recover sufficient returns from its investment when commercializing a new technology.[42] However, there are other ways to perform this function, e.g. by means of secrecy, efficient production or efficient marketing. Mostly these other ways are complements rather than substitutes for using patents. Moreover, there are other advantages of a patent to a company, as well as disadvantages. Thus, a company might apply for patents even if they are not important in commercializing new technologies, just as a company could refrain from patenting even if it is important. The questionnaire survey tried to assess the effectiveness of patents in fulfilling their main function relative alternative methods, as well as the advantage of patents in this respect relative to other advantages and disadvantages.

Table 16 shows the survey results at country level, where the data for the USA are derived from Levin et al. (1987).[43]

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[42] There are several ways to express this function – capturing the returns from R&D, appropriating the benefits of innovation, protecting the competitive advantage of new or improved products and processes. No essential distinction between these expressions is made here.

[43] The US study used a scale from 1 to 7 so its data have been transformed to the scale 0 to 4 used here. The survey respondents in the US study were typically R&D managers, while the respondents in this study were typically IP managers, who were likely to put more emphasis on patents. Nevertheless, patents were not emphasized in the Swedish responses.

Table 16. Means for commercializing new product technologies

(Scale: No importance = 0,1,2,3,4 = Major importance)

Means	Japan[1)]	Sweden[1)]	US[2)]
(a) Taking out patents to deter imitators (or to collect royalties)	3.3	1.9	2.0
(b) Exercising secrecy	2.4	2.0	1.7
(c) Creating market lead times	2.7	2.4	2.9
(d) Creating production cost reductions	2.9	2.7	2.7
(e) Creating superior marketing	2.7	3.0	3.1
(f) Creating switching costs at user end	1.9	1.7	n.a.

Notes:

1) Current sample of 24 Japanese and 23 Swedish large corporations. Perceptions for 1992.

2) As reported in Levin et al. (1987). Perceptions for mid-1980s, rescaled to the scale used in the current study.

A few observations deserve to be pointed out:

1) Patenting ranked highest in Japan, while close to the bottom in Sweden and the USA, with the means of commercialization differing most among the countries.

2) Superior marketing ranked highest in Sweden and the USA, while Japan fell in the middle range.

3) Creating switching costs (”lock in” of customers) ranked lowest in both Japan and Sweden (data missing for the USA), and thus to ”lock out” competitors from the market through patents and other means was perceived as more important.

4) Sweden and the USA were fairly similar in their average responses, while Japan deviated most.

Thus, the data indicate a clear difference between Japanese and Western companies, in particular regarding the role of patents.

A further breakdown of the data for industrial sectors in Japan shows that:

1) Patenting ranked highest for both products and processes in chemical and electrical companies, with secrecy close to the bottom.

2) Mechanical companies deviated from the chemical and electrical firms for both products and processes, with the highest emphasis on production cost reductions and production process secrecy.

The country and sector differences challenge some notions commonly held, at least in the past. One is that patents play a secondary role overall compared to marketing and production efforts. This is certainly not true for Japan. Another common notion is that secrecy plays a larger role than patenting in the protection of process technology. This is not true for Japan either, except for mechanical companies.

There may be a changing role regarding secrecy in the chemical and electrical companies in general, due to technological changes facilitating reverse engineering. For example, new types of chemical analysis can trace minuscule amounts of a wide range of substances in a product, from which the production process can be inferred. This not only helps competitors to reverse engineer, but it also helps patent holders to detect infringement through reverse-engineering of the suspicious products of their competitors. Thus, a weakening of secrecy protection by more cost-effective tools for reverse engineering increases the propensity for patenting (everything else being equal) in two ways: First, the innovator's secrecy barrier is more easily penetrated by imitators. Second, the imitator's secrecy barrier is more easily penetrated by the innovator's ability to detect infringement. This also holds true if secrecy protection is generally weakened for other reasons, e.g. outsourcing of process equipment and process engineering services to leaky suppliers, although the incurred savings in intelligence operations may differ substantially among competing companies.

Although some new technologies make it easier to overcome secrecy barriers, such barriers on the other hand might become easier to erect as products and processes become more complex and multi-technological in character. For this and other reasons, complexity could conceivably raise imitation costs to the point that patents become relatively less useful. However, this is not corroborated by the cata but rather the contrary (see further Granstrand 1999).

10 Diversification and Growth in US, Japanese and European Multi-technology Corporations[44]

10.1 Introduction

The aim of this section is to analyze the relationship between corporate diversification and growth. Three dimensions of diversification are focused upon: technologies, products and markets. This analysis will be conducted in three steps. First, a set of hypotheses will be deduced from a literature survey and previous research on the relationship between diversification and corporate growth, and these hypotheses will be tested in a formal model. Secondly, a search for additional explanatory factors for growth will be pursued. The key issues here are: What kind and sequence of strategy has been most successful regarding diversification or specialization of products, markets and technologies? Should companies ”stick to their knitting” to a larger extent, as with many Western companies, or rather, should they expand the range of products and markets? If so, how should this expansion be carried out? Thirdly, these new explanatory factors will be integrated into the literature based model and tested.

10.2 Previous research and a set of hypotheses

Kodama (1986) defined ”technological diversification” as each industrial sector’s R&D activity outside its principal product field and showed significant evidence for the phenomenon of technology diversification in Japan. Pavitt et al. (1989) studied more than 4000 successfully commercialized innovations in the UK between 1945 and 1983 and showed a general trend toward increasing technological diversification. Oskarsson (1990) showed strong evidence for increased technology diversification at industry, corporate and product area levels in Swedish industry between 1980 and 1990. Granstrand et al. (1990) presented results from 91 interviews from top technology and business executives in 42 multi-technology corporations from Sweden, the USA and Japan. The interviews indicated that at least thirty-five of the forty-two companies had diversified their technology base significantly during the last decade. The first research hypothesis can then be stated as follows: *Hypothesis 1: There is a general trend towards an increase in technology diversification for Japanese, US and European (multi-technology) corporations.*

Concerning the direct relationship between technology diversification and growth, Granstrand & Sjölander (1990) and Oskarsson (1990) presented a strong association between sales growth and increased technology diversification in Sweden. Moreover,

[44] This section is an abbreviated and revised version of the paper Oskarsson, C.: ‘Diversification and Growth in US, Japanese and European Multi-Technology Corporations’, published in Oskarsson (1993).

Granstrand & Oskarsson (1991) suggested that increases in technology diversification *lead* to growth of R&D costs. A second hypothesis can then be stated as: *Hypothesis 2: Growth in technology diversification will not only be associated with, but also lead to, growth in R&D expenditures.*

Granstrand, Sjölander & Alänge (1989) studied diversification in Japanese multi-technology corporations, and identified a consistent strategy from fourteen Japanese companies which involved conducting systematic product diversification from a common and expanding technology base. The third research hypothesis can then be stated as: *Hypothesis 3: Increases in technology diversification is positively related to and a cause for increases in product diversification.* Moreover, they suggested that there was a trend towards increased product diversification in Japan, and a trend towards product specialization in Europe and the US. This leads us to *Hypothesis 4: Product diversification increases in Japan and decreases in the US and Europe.*

The increasing technology diversification could be argued to have its fundamental impetus in an expanding technological opportunity set, as argued by Granstrand & Sjölander (1990) (see also Jaffe 1989). In order for firms to capture the benefits from this opportunity set, they will need to allocate more funds to R&D. The more R&D, the more of the opportunity set can be exploited in terms of new and/or modified products. We would therefore expect that firms which exploit the opportunity set with a fast growth of R&D will grow faster than those who choose to increase R&D at slower pace. Thus, it seems reasonable to also test the relationship between growth in R&D expenditures and sales growth. *Hypothesis 5: Growth in R&D expenditures will be associated with sales growth.*

Turning to product diversification, the phenomenon of diversification of products is amply described in the literature. The vast body of literature, some of it based on Gore (1962) and Rumelt (1974), has identified two distinct modes of product diversification: unrelated and related. Unrelated diversifiers have been defined as firms that diversify predominantly across industries, while the related diversifiers have been defined as firms that diversify predominantly within industries (Palepu 1985, Kim et al 1989). Studies of product diversifications breadth and performance have shown that related product diversification, i.e. reaping the fruits of economies of scope and other synergies, performs better than unrelated product diversification (Rumch 1974, Montgomery 1979, Suzuki 1980, Bettis 1981, Palepu 1985, Simmonds 1990, Teece 1980, Teece 1987). Moreover, Granstrand, Sjölander & Alänge (1989) suggested that growth in product diversification was an important factor behind sales growth in Japanese companies. Hypothesis 6 is therefore: *Hypothesis 6: Product diversification is positively related to sales growth.*

