The economics and management of technology trade: towards a pro-licensing era?

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Abstract: This paper summarises a sequence of studies of technology trade and strategies for acquisition and exploitation of technology in large corporations in Sweden, the USA and Japan during the 1980s and 1990s. Licensing in and out, and technology trade more generally, have old origins but have played only a marginal role in most companies across industries as a co-evolving complement rather than substitute for internal R&D and product sales. However, external acquisition of technology through acquisitions, joint ventures, technology purchasing and intelligence was found to have increased substantially in recent decades across sectors in large Japanese, Swedish and US corporations. With the advent of the pro-patent era in the 1980s and the concomitant surge in patenting and IP activities more generally, a pro-licensing era could be hypothesised to follow. Various empirical studies and observations have also recognised the growing importance of technology markets in general and the growth and changing nature of licensing.

Keywords: strategy; licensing; technology trade; technology markets; intellectual property.

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1 Introduction

Buying and selling on some kind of technology market has taken place for centuries. It is nothing new, although it has never commanded a significant role compared to other forms of trade due to various factors, such as the inherent difficulties in trading information and knowledge in general [1–6]. The patent institution, going back at least to the 15th century, has been created to stimulate not only investments but also trade in new technologies, but has traditionally had only limited impact. However, a so-called pro-patent era has emerged since the early to mid-1980s, mainly as a consequence rather than a cause of the emergence of a new type of economy [7]. It is thus natural to ask whether there is, or will be, an emerging pro-licensing era connected with these developments. The purpose of this paper is to probe this question in general. The paper therefore summarises a series of studies before and after the advent of the pro-patent era to see if significant changes have occurred.

2 A framework for analysis

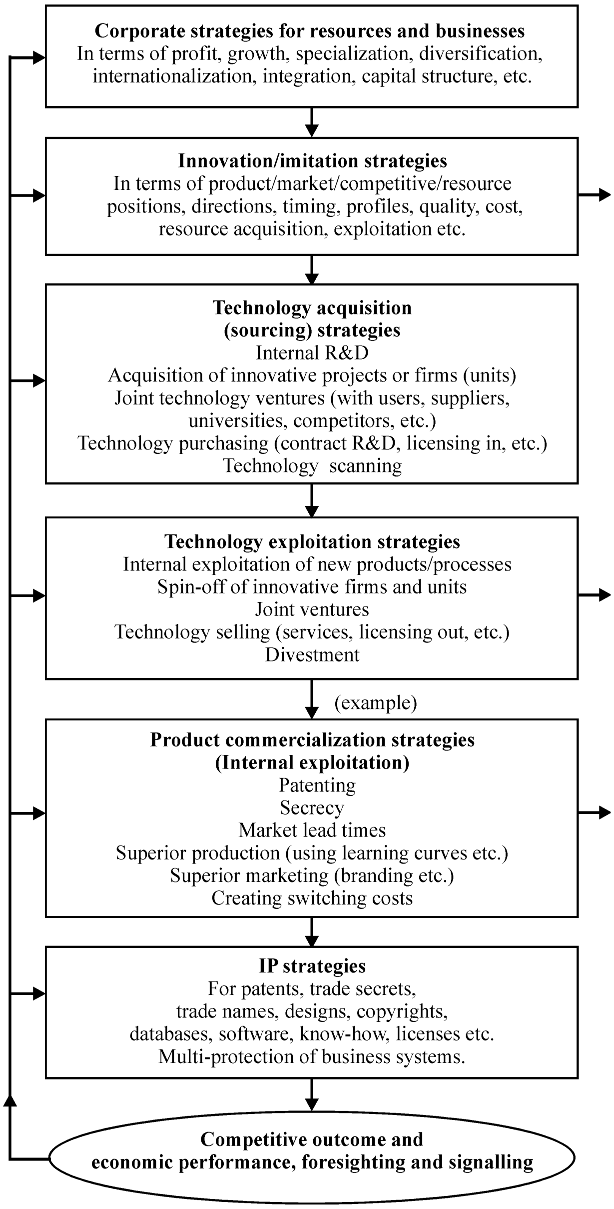
2.1 Concepts

Technology, being by definition a body of technical information and/or knowledge, can appear in a market transaction as embodied in people, products and/or companies, or as disembodied (still possibly with a physical fixation, e.g. on paper, tapes or discs). Technology trade, i.e. purchasing (buying) and selling technology on some kind of market, thus appears in many forms. Pure technology trade, in a narrow sense of trade of disembodied technology, is also a special form of technology transfer as well as a special form of trade. Two conceptual difficulties then arise. Firstly, technology trade has to be separated conceptually and empirically from other forms of trade. It may then be difficult to separate out the technology trade component in a joint venture, company acquisition, or delivery of, for example, a technologically advanced telecommunication system or chemical plant involving a great deal of 'software' with perhaps engineering and management services, education of customer personnel, technical documentation and after-sales services. Secondly, technology trade has to be separated from exchange or diffusion of technical information in general, possibly on an explicit or implicit barter basis. Flows of legal rights, money, information, materials, or services may then not be synchronised to such an extent that one can readily identify discrete market transactions. For example, the exchange of information in a community of technologists may be guided by quite subtle quasi-market mechanisms as reported by Rogers [8] and von Hippel [9]. Together with economic and accounting difficulties in valuation and pricing of licences (see below), these conceptual difficulties make official technology trade statistics very error-ridden.

2.2 A typology of generic strategies for acquisition and exploitation of technology

As technology in the post-war era has gradually gained top management attention as a strategic asset in most companies, a concomitant need to integrate technology strategies into corporate business strategies has emerged [10]. Since such integration does not come readily, a gap between these strategy levels has often been recognised. As intellectual property (IP) issues have also gained strategic attention in the pro-patent era, a similar gap has emerged between IP strategies and corporate business strategies. Figure 1 is one attempt to bridge these gaps by means of a 'strategy ladder' with steps to be taken in an iterative fashion in formulation and integration of strategies at different levels in a technology-based firm.

Figure 1 Types of strategies for the technology-based firm

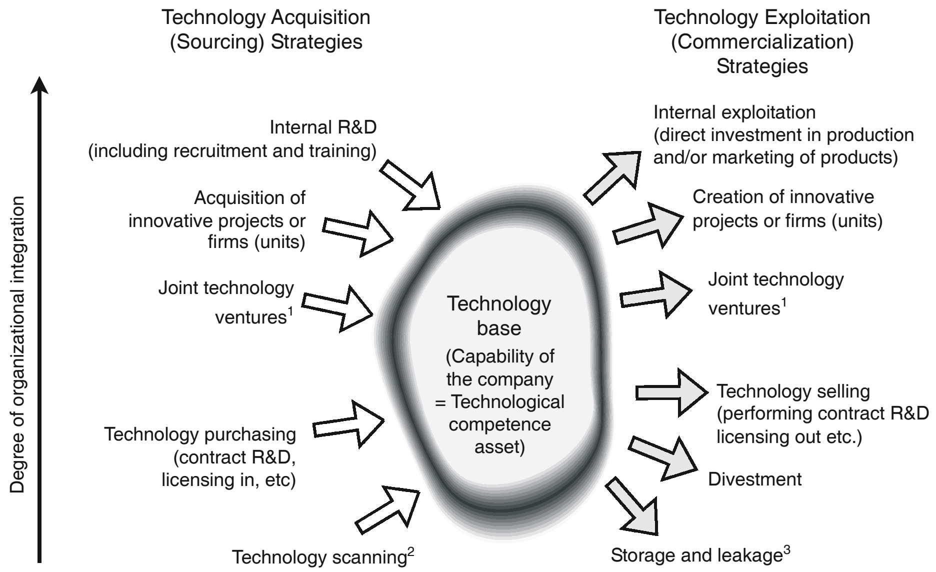


Source: Adapted from Granstrand [7]

At corporate level, objectives and strategies are formulated in the standard strategic dimensions of profits/profitability, size/growth, specialisation/diversification, internationalisation etc. for the corporation as a whole, typically encompassing a portfolio of interdependent products or businesses, markets and technologies. At each product or business area level, similar strategic dimensions could then be used, but be more specific as to innovation and imitation, competitive positions, resource acquisition and exploitation, investments, financing, R&D, production, marketing etc. A key resource here is technology.