As in the case of related product diversification, research in international market diversification has found a positive relationship between market diversification (often measured as internationalization of market operations), growth and profitability (Geringer et al. 1989, Granstrand & Sjölander 1992, Severn & Laurence 1974, Leftwich 1974, Wolf 1977, Rugman 1979, Caves 1974). Therefore, it seems reasonable to test *Hypothesis 7: growth in market diversification is positively related to sales growth.*

These hypotheses are firmly based on the literature. However, there is some evidence of an additional set of explanatory variables. Granstrand & Sjölander (1990) argued for a winning patter among Swedish firms. The companies which followed a pattern of product specialization followed by market diversification (internationalization) and increased technology diversification grew significantly faster and were more profitable than other Swedish companies. Based on firm interviews, Granstrand et al. (1990) reported a different "winning pattern" for Japanese companies. More than half of the Japanese corporations had explicit plans for diversifying their product portfolios and their technology portfolios as part of their corporation strategy, plans not found among the US or European corporations. This indicates that there might be a winning Japanese pattern, distinct from the winning Swedish pattern. Though these results are interesting, one must acknowledge that they are either based on studying a very small country, Sweden, or in the case of Japan, they are interview based, relying on the personal perceptions of managers.

Given the tentative character of these additional variables, it seems reasonable to go from testing hypotheses to a more investigative research approach. This is a first attempt to do so by trying to answer the following research questions:

- How do different diversification behavior sequences relate to different corporate growth patterns?
- Can growth and diversification behavior be explained by what generic technological domain the companies operate in?

We will first test the hypotheses 2, 3, 5, 6 and 7 presented above in a model for growth and diversification. After testing the model, we will test the regional differences between Japan, the US and Europe (hypotheses 1 and 4). Finally, a further developed model based upon both previous research and the empirical findings will be tested.

10.3 The Empirical Study

There are fourteen Japanese[45], sixteen US[46], sixteen non-Swedish European[47], and fifteen Swedish corporations[48] included in this study. All the companies are large, technology-based and for the most part multi-national corporations. The companies were selected by a handful of well-informed observers of Japanese, European and US industry who were asked to name those large manufacturing companies which they considered to be at the forefront of the management of technology. We do not argue that this is a representative sample of the industrial activities of these countries in any way. The companies in the study however account for a larger part of the entire industrial R&D expenditure of the corresponding countries: 38 percent (1988) for the sixteen US companies, 21 percent (1988) for the fourteen Japanese, 12 percent (1988) for the 15 non-Swedish European and 91 percent (1988) for the fifteen Swedish companies. Our work involves a quantitative analysis of 57 of these 61 companies[49] regarding diversification of technologies, products and markets and growth of R&D costs and sales.

Technology diversification, and the changes therein will be assessed by patent statistics here. The patent database used in the study contains patents granted in the US between 1969 and 1988, their country of origin, the US patent class and the name of inventing company. The companies have been viewed as they were consolidated 1988. This means that mergers and acquisitions during the period of analysis[50] will not be taken into account in the patent data. However, Oskarsson (1990) compared the variables from unconsolidated and consolidated data for Swedish industry, and the tendencies concerning technology diversification was strikingly equal. This may suggest that the problem of mergers and acquisitions should not be overemphasized. The patent data has been supplied by the Science Policy Research unit.[51]

The data concerning product diversification, market diversification and sales growth has been compiled through analyses of annual reports and other printed material received from the companies and from other public sources. Product diversification was assessed at the

[45] Canon, Hitachi, Honda, JVC, Kyocera, Matsushita, NEC, Nippon Steel, Sanyo, Sony, Sumitomo, Toshiba, Toyota and Ulvac.
[46] 3M, AT&T, Corning, Digital Equipment (DEC), DuPont, Ford, General Electric (GE), General Motors (GMC), Honeywell, IBM, Eastman Kodak, Merck, Motorola, Texas Instruments (TI), and Xerox.
[47] Aerospatiale, Alcatel, BASF, Bayer, FAG, Fiat, Glaxo, ICI, Lóreal, Olivetti, Philips, Rhone Paulence, Sandoz, Siemens, Thomson CSF, Unilever.
[48] ABB, AGA, Alfa Laval, ASTRA, Atlas Copco, Electrolux, Ericsson, ESAB, Nobel, Pharmacia, SAAB-Scania, Sandvik, SCA, SKF, and Volvo.
[49] Four companies were omitted because of missing data.
[50] The patent analyses in this paper are based on patenting between 1980 and 1988.
[51] The patent database was supplied to SPRU by the US Department of Commerce, Patent and Trademark Office. SPRU then classified the base patent data into 34 technology classes.

product area level. For each company, discrete product areas (classified as close as possible in accordance with the 4-digit ISIC product classification) were identified and sales in each product area were assessed for each year. For example, in a car producing company, it could be sales in the categories of passenger cars, trucks and motorcycles. Finally, market diversification was assessed accordingly by analyzing sales for each year in the six regions of Europe, the USA and Canada, Latin America, Japan, non-Japanese Asia (incl. Australia), and Africa.

Regarding the measurements of diversification, Hoskisson et al. (1993) showed strong convergent, discriminant and criteria-related validity for the entropy measure of diversification. Not surprisingly, the number of researchers utilizing the entropy measure for economic and strategy research is therefore large and continues to expand. Diversification in products, technologies and markets will also be measured here by an entropy-based measure. In order to increase the reliability of the results, a second measure is used, defined by (1-H), where H is Herfindahl's concentration index.

10.4 An Explanatory Model of Diversification and Growth

We hypothesized above that R&D expenditures were driven by increasing technology diversification. We also hypothesized that growth in technology diversification leads to growth in product diversification. We also said that growth in R&D expenditures was related to sales growth, and that increase in product diversification and market diversification was positively related to sales growth. This line of reasoning, with the variables that are included in the analysis, leads us to the model in Figure 1.

Figure 1. An explanatory model of diversification and growth.

To test this model, a system regression analysis was performed.[52] The following variables were included in the analysis:

- TDIVGROWTH A-B= The growth in technology diversification index between years A and B, operationalized as the difference of the technology diversification index between years A and B.

- PDIVGROWTH A-B= The growth in product diversification index between years A and B, operationalized as the difference of the product diversification index between years A and B.

- MDIVGROWTH A-B= The growth in market diversification index between years A and B, operationalized as the difference of the market diversification index between years A and B.

- SALESGROWTH A-B= The relative growth in sales between years A and B, operationalized as the percentage growth of inflation-adjusted sales between years A and B.

- R&D-GROWTH A-B= The relative growth in R&D costs between years A and B, measured as the percentage growth of inflation-adjusted R&D spending between years A and B.

Before testing the complete model with multiple system regression, the causal links between technology diversification, product diversification and growth in R&D expenditures (hypotheses 2 and 3) were tested in three steps. First, the association between the two variables during the same time period was calculated. Second, one of the variables was lagged five years, and a second association is calculated. Third, the other variable was lagged five years, and a third association was calculated.[53] The regressions are presented in Table 17 below.

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[52] The variables were first standardized to create coefficients directly corresponding to partial correlation coefficients. The SAS program SYSSREG was used to perform the data analysis.

[53] The time lag five years was chosen after carefully going through the statistical material for technology diversification, product diversification, market diversification and growth, and assessing that the time lag between changes in these variables was between three and six years. This was done in order to investigate causal links.