A central notion at technology level is the technology base of a company as well as of a product. The technology base of a company is essentially the aggregate asset of the technological competence or capability (knowledge and skills) that the company possesses or controls, and thus encompasses (without being confined to) the technology bases of the various products of the company. As an asset the technology base can be acquired, developed and exploited in various ways. Thus, with this view, a typology consisting of a set of different technology acquisition (or sourcing) strategies for building up the technology base, and a set of different technology exploitation strategies for exploiting it, could be constructed. The basis for this typology is the type of contractual form for supplying and appropriating technology, including the absence of contracts which fall under the categories of technology scanning, storage, loss and leakage; see Figure 2. The different strategy types have been identified from empirical observations (see Section 3 below).

Figure 2 Generic strategies for acquisition and exploitation of technology [7]



Notes:

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

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

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

The typology has then been theoretically consolidated so that the different contractual forms are ordered according to falling degrees of managerial (or organisational) integration, or conversely, according to increasing degrees of external technology acquisition and exploitation. *Internal R&D* is based on the employment contract and thus constitutes a high degree of integration, implying basically a hierarchical relationship. In transaction cost terms, the asset specificity of human capital in R&D and innovation explains and requires a high integration of R&D personnel with an innovative firm, mainly due to the high degree of tacitness of entirely new technical knowledge [11]. Secondly, *a firm's acquisition of an innovative firm or out-house project* may be regarded as an extension of the firm, since the acquired unit also uses employment contracts. However, buying (contracting) a portfolio of employment contracts means that contracting is compounded, so it is not clear-cut how to assess the overall degree of integration from pre- and post-transaction degrees. Since licensing often leads to joint ventures, in turn sometimes leading to acquisition in a multi-stage integration process rather than the other way around, there is additional reason to regard acquisition as having a higher degree of innovation than joint ventures. This assessment is of course complicated by the fact that the acquired unit may not be fully owned, and moreover it may take time (by design or default) to integrate the acquired unit. The degree of integration for *joint ventures* is lower than for acquisitions also since several firms are involved, regardless of whether the joint venture is informal or formalised with company status with separate owners.

The category *technology purchasing* comprises a wide span of contractual forms and may thus be further decomposed, here into two main sub-categories: contract R&D and licensing in. This has been done in the questionnaire studies reported in Section 5. Of these two sub-categories, contract R&D generally has a higher degree of integration as the seller usually promises to supply the buyer with results and information to be controlled by the buyer [12,13]. Licensing in is often non-exclusive with other licensees using the same information, including the licence seller. Moreover, contract R&D may, depending on the particular case, have similarities with an employment contract if, for instance, the contract is of long duration, the buyer is dependent on the seller's facilities, etc. *Technology scanning*, finally, is not a contractual form but includes legal, semi-legal and illegal forms of acquiring technological know-how from the outside with no explicit purchase contract involving the original technology source (albeit possibly with intermediate agents).

The *technology exploitation strategies* follow the same order of integration as the technology acquisition strategies, and the reasoning above on technology acquisition strategies applies with similar logic to technology exploitation strategies.

The different strategies for technology acquisition and exploitation could now be combined into different segments of a value chain (or value network). Table 1 shows examples of how companies may base their dominant business idea and business model on various such combinations. Most companies work with many combinations altogether, however. Table 1 highlights licensing but could be extended to include examples of joint ventures as well, e.g. a 'network firm' operating substantially with joint ventures for both sourcing and exploitation (cf. a news agency). Different technologies and sub-technologies could moreover be distinguished in the technology base, and different pairs of acquisition/exploitation strategies applied to them.

Table 1 Examples of combinations of technology acquisition and exploitation strategies

	Technology exploitation strategy		
Technology acquisition strategy	*Internal exploitation*	*Divestment/ Spin-off*	*Licensing out*
Internal R&D	Traditional engineering companies[1]	Friendly (rather than hostile) spin-off schemes Corporate venturing De-diversifying firms	Start-up firms (e.g. in IT and biotech) Stand-alone licensing firms Rare and risky[2]
Acquisition	Large firms acquiring small innovative firms for integration	Corporate venturing units with external entries and exits	Large firm acquiring an engineering consultancy firm
Licensing in	Japanese companies, especially in the 1960s and 1970s	Rare but conceivable for venture companies	Licence broker/dealer

Notes: [1] Usually using other strategy mixes as well, but with a dominance of internal R&D and internal exploitation through in-house integration of production and product marketing.