Table 17. Regressions[54] Regarding R&D Expenditures, and Technology and Product Diversification for 57 MTCs from USA, Europe and Japan (n=55)

Nr	Dependent Variable	Variable Entered	Coefficient	Model R^2	Model F-Ratio	Significance (2 tail)
	Bivariate regressions					
1	PDIVGROWTH	TDIVGROWTH 1980-1988	0.246	0.103	6.314	0.015
2	PDIVGROWTH	TDIVGROWTH 1980-1985	0.280	0.114	7.074	0.010
3	TDIVGROWTH	PDIVGROWTH 1980-1985	-0.014	0.000	0.017	0.897
4	R&D-GROWTH	TDIVGROWTH 1980-1988	4.995	0.325	18.743	0.000
5	R&D-GROWTH	TDIVGROWTH 1980-1985	1.473	0.337	23.429	0.000
6	TDIVGROWTH	R&D-GROWTH 1980-1985	0.018	0.029	1.158	0.288

Growth in product diversification in the early 1980s was not associated with growth in technology diversification in the late 1980s (regression model 3). Instead, technology diversification in the early 1980s was associated with growth in product diversification (model 29 in the late 1980s. Therefore, there is reason to believe that a causal relationship exists between increases in technology diversification and increases in product diversification and sales. Between growth of technology diversification and R&D expenditures, the results in Table 17 support the suggested causal link between increased technology diversification and increased R&D expenditures.[55]

After testing hypotheses 2 and 3 concerning the causality between technology diversification, product diversification and growth of R&D expenditures, we tested the complete literature-derived (hypotheses 2, 3, 5, 6, 7) multiple system regression mdel:

SALESGROWTH= CONST + R&DGROWTH (TDIVGROWTH)+ PDIVGROWTH (TDIVGROWTH)+ MDIVGROWTH

[54] Bivariate regressions between R&D expenditures, technology diversification and product diversification were conducted. For all diversification variables, both the Herfindahl diversification index and the entropy diversification index were tested.

[55] Hypothesis 2.

for the time period 1980-1990. Figure 2 below shows the structure and partial standardization correlation coefficients and the explanatory power (R^2) of the model.

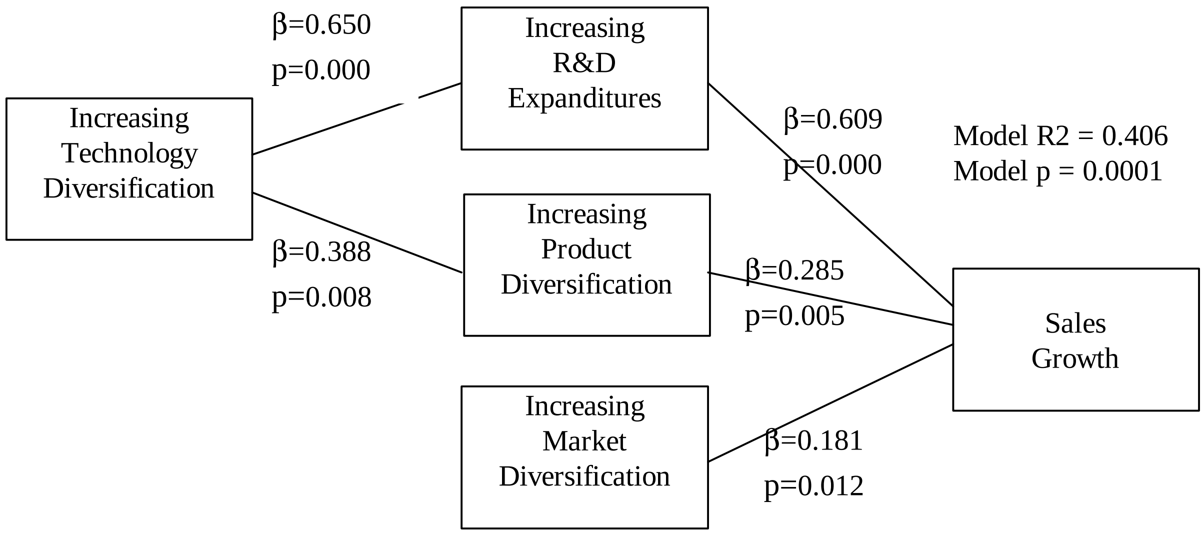

Figure 2. Summary of the test of an explanatory model for the relationship between diversification, growth of R&D expenditures and growth of sales (n=55).

The model in Figure 2 gives support to our earlier reasoning of what explains[56] corporate growth. Sales growth is explained well (R^2=0.406, F=17.797, p=0.0001) by growth in R&D expenditures, growth in product diversification, growth in technology diversification (as an underlying variable for growth in R&D expenditures and product diversification) and growth in market diversification. The link between growth in R&D expenditures and sales growth is strong (β= 0.609, p=0.000). Also, the link between growth in product diversification and sales growth is strong and significant (β= 0.288, p=0.005), as is the link between growth in market diversification and sales growth (β=0.181=0.012). Finally, the link between growth in technology diversification and growth in R&D expenditures is *remarkable strong* (β=0.650, F=30.555, p=0.000). The link between technology diversification and growth in product diversification is also strongly significant (β=0.388, F= 7.658, p=0.008). Thus, technology diversification is an important fundamental variable

[56] The causality between sales growth and growth in R&D expenditures, growth in product diversification and growth in market diversification were tested in three steps. First, the association between the two variables during the same time period was calculated. Second, one of the variables was lagged five years, and a second association were calculated. Third the other variable was lagged five years, and a third association was calculated. The result showed that growth in R&D expenditures probably leads to sales growth, not the opposite. For growth in product diversification and market diversification, no timer lag was identified with sales growth. This is not surprising since product diversification and market diversification are measured as sales in products and markets.

for growth in R&D expenditures, increased product diversification, and even more importantly, for growth of sales. Thus, the results presented in the model above support previous research.

10.5 Patterns of Diversification and Growth in European, Japanese and US Corporations

We will now test the hypothesis (1) that technology diversification increases in all regions and the hypothesis (4) that product diversification increases in Japan and decreases in the US and Europe. In this section we will also analyze whether winning patterns exist or not, and if they are statistically significant.

Table 18 shows tendencies expressed as the average levels of differences and the significance levels of these differences, for sales growth, growth in R&D expenditures, as well as the patterns of diversification concerning products, markets and technologies presented for the thirteen[57] Japanese, fourteen[58] US and thirty European (incl. fifteen Swedish) multi-technology corporations MTC's).

[57] The number of companies was reduced to thirteen because of missing data in one case.
[58] The number of companies was reduced to fourteen because of missing data in two cases.

Table 18. Changes in level[a] of Growth[b], Diversification and R&D[c] between 1980 and 1990 by Region[d]

	USA		Japan		Europe (incl. Sweden)		Sweden		All 57 Observations	
Number of Companies	14		13		30		15		57	
	Average	p(2tail)	Average	p(2tail)	Average	p(2tail)	Average	p(2tail)	Average	p(2tail)
Sales Growth	+0.396	0.006	+1.057	0.001	+0.321	0.002	+0.419	0.009	+0.507	0.000
TDIV Entropy	+0.128	0.000	+0.221	0.009	+0.203	0.000	+0.251	0.006	+0.192	0.000
PDIV Entropy	-0.088	0.158	+0.211	0.007	-0.077	0.006	-0.088	0.069	-0.014	0.443
MDIV Entropy	+0.029	0.433	+0.047	0.917	+0.019	0.910	-0.088	0.100	+0.028	0.730
R&D Growth	+0.770	0.005	+4.434	0.008	+1.224	0.012	+0.848	0.006	+1.684	0.000
Average US Patent Intensity/Employee[e]	1.795	-	3.328	-	1.342	-	0.805	-	2.028	-

Notes:

a) Measured as the differences in relative levels of technology, product and market diversification between 1980 and 1990. The comparisons were made with the entropy diversification index and the Herfindahl diversification index for each variable. All differences that are significant in the table with the entropy index were also significant with the Herfindahl diversification index. The significance test for each region is made with a two-sided Wilcoxon Signed Ranks Test. All significant differences in Table 18 were also significant with the Fisher Linear Discriminant Function.

b) Sales growth for all the analyses in this study is real growth adjusted for inflation and changed exchange rates. The deflation was performed with OECD Private Consumption Deflators. Aggregates were computed on the basis of 1987 GDP weights, expressed in 1987 US Dollars.

c) Growth of R&D expenditures for all the analyses in this study is real R&D growth adjusted for inflation and changed exchange rates. The deflation was performed with OECD Private Consumption Deflators. Aggregates were computed on the basis of 1987 GDP weights, expressed in 1987 US Dollars.

d) 1988 for technology diversification, since 1988 is the last year that patent data are consolidated for in this sample.

e) Operationalized as average annual number of patents per 1000 employees.

As can be seen from Table 18, technology diversification increased significantly in all regions between1980 and 1988. The largest increase in technology diversification was in Japan and in Sweden. Eleven of fifteen Swedish companies and twelve of thirteen Japanese companies increased their technology diversification during this period. Secondly, Japan was the only region with a significant increase in product diversification. Product diversification increased substantially in ten of thirteen Japanese companies, and the increase is significant (p=0.007). The US companies showed a mixed pattern. Product diversification decreased in eight of the fourteen US companies, and increased rather strongly in six of them. The European companies showed a strong product specialization pattern (p=0.006), with 23 (of 30) companies concentrating their product portfolios during the 1980's. These results are consistent with previous research and support the conclusion that technology diversification and product specialization is the dominant strategic behavioral pattern among firms in the West, while the predominant pattern among the Japanese firms is technology diversification in combination with product diversification.

Concerning market diversification, all regions showed a mixed pattern with no clear tendency. For Japan, this was despite rapidly increasing export and internationalizing R&D and production for all the companies, where the pattern pointed towards decreased market diversification during the period. This can be explained largely by a remarkable sales increase in the Japanese domestic market.

Thus, Japanese companies in the 1980's diversified their product portfolios to a larger extent than US and European companies, and the difference is strongly significant when compared to the US, Europe and Sweden. The average US and European companies even *specialize* their product portfolios, which makes the differences between the growth strategies pursued in Japan even more apparent. Thus, Japanese diversification management differs from US and European management.

Obviously there are reasons other than regional for the differences in sales growth among the 57 companies. We will therefore analyze potential technology specific and strategy specific reasons for growth and diversification of products, markets and technologies next.

10.6 Patterns of Diversification and Growth by Technology Domain

We want to explore if there are any technology-specific differences regarding diversification and growth. All 57 companies were classified into four broad technology groups: electronics and computers, chemical and pharmaceutical, machinery and others. Sales growth increased most in the electronics and computers category. The increase was significant compared to mechanical engineering, but not compared to chemistry and pharmaceutical categories. Product diversification increased significantly in electronics and computers compared to (non-electric) machinery, but the difference was not significant compared to chemistry and pharmaceutical. The conclusion we draw here is that, except for with product diversification, strategic behavior regarding diversification does not differ significantly between companies from different technological domains.

10.7 Diversification Strategies for Growth

Here we will explore if there are certain corporate diversification sequences that are associated with high growth. Our 57 observations were classified according to sequences of diversification and specialization of technologies, products and markets.[59]

Four main behaviors[60] were identified[61].

A. Fourteen companies from all regions[62] followed a diversification sequence of first increased technology diversification, followed by product diversification and market diversification. Six companies in this group diversified technology first, then products and their markets last. The remaining eight companies diversified their technology first, their markets second and their products last. Since these companies diversified in all three dimensions, we will designate them as "aggressive diversifiers".

B. Nineteen companies from all regions[63] followed a typical pattern of increased technology diversification first, followed by either product specialization or market diversification, or its reverse, market diversification followed by product specialization. These companies will be designated "stick to the knitting" companies, what could be considered the " Western strategic management style" of concentrating on well known products, and broadening the technology base in order to stay competitive with international competition. Fifteen of these companies increased their market diversification, while four of them also increased their market specialization.

C. Five companies[64] followed a strategy of increased technology diversification followed by product diversification combined with market specialization. These companies will be

[59] It should be noted that we have not analyzed the strategic intent of these companies, only observed behavior concerning diversification of technologies, products and markets.

[60] These patterns have nothing to do with Porters (1989) generic competitive strategies.

[61] There are 64 possible permutations of these diversification strategies. However, only four of the patterns had more than three companies.

[62] 3M, Astra, ABB, Canon, Digital Equipment, Honda, Kyocera, Matsushita, Motorola, Nec, Sandoz, Sony, Toshiba, and Toyota.

[63] BASF, Bayer, Electrolux, ESAB, DuPont, Ford, Glaxo, General Motors, Hitachi, IBM, KODAK, Thone Poulenc, Pharmacia, Lóreal, Nobel, Ericsson, Unilever, Volvo and Xerox.

[64] Sumitomo, Sanyo, Merck, Nippon Steel and Siemens.

named “ market specializers”, since they strengthened their positions with more products and more technologies in fewer markets. All five of these companies had a large part of their sales on the domestic market.

D. Eight companies[65] will be designated “defenders”, since they specialized both product-wise and market-wise and sometimes even technology-wise. It should be noted that the notion “defenders” has nothing to do with the strategic intent of these companies.

Eleven companies followed four other strategic sequences, and all of them either grew slowly or declined. They had neither rapid increase or decrease in diversification, and therefore they will not b analyzed separately in the following analysis, besides that they are included in the total of 57 companies.

We tested sales growth as well as technology, product and market diversification, expressed as average levels of differences and the significance levels of these differences, for the four main categories of diversification strategies identified above (A, B, C, D).

In Table 19 below, pair-wise comparisons are made between the “aggressive diversifiers” and the “stick to the knitting” companies, and between the “aggressive diversifiers” and the entire sample. Only the two most successful sequences of strategies are compared in Table 19, since the other groups of strategies experienced slow growth during the period.

[65] General Electric, Aerospatiale, ICI, FAG, Thomson CSF, Olivetti, Texas Instruments and Philips.

Table 19. Comparisons of Strategy Sequences[a] in Growth, Technology Diversification, Product Diversification and Market Diversification from 1980 to 1990

	Aggressive Diversifiers	Stick to the Knitting		Aggressive Diversifiers	All 57 Companies	
Number of Companies	14	19		14	57	
	Average	Average	p(2tail)	Average	Average	
p(2tail)						
Sales Growth 80-90	+1.161	+0.507	0.002	+1.161	+0.507	0.000
TDIV Entropy	+0.359	+0.214	0.116	+0.359	+0.192	0.010
PDIV Entropy	+0.215	-0.106	0.000	+0.215	-0.014	0.000
MDIV Entropy	+0.106	+0.053	0.701	+0.106	+0.028	0.104

Note:

a) The comparison was made with the entropy diversification index and the Herfindahl diversification index for each variable. All differences that are significant with the entropy index were also significant with the Herfindahl diversification index. The significance test for the strategy differences was tested with the Fisher Linear Discriminant Function. .

The “aggressive diversifiers” grew significantly (and at more than twice the speed) and diversified their product more than the “second best” strategy, i.e. the “stick to the knitting” companies. Furthermore, compared to the entire sample, these companies grew significantly faster and expanded their technology base and product base significantly more than all other companies. Even the (increase in) market diversification was larger compared to the entire population. Thus, we have identified a “winning sequence” of diversification among the 57 companies, where increased technology diversification, followed by either increased product diversification and market diversification, or its reverse, led to significantly higher growth than all other combinations.

Canon is the company which grew fastest of all the 57 companies between 1980 and 1990. Canon also followed the “aggressive diversifier” strategy during the period.

10.8 An Expanded Model of Growth and Diversification

Above we have tested an explanatory model for growth and diversification based on hypotheses derived from previous research. We will now modify this model with the additional knowledge generated so far with an exploratory research approach.

Companies following the “aggressive diversifier” sequence of diversification of technologies, products and markets, have grown significantly more than other companies. We can therefore integrate the “strategic behavior” as an additional explanatory factor behind sales growth in the model. Region is also seen as an explanatory factor behind the “strategic behavior” in the model, since eight of the companies following this strategy were Japanese. Japanese companies also diversify their product bases more than US and European companies. We should therefore integrate the regional (national) differences as explanatory factors behind increasing product diversification.

We have also seen that companies from the electronics and computer technology domains grew faster and diversified their product bases to a larger extent than companies from other technology areas. Therefore we integrated the technological opportunities estimated by technology domain as an underlying factor behind increased technology diversification and behind increased product diversification, as suggested by Granstrand & Sjölander (1992). The suggested modified model is presented in Figure 3 below.

Figure 3. A modified explanatory model for growth and diversification.

To test this model system regression analysis was performed. The following variables were included in the analysis:

- TDIVGROWTH A-B= The growth in technology diversification index between years A and B, operationalized as the difference of the technology diversification index between years A and B.

- PDIVGROWTH A-B= The growth in product diversification index between years A and B, operationalized as the difference of the product diversification index between years A and B.

- MDIVGROWTH A-B= The growth in market diversification index between years A and B, operationalized as the difference of the market diversification index between years A and B.