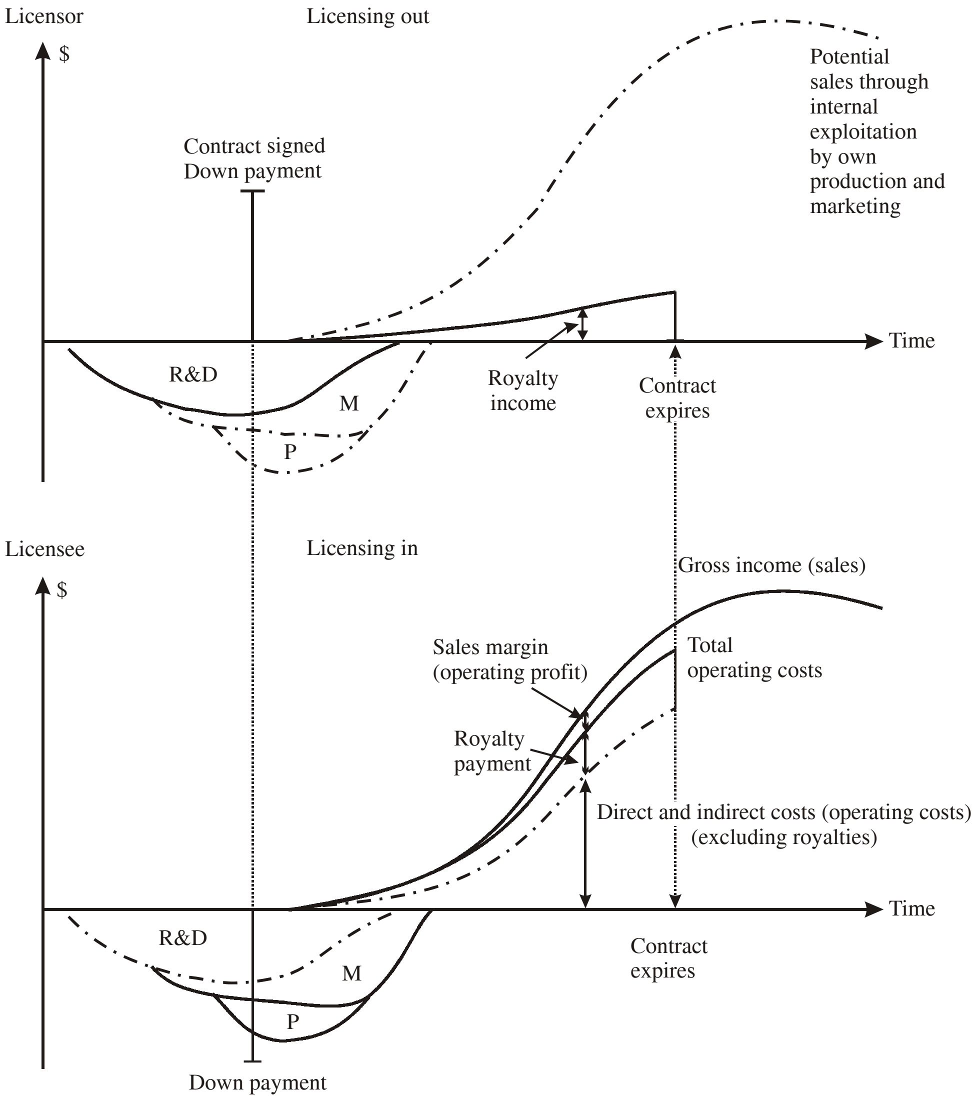
[2] In the software sector the risk is lower and the strategy mix more common, with perhaps Microsoft a case in point.

2.3 Economic impact of licensing

The different technology acquisition and exploitation strategies have different implications for corporate strategies and development. In order to illustrate this, the economic implications of licensing in and out will be dealt with here.

Consider a stylised situation of a licensor (licence seller) doing all R&D and licensing out all technology in the form of patents and/or know-how (trade secrets) for a new product to a licensee (licence buyer), who in turn undertakes all production and marketing but no R&D. In this situation, licensing impacts on the cash flows of the licensor and licensee as shown in Figure 3. Payments then typically consist of a down payment and a running royalty, with a royalty rate set as a percentage of sales as a royalty base. As can be deduced from the diagrams, licensing out has the potential of being a high-profit but low-growth strategy for the licensor, whilst potentially being a high-growth strategy but with lower profits for the licensee.