- SALESGROWTH A-B= The relative growth in sales between years A and B, operationalized as the percentage growth of inflation-adjusted sales between years A and B.

- R&D-GROWTH A-B= The relative growth in R&D costs between years A and B, measured as the percentage growth of inflation-adjusted R&D spending between years A and B.

- REGION= The regional background of each company.

- TECHNOLOGICAL DOMAIN= The major technological domain of each company.

- STRATEGIC DIVERSIFICATION BEHAVIOR= the strategic behavior identified for each company.

The variables presented above were tested in the multiple system regression model:

SALESGROWTH= CONST + R&DGROWTH (TDIVGROWTH(TECHNOLOGICAL DOMAIN)) + PDIVGROWTH (TDIVGROWTH (TECHNOLOGICAL DOMAIN) + REGION) + MDIVGROWTH + STRATEGIC DIVERSIFICATION BEHAVIOR (REGION)

The model was tested for the time period of 1980-1990. Figure 4 below shows the structure, partial standardization correlation coefficients and the explanatory power (R^2) of the suggested model. Feedback loops have been omitted from the analysis because of lack of data.

Model R2=0.597

Model p=0.0001

Not significant =Not significant at the 10% level.

β = standardized partial correlation coefficients.

originated from, was *not significantly* related to either strategic diversification behavior nor product diversification. The reason for this is that the Japanese companies in this study can be divided into two sub-groups. One group consists of nine companies with large increase in product diversification, and one group consists of four companies with either low product diversification, no increase in product diversification, or even product specialization.

Moreover, technological opportunities, estimated as technological domain, were also *not significant* as an explanation for increased technology diversification and product diversification. This is not so surprising, since the differences between the technological domains were rather marginal.

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[66] This is explained by the fact that there is some degree of multi-collinearity between product diversification and the 'aggressive diversifier' strategy, which to a minor extent disturbs the explanatory power of product diversification. However, the statistical analysis (performed in SAS) takes into account multi-collinearity in the model, and the model remain strongly significant with both of the variables present.

10.9 Summary and Conclusions

To sum up, we have used the results from an exploratory statistical analysis to expand the initial explanatory model of growth. Several interesting conclusions emerge. First, strategic diversification behavior turned out to be highly significant and added greatly to the explanatory power of the regression. This clearly suggests that the pattern and sequence of diversification is an independent variable in explaining growth. Second, the previously significant relationship between region and product diversification disappeared. Third, the relationship between region and strategic diversification behavior fails to be significant in spite of the observed "winning pattern" of Japanese firm and the least partial statistical evidence in favor of such a pattern.

The general conclusion is that it is not region, nor technology domain, which truly matter for growth, but *diversification* in all three dimensions (technologies, products and markets) and particularly the strategic diversification management and behavior.

11

Discussion and Summary

11.1 Empirical summary

Some major empirical findings reported upon in previous sections were as follows:

1. Technology diversification at firm level, i.e., the firm's expansion of its technology base into a wider range of technologies, was an increasing and prevailing phenomenon in all three major industrialized regions, Europe, Japan and US. This finding has also been corroborated by Patel and Pavitt (1995).

2. Technology diversification was a fundamental causal variable behind corporate growth. This was also true when controlled for product diversification and acquisitions.

3. Technology diversification was also leading to growth of R&D expenditures, in turn leading to both increased demand for and increased supply of technology for external sourcing on emerging technology markets of various kinds.

4. Technology diversification and product diversification were strongly interlinked, often in a pull-push pattern in economically successful firms, leading to hybrid MPC/MTCs. Thus, one could observe both product related technology diversification as well as technology related product diversification.

5. High-growth corporations followed a sequential diversification strategy, starting with technology diversification, followed by product and/or market diversification. This result was independent of region and industry.

6. Japanese companies had on an average the most developed managerial capability for concerted technology, product and market diversification.

7. R&D grew and the technology base of products and processes became increasingly diversified over a series of product generations, with typically more technology enhancement (diversification) than technology destruction (substitution). Technological diversity could also temporarily decrease due to redefinitions.

8. There are several patterns and types of processes of technology diversification. Just as product diversification may be technology related or not, technology diversification may be product related or not. Product related technology diversification may involve differentiation of core technologies, search for adjacent (neighbouring) technologies, substitution by new technologies, not necessarily “close” in some sense in technology space, and experimentation with entirely new technologies.

9. New and better indicators of technology diversification were also used and developed, e.g. based on the educational profile of engineers. Operationalizations are strongly dependent upon conceptualizations of technologies, however.

10. Corporate R&D is relative US and especially Sweden highly centralized in Japan. A majority of large Japanese corporations had large central laboratories for long-range, strategic, interdivisional R&D. A centralized technology management structure at corporate level was also common. Technology issues were of top concern in the corporations, which all had a vice president with corporate-wide executive powers. Intra-firm (interdivisional, interfunctional) technology coordination and transfer was much attended to and relatively successful, ***much because of intra-firm mobility of engineers and a communication-rich corporate behavior***. These were all management capabilities that were stronger in Japan than in the Swedish and US corporations. Partly they were a consequence of and a necessity for effective technology and product diversification.

11. Corporate R&D is less internationalized in Japan than in the USA and especially Sweden. Internationalization of Japanese R&D has since increased the late 1980s and a particular Japanese mode has been adopted with relatively stronger emphasis on technology sourcing and on utilization of US universities.

12. Intellectual property has since the 1980s rapidly become an area of strategic concern among large Japanese, Swedish and US corporations with a concomitant growth of IP resources, especially in Japan. Japanese corporations organize and manage their IP operations quite different from the traditional IP organization in Western companies. The typical IP department in a large Japanese corporation has evolved into a department which is comprehensive regarding IP responsibilities, relatively large, engineer dominated, embedded in a corporate patent culture, and of strategic concern to business managers, technology managers and top managers.

13. Japanese industry has developed special skills in exploiting new technologies commercially through synergetic product and technology diversification, speed to technology and speed to market, application and user orientation and IP protection, licensing and patent monitoring. Patents were considered by Japanese corporations far more important for commercializing new technologies compared to Swedish and US corporations who rather emphasized marketing.

In summary, there are stark dissimilarities between technology management practises in Japanese, Swedish and US corporations. The studies reported upon here were designed to identify national and corporate differences in technology management, rather than sectorial differences. To the extent sectorial differences could be compared to national differences the latter seemed to dominate. This would mean that corporate innovation systems are more national than sectorial in character. Let us therefore focus on national differences and why they arise.

11.2 Technology management in Japan

There are several good writings available in English on Japanese technology management and related matters. See e.g. Branscomb and Kodama (1993), Bowonder and Miyake (1993), Eto (1993), Fransman (1995), Funk (1993), Imai (1986), Kenney and Florida (1993), Kodama (1995), Liker et al. (1995), Miyazaki (1995), Nonaka (1990), Nonaka and Kenney (1991), Okimoto and Nishi (1994), Sigurdson (1996), Urabe et al. (1988), Yamaji (1997), Woronoff (1992).

What then characterizes Japanese technology management? According to Westney (1993, p. 37), commonly recognized characteristics of the technology behaviour of Japanese firms, compared to US firms, are as follows:

1. Shorter development times
2. More effective identification and acquisition of external technology, on a global scale
3. More effective design for manufacturability
4. More incremental product and process improvement
5. Innovation dominated by large rather than small firms
6. Greater propensity for competitive matching of products and processes
7. Greater propensity for interfirm collaboration in developing technology
8. Greater propensity to patent
9. Weakness in science-based industries, for example, pharmaceuticals, chemicals, biotechnology

Several of these general characteristics have been corroborated in our research as well, such as shorter development times, skills in acquiring external technology (including using interfirm collaboration), incremental and coordinated product/process improvements, high patenting propensity and skills, and the remaining weakness in certain science-based industries.

In comparison with the Swedish corporations in the corporate samples studied here, Japanese corporations had (cf. the empirical summary above):

1. A higher degree of technology and product diversification.
2. More centralized R&D resources, with larger corporate R&D labs.
3. More centralized technology management structures with various committees, executive VPs for technology, more technologists in top business management, and larger corporate staffs, e.g. for technology planning and IP.
4. A much lower degree of foreign R&D.
5. A higher reliance upon US universities in technology sourcing.
6. A much lower propensity to acquire and spin-off small, innovative companies.
7. A lower propensity to use special organizations or units for corporate venturing.
8. A seemingly lower propensity of NIH-effects and conflicts among professional S&T subcultures.
9. Significantly larger patent portfolios with larger technological diversity.

How do differences like these in corporate innovation systems arise? Institutional factors (like the Japanese patent system or employment system) naturally play an important role, as well as geographical factors (like the scarcity of natural resources in Japan and abundance in the USA) and political and demographic factors (like the large domestic market in the USA and the small one in Sweden). However, an important set of factors that will be emphasized here is the historic and stage-specific factors of a nation's industry.

Especially, the unique catch-up of Japanese industry has to a considerable extent shaped , created or reinforced several unique features of corporate innovation systems and technology management capabilities in Japan. Section 9 described this with regard to commercialization skills. For example, it is quite natural that in a catch-up stage one has to move faster than the leaders. Many managerial capabilities have developed due to this simple condition, e.g. speed to market techniques (see Cordero 1992 for a survey), concurrent engineering and tight coordination of R&D, production and marketing.[67] It is also natural in an initially resource-scarce catch-up stage to learn how to acquire new technologies cost-effectively from outside through various means and economize upon them through technology leveraging through transfer and sharing. In identifying new technologies, reverse engineering and patent monitoring and protection skills are also

[67] Note that the M-form, which most large corporations in Japan, Sweden and the USA has adopted improves such coordination compared to the previously prevailing U-form. Still the interfunctional coordination has been sequential rather than concurrent in Western companies.

instrumental and developed accordingly (see Granstrand 1999). As a result NIH-attitudes among engineers, aggravating coordination, did not develop as much as in traditional leading companies in the West. Also, small step-by-step product improvements, process cost control and ‘trickle-up’ marketing become natural in a catch-up stage. Japanese companies could also select from a wide array of managerial concepts and techniques, mostly with US origin, those that were conducive for a technological catch--up and then adapt and gradually improve upon them in the course of the process.[68]

An important political factor, contributing to the development of commercially viable management capabilities in Japan, has been the absence of a large military-industrial complex (at least in the past) and the presence in the USA of such a one, USA, being at the same time the primary foreign market for Japanese industry. This is a too large issue to be dealt with here. Suffice to say that technology management as well as marketing management for civilian and military customers differ substantially (see e.g. Granstrand 1982). Although there are dual civilian/military use and spill-overs between civilian and military industries of management concepts and techniques (like PERT, CPM and OR), as there are regarding technologies as such, military technology management capabilities are rather deceptive and counter-productive in civilian settings. Thus, Japanese industry could grow appropriate managerial capabilities for commercialization at the same time as many of their main competitors on civilian markets were hampered in this respect by dysfunctional influences from their military businesses.

A pending issue now is to what extent managerial capabilities and corporate innovation systems developed under primarily a catch-up regime, are also functional in a new stage, in which catching-up is no longer the primary goal but rather forging ahead. This issue was briefly raised in section 9. If managerial capabilities (and corporate innovation systems) are to some extent stage specific, a certain degree of convergence of best practice managerial trajectories could be expected when corporations enter the same stage (at least after any transient effects).

There are some factors contributing to such a convergence. First, internationalization of management research, education and consulting, disintegrated from industrial corporations, by and large favor managerial convergence. Second, a certain global dominance of relatively homogeneous US influences contribute expecially among MNCs.

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[68] As described in Fransman (1994) also managerial innovations considered typical Japanese, like JIT and Kanban, also evolved in a piece-meal fashion, often as a pragmatic response to Japanese weaknesses.

Third, unpatentability of managerial ‘inventions’ facilitates their diffusion in principle.[69] At the same time imitation of managerial capabilities is not easy due to their tacit nature and embodiment in organizations and people. Managerial techniques resemble production techniques in that they are not easily reverse engineered and could more easily be protected by trade secrets.[70] Mobility of managers counteract this tendency, however. A fourth factor then is mobility of top managers across MNCs and across nations, which seems to increase, although slower in some countries (like Japan) than in other (like Sweden). Fifth,cross-national mergers also likely contribute to a reduced variety of managerial best practices, if not convergence.

There are also a number of factors counteracting any managerial convergence tendency. In principle a high rate of managerial innovations with a slow diffusion would do so, as would the presence of multiple equilibria (optima) and uncertainty among managers about them.

11.3 Rise of quasi-integrated corporate innovation systems

The preceding sections have shown that external acquisition of technology is an increasingly important strategy at both company and product levels.
A natural question now is what are the causes to and effects from external technology acquisition. A direct link from external acquisition of technology to economic performance has not been possible to find in the data. However, technology diversification seems to be a fundamental causal factor giving rise to both increasing R&D costs and increasing external technology acquisition. Pressure to keep R&D cost increases down and to keep R&D times low (R&D times in general do not increase as fast as R&D costs at product level) leads to an increased propensity to acquire new technologies externally, i.e. to an increased demand on the external market for new technologies, everything else equal.

Technology diversification is moreover leading to growth of sales. Thus, external technology acquisition enters as an intermediate variable between technology diversification and sales growth and in that sense is complementary to technology diversification, which contributes to economic performance.

However, the benefits from technology diversification and external technology acquisition do not come automatically but are realized through effective technology management. Technology diversification at product level justifies the notion of multi-technology products

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[69] The recent practice to grant patents to business methods as well as to management methods embedded in patentable software may change this condition, at least to some extent.

[70] Industry has traditionally been fairly open regarding their management techniques, but indications are that secrecy about them increase.

– or “mul-tech” products for short. While “hi-tech” products typically refer to products with high R&D content (high R&D intensity or high R&D value added), based on recent technological advances not widely available on technology markets, “mul-tech” products refer to products that are based on several technologies, which do not necessarily have to be new to the world or difficult to acquire. (The two concepts are not mutually exclusive, however).

Although products, as well as the processes by which they are produced, may have both hi-tech and mul-tech features as mentioned, the emphasis and style in technology management differs between the corresponding two types. Technology management for hi-tech products typically emphasizes such things as scientific creativity, advanced customer demands, elitist recruitment, technological leadership and technology protection. Technology management for mul-tech products on the other hand typically emphasizes such things as technology scanning and other forms of external acquisition of technology, combining innovation and imitation (rather emphasizing improvements than major technological breakthroughs), technology synergies and fusion, composing inter-disciplinary R&D teams, avoidance of NIH-effects and communication and coordination in general.

Differently expressed, we have observed a rise of what may be called quasi-integrated corporate systems of innovation, in which different strategies with different degrees of organizational integration are recurrently used to acquire technologies. To manage technology and innovation effectively in such a system requires a broader range of social, economic, legal and engineering skills and responsibilities (e.g. being able to play the technology market) and different emphasis than traditional management of in-house (fully integrated) R&D. Not that external technology acquisition is a substitute for in-house R&D at company level (at product level it may be). For example, in-house R&D is often needed in order to access and absorb external technology. In fact, different strategies for external technology acquisition are complementary to in-house R&D at company level.

What then could be said about the optimal degree and form of external technology acquisition? Unfortunately, not very much at present, except to point at the risks connected with a high reliance on external acquisition. Rising R&D costs and economies of speed are likely to stimulate demand of external technology.[71] Rising R&D costs also stimulate supply of technology on the market, especially from product specialized producers of generic technologies with many applications with a lack of competition between supplier and buyer. The notable worldwide increase in a number of firms with leading-edge R&D and increased diffusion of technologies also increase potential supply of technology as does the availability of substitute or competing technologies. As rebuys of the same knowledge is unnecessary

[71] Assuming that the market for technology is competitively efficient.

first mover advantages occur among suppliers, which increase their propensity to sell ("If we don't sell, someone else will"). However, the strategic value of some other firm's technological leap in a key technology could raise the risk of fore-closure or sustained and/or discriminatory release. Having something to offer based on unique in-house R&D in complementary technologies then gives a "ticket of admission" (e.g. to patent-pools, cross-licensing arrangements, collective R&D and other forms of swapping technologies) and could mitigate such risks.