Figure 3 Economic value arising from licensing a patent [7]



Legend:

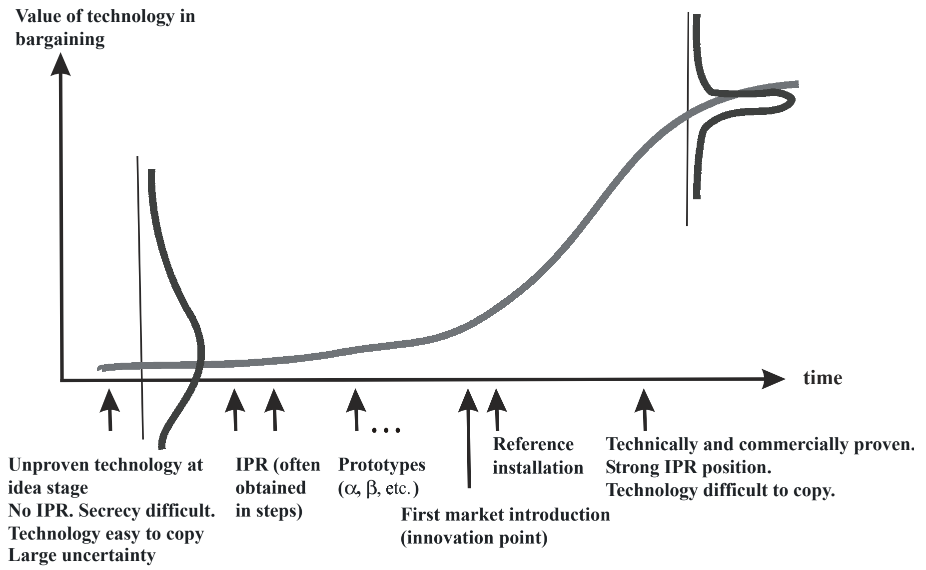
- · – · – · Potential cash-flow.
- ——— Real cash-flow.

R&D, P, M Investments in R&D, production and marketing, respectively.

Note: Cash outflow in form of investment expenditures is plotted downwards, whilst operating costs are plotted upwards for a clearer exposition of profits.

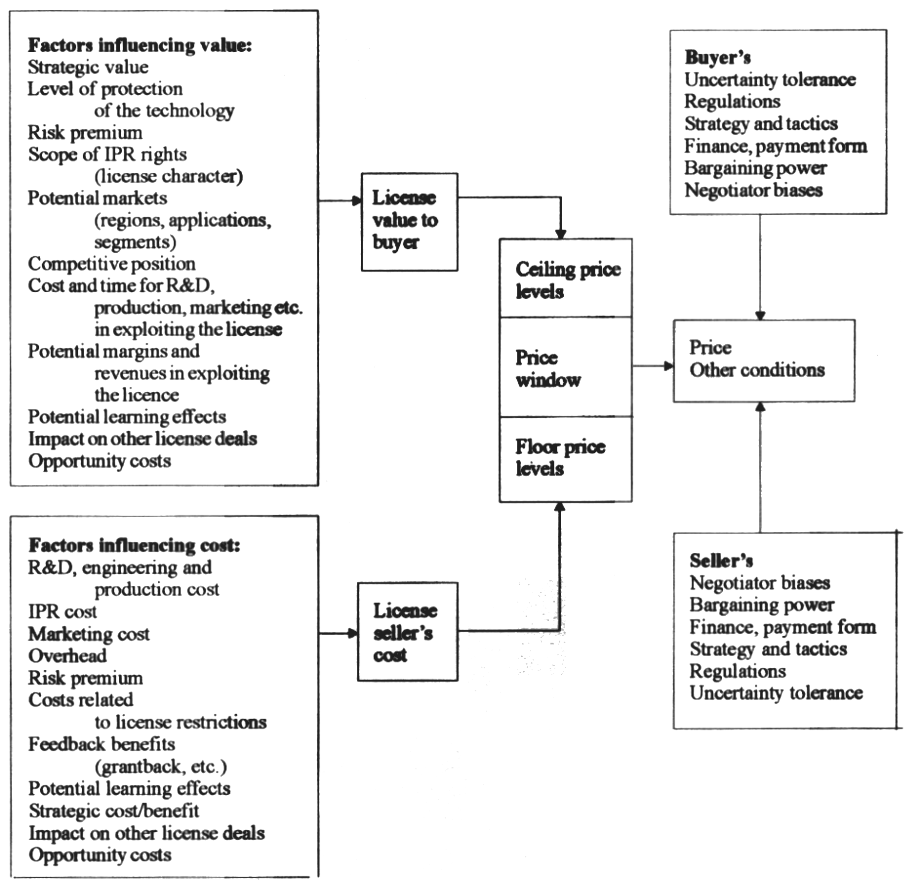
The market value of a licence typically increases whilst risk decreases on average as different stages and milestones are passed in the innovation and business development process, as shown in Figure 4. However, the value is also influenced by a number of other factors in a licensing negotiation, which is shown in Figure 5. The market value of a patent in turn can in principle be determined (at least as a good approximation) as the value of a corresponding exclusive, non-restricted patent licence. Since licences can be of various other types as well (non-exclusive, restricted and so on), the valuation of a patent or a set of patents is a special case of licence valuation. To make valuations with any precision is extremely difficult, though. The difficulties arise from the inherent nature of a patent, the long time horizons (up to 20 years or even more), and the compounded technical, commercial, legal and economic uncertainties involved. Nevertheless, numerous licence agreements are being signed every day on the basis of some kind of valuation.