Thus, beyond some point internal technology acquisition, i.e. in-house R&D, would be advisable for risk reduction purposes. More in-house R&D would lead to higher R&D costs, however, but if the in-house technologies are common to several products or processes the product development and manufacturing cost per product could be kept low. This then raises the issue of product diversification as a strategy to limit external technology acquisition as well as a strategy to spread R&D costs as an alternative or complement to spreading them through market diversification into more market segments, applications or geographic regions (typically through internationalization). In connection with product diversification, it is important to distinguish between the different types of shared input that give rise to economies of scope (management, finance, technology, materials, etc). Here technology-based product diversification is considered, in contrast to the traditional management and finance oriented product diversifications, that mostly have proven not to be successful in the West in the last decades, as is well known. The amount of technological synergies among different products is crucial to curbing R&D cost increases from product diversification, of course. An example of a successful technology based product diversification is Ericsson's move in the 1980's into mobile communications, using its switching technology. On the other hand, Ericson's move into personal computers , also in the 1980's, was lacking technological and especially marketing synergies and for this and other reasons became unsuccessful.

Thus, consideration of risks associated with external technology acquisition strategies plus rising R&D costs ought to lead technology-based companies to consider technology-based product diversification as a company development strategy. Figure 5 depicts this consideration as a strategic choice for expository purposes and also summarizes the discussion above.

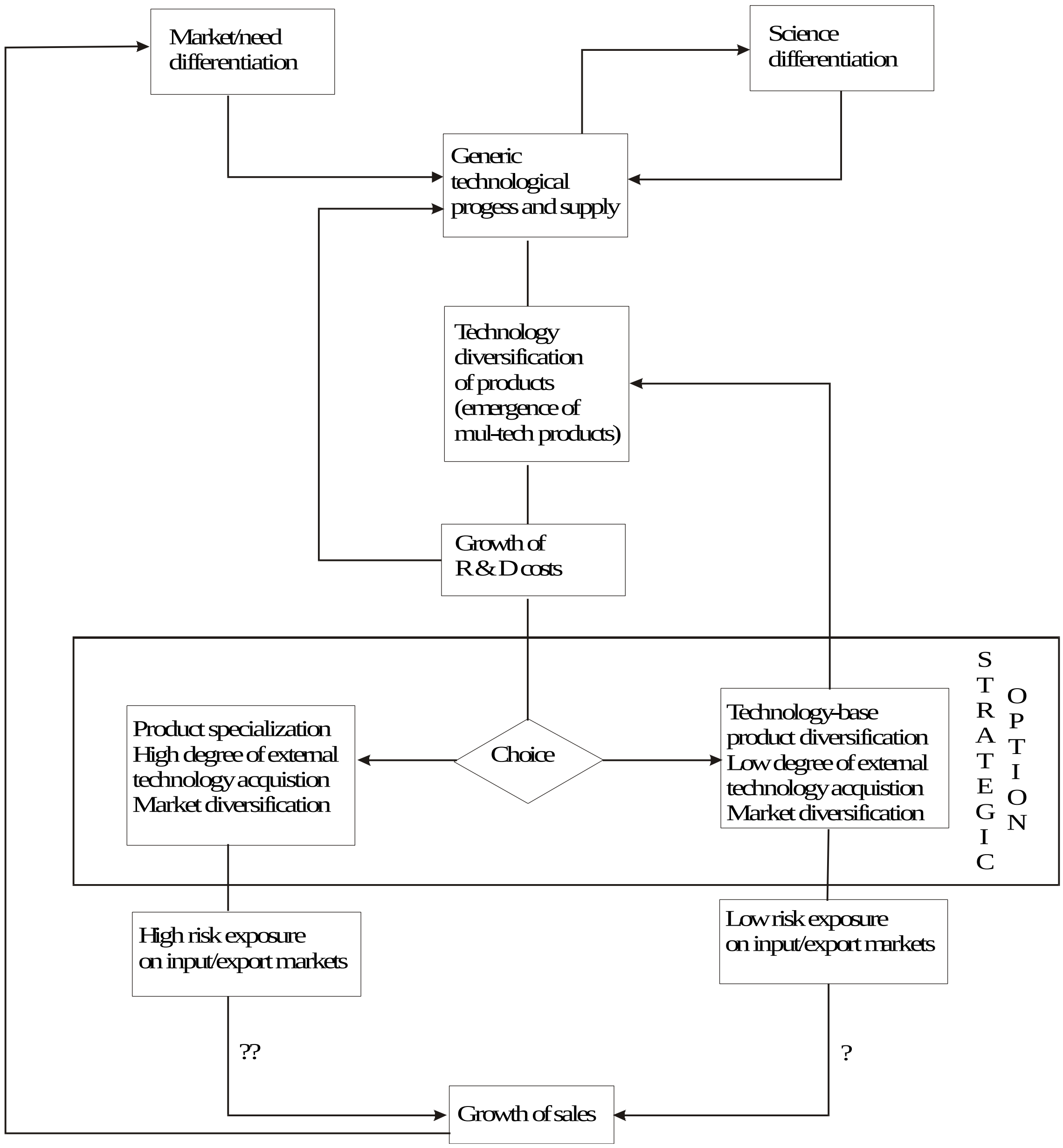

Figure 5. A strategic choice of technology management in "Mul-tech" Corporations

11.4

Evolution of Managerial Capabilities

In neo-classical economic theory the management factor enters only as an assumption about managerial behavior as maximizing something, usually profit or some more general utility measure. In my opinion the crucial inadequacy of this assumption is neither that managerial behavior is equated with a maximizing algorithm, nor that profit or some more general utility is maximized, but that it fails to consider the uneven distribution of limited managerial knowledge, skills and learning capabilities. In fact, an assumption which associates an extreme trajectory in an abstract space with the behavior of the management of a firm is flexible enough to deal with a range of objections based on notions of satisfying behavior, bounded rationality, imperfect information, multiple goals, sequential attention to goals and the like. But as long as all managers are assumed to be equally skilled in maximization with equal access to information and other factors of production, the theory will fail to explain differences between firms. This may, however, be done by varying the starting conditions of the firms in a dynamic model, by introducing differences in access to information, by varying the values used by management in maximizing or by simply introducing random elements to reflect pure luck. But what reason would there be then for not differentiating the qualities of management, including the quality of managerial learning? It is to be noted that profit is clearly recognized by Schumpeter as an entrepreneurial motive in capitalist economies but at the heart of his argument is also the view that entrepreneurial talents are skewly distributed in population.

It may be argued that much of the ignorance about the management factor in economic theory has more to do with a lack of empirical insight and difficulties in incorporating management qualities in quantitative analyses than with the level of aggregation in analysis. To support the last statement, attention may be drawn to a few examples. In comparing economic performance among different nations, attributions to differing qualities of management in industry are not uncommon. The shift in topics for public discussion during the 1960's from a technology gap to a management gap between the United States and Europe illustrates this point, as does the later discussion of Japanese methods of management. In addition to management styles, management education and research may also be compared at an international level. At the sectoral level, the notion of innovation by invasion (Schon 1967, Utterback 1994) may illustrate different qualities of management in different sectors of industry, and managerial backwardness in some sectors. At the level of the firm, there is a skew distribution of entrepreneurial talent as Schumpeter claims, which for example could imply a tendency of the same firms to persist for some time at least to be pioneers through innovating.[72]

[72] However, there does not have to be a similar distribution of managerial talent in a wider sense since imitators may be just as economically successful as innovators as may late adopters in relation to early adopters of an innovation.

The economies of managerial knowledge has been recognized at least since Adam Smith, and associated with questions of the questions of division of labor, co-ordination, resource allocation, competitive behavior, size and efficiency, etc. Also, a division of management itself into different specialities, functions, roles and so on has long been recognized and notions about the corresponding economies attached to it. Penrose (1972 [1959]) includes marketing, financial and research economies in managerial economies. Also, there are managerial diseconomies, associated with limits to size, growth and diversification of a firm. This is a common view, and sometimes references are made to “the law of diminishing returns of managerial control”. Such a “law” then has implications for questions about market structure and limits of management. However, any implications of that kind would have to be modified when technological and managerial innovations are taken into consideration. Certainly the operations of a multi-national corporation of today are more complex than those of a large firm century ago, but managerial knowledge has increased and so has the stock of available management tools, including technological innovations such as the telephone, the computer and the Internet, therefore, has not necessarily become more difficult. On the other hand, the cumulation of knowledge and tools for management leaves more room for differences in utilizing available knowledge and tools among different firms. The skewness in the distribution of managerial qualities in industry does not necessarily increase as a result of such a cumulation, but at least the range of possible variation has increased, although not necessarily in the top tail of management best practices.

Managerial innovations, together with technological innovations, could thus be viewed as dynamic factors in an economy, which not only change optima and limits of production but also change optima and limits of market structure and management itself. A high rate of managerial learning in a less efficient economic system could – on pure logical grounds if nothing else – very well lead to superiority over an initially more efficient economic system with a low rate of managerial learning.

While it is clear that technological innovations influence management and may partially be substitutable with managerial innovations, one may ask how management influences technological innovations. If both the technology factor and the management factor are important for economic development, their joining in the form of technology management should be particularly important. It is important in this context that technology management is interpreted in a wide sense as influencing technological innovation through managerial action at different levels. Technology management is thus not just confined to, say, management at some R&D department or laboratory level, but encompasses as well external technology sourcing and exploitation and the exercising of corporate entrepreneurship. At the same time it must be remembered that it is certainly not the case that R&D and technological innovation could be perfectly controlled.

It may be observed that in a competitive economy with qualities of technology and management among the means for competition, an increased complexity in the corporate environment and an increased information load on management reinforce the effects on skewly distributed managerial talents. Part of this complexity derives from technological innovation, which thus upgrades the importance of the management factor. Schumpeter's view that the "creative destruction" in the "perennial gale" of technological change is the only important form of competition in the long run then places emphasis on technology management (Schumpeter, 1976, pp. 83-85).

Thus, there is an important interplay between managerial and technological innovations. There is also an important interplay between the growth of managerial and technological knowledge and its manifestations as artefacts. (Managerial artefacts would include, for example, formal organizations, contracts and adopted organizational routines and policies.) There are effects from learning by doing both regarding technological innovations and managerial innovations. It is thus conceivable that experimentation and innovation lead to incremental adoption of different organizational forms, the efficiency of which will change over time depending upon the state of both management and technology.

Apart from learning by doing one might ask about the role of management science (in a broad sense) in managerial evolution. Looking at the stream of managerial end technological innovations over time one may conclude that knowledge about managing technology has increased considerably during recent decades. However, it has largely been true that management theory has been lagging behind management practice, at least the best practice. It is also true that so far research in management seldom has been a source of radical managerial innovations. Systematic, scientifically, oriented empirical studies appear to be able to contribute more to the gradual improvements in management. By analogy with the increasing role of science in technological innovation, one may hypothesize an increasing role of management science in managerial innovation in the future. It is quite conceivable that the art and science of management at enterprise as well as national levels is (perhaps slowly) becoming more closely related to social science just as well as engineering art or handcraft has become more closely related to natural science over the last centuries. In particular one can argue that not only is management increasingly becoming an object of scientific inquiry but also that management practice increasingly draws on results from such inquiries, although perhaps still to a small extent.

11.5 Some Policy Issues

It is pre-maturely to draw firm policy conclusions from the little evidence we have on the issues raised in this paper. However, a wide array of policy issues, could be raised, e.g. regarding the functioning of markets for labour, capital, technology and corporate control. Some of them will be briefly indicated here.

A first policy issue that naturally comes to mind is whether the formation of large, multi-technology, product diversified corporations and their quasi-integrated corporate systems for innovation should be stimulated. How could such corporate systems of technology and innovation be an efficient component in a national system of innovation and technology, as elaborated by Freeman, Nelson and others?[73] Keeping in mind the successes of many large Japanese conglomerates and the failures of many Western large conglomerates this is not immediately clear. Moreover, they could function as important "technology carriers" in a nation but then perhaps at the expense of the development of a necessary stratum of small and medium-sized technology-based companies.[74] Large firms acquiring small ones increases in frequency and further thins this stratum, but on the other hand stimulate mutual growth as shown in Granstrand and Sjölander (1990b). Thus, a system consisting of large technology based firms interacting through acquisitions and spin-offs with a sufficiently sized population of small, technology based firms, specialising in early stage innovation is conceivably innovation and efficiency inducing.

Moreover, a diversified portfolio of product specialised companies, highly subjected to competition as is the case in Sweden, could also conceivably substitute for a higher degree of integration into product diversified corporations. What is crucial in this context, however, is the proper functioning of various mechanisms for technology transfer among and between firms, large and small, and their divisions and functions and between firms and other institutions of S&T and within and between regions. A second policy issue thus concerns how technology transfer and diffusion in various dimensions could be stimulated in order to reap technological economies of scope. Since technology is most effectively transferred through individuals, the movements and communication behaviour of scientists and engineers should primarily be considered. First of all, geographical and cultural proximity is of importance, and the agglomeration economics of a region like Silicon Valley have been much praised in this respect (despite its congestion problems). However, technology transfer is a complex issue with many aspects.

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[73] The important role of a national system of innovation has been cogently pointed out by Freeman (1987) in his analysis of Japan. The benefits of product diversification in relation to R&D has been pointed out in a classic article by Nelson (1959).

[74] See Granstrand and Sigurdson (1985) for the contrasting cases of entrepreneurship in Korea and Singapore versus Taiwan and HongKong.

For example, high inter-firm mobility of engineers (as e.g. in Silicon Valley) is said to contribute to technology transfer among firms. To some extent this is true but, on the other hand, a firm is not very inclined to invest in training an engineer, nor to entrust him with proprietary information, if the engineer is expected to leave the firm in a couple of years, even if the engineer may be hired back in the more distant future, which sometimes happens. The incentives to invest in human capital is higher with life-time (or rather as is in fact the case in Japan – long-term) employment, and long-term employees can be more safely entrusted with proprietary information. Second, a high level of intra-firm mobility of engineers and communication among different functions of the firm (R&D, manufacturing, purchasing, marketing) is desirable from the point of view of transferring technology between R&D, manufacturing and marketing stages, as is mobility of engineers between product division for transferring technology among them, which is crucial in a multi-technology corporation. As increasing product complexity and customer functionality require many technologies to be combined, the ability to select, access, transfer and absorb different technologies becomes increasingly critical for a firm. It is clear that NIH-effects and territorial instincts are hampering technology transfer and cross-disciplinary work. It is less clear whether technology transfer is speedier and more effective within firms than between firms. This depends not only on the engineer mobility pattern and NIH-effects but in general on the relative effectiveness of market mechanisms versus management efforts and organisational behaviour. Certainly, there is much evidence of the shortcomings of market mechanisms in trading technological information. In the case where technology is embodied in persons who in principle trade themselves on the labour market, there are long-run limitations of inter-firm engineer mobility in transferring especially advanced technology due to appropriability problems perceived by the technology generating firms. The limitations are less severe for less advanced and more widely diffused technology. This, in turn, points at the perhaps overriding advantage of intra-firm technology transfer – under the assumption, of course, that the technology in question is available in-house – namely that it is potentially speedier than inter-firm technology transfer, everything else equal. However, it might not be less costly if the corresponding in-house R&D cost is taken into account. On the other hand large, diversified Japanese firms have the advantage that they can spread their fixed R&D costs for technologies common to several products through their internal technology transfer processes without incurring too much of additional variable costs. Thus, their average technology costs for a product are lowered. At the same time their technology transfer and absorption processes may be speeded up by transferring technology through movements of engineers. This casts some doubt on the contribution of a high degree of inter-firm engineer mobility in a country to her international competitiveness, compared to a high degree of intra-firm engineer mobility in her large corporations.

Regarding in-university teaching one may ask whether there is too much emphasis on advanced specialist training and too little on interdisciplinarity. The training of "hybrid" engineers (rather than true generalists) mastering a few specialties might be a good thing, that is scientists and engineers bridging e.g. mechanical and electrical engineering or biology and chemistry. Moreover, the prestigious aura around advanced science and hi-tech cultivated in some universities in some countries more than in other contribute to a culture that may even be counter productive to industrial innovation and competitiveness.

Finally, it must be kept in mind that these policy issues are broad and complex and could not be dealt with on the basis of simple categories or just a few variables. Hopefully, studies of phenomena like technology diversification, technology markets, and multi-technology corporations and corporate innovation systems could throw some light on them from a new angle. Managerial capabilities then play the role of intermediate varibles in the interplay between technological changes and economic performance. While economics has, since a few decades, recognized the surprisingly great role of technological change in economic growth, it has still as a scientific discipline to come to grips with the role of the complex management factor.

12

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