Figure 4 The rising market value of a licence in different stages of the innovation and technology development process



The various factors in Figure 5 that the buyer and the seller might consider could be translated in several ways into ceiling price levels and floor price levels. Often it is useful to distinguish between two floor price levels with the higher floor price related to total cost, including a portion of fixed R&D costs, and the lower floor price related only to operating costs. Similarly, different ceiling prices could be related to different ranges of factors influencing value, for example, pertaining only to a narrow commercial value in a particular area or to a higher strategic value, incorporating spillovers to other areas in the buying company or consequences for future licence deals. Needless to say, the difficulties in valuation and the considerable uncertainties involved in licensing leave much room for exercising negotiation skills, and they may create considerable transaction costs as impediments for the deal flow. Managerial capabilities in technology marketing are then of crucial importance for the well-functioning of technology markets. Managerial learning co-evolves with technology markets through 'learning by dealing', but the traditional low and temporary activities on technology markets create a need to improve technology marketing management by other means as well, such as teaching, training and research (e.g. in valuation models).

Figure 5 A valuation and pricing model for patents and licences [7]



3 Role of technology trade in Swedish companies before the pro-patent era

3.1 Introduction

This section reports on an empirical study at both macro and micro levels of technology trade in Swedish industry. The study was carried out in 1980, i.e. before the advent of the so-called 'pro-patent era' emerging from the early to mid-1980s onward. The main part of the study consists of case studies of history, strategy, and structure of technology trade at company level. In the set of technology acquisition and exploitation strategies described in the preceding section, technology purchasing and technology selling will be focused upon, and especially compared to internal (in-house) R&D and internal exploitation through product trade respectively.

3.2 Method

The macro-level study was based on industrial statistics collected periodically by the National Central Bureau of Statistics in Sweden (SCB) for the whole of Swedish industry. Sector-level data are official, as reported in SCB [14], whilst company-level data are confidential. Thus, compilation and computation of company data as shown below were done with the assistance of SCB. It must be emphasised again that technology trade statistics are fraught with errors since there are few incentives for companies to track all licensing costs and revenues, accounting also for cross-licensing and intra-firm licensing, the latter typically also having distorted royalty streams for various reasons. Thus, official statistics may be misleading in many respects and can be used only as a rough indicator.

The micro-level study consisted of case studies of six large companies and one small company. The two industrial sectors at two-digit ISIC-level with the largest technology trade were the chemical (with ISIC code 35) and engineering (with ISIC code 38) sectors. These sectors were also the most internationalised ones in Swedish industry. In addition, the trading sector as such was chosen in order to see how technology trade possibly fitted into the business ideas of typical trading companies. Two large multinational companies from each of these three sectors were chosen for case studies. The resulting sample consisted of Alfa-Laval and Ericsson in mechanical and electrical engineering, Nobel and Perstorp in chemicals, and the Salén Group and the Johnson Group in the trading sector (with several industrial companies in the latter group as well). These companies were studied by documents and interviews at corporate as well as at divisional level, and one division or subsidiary was especially focused on. In addition the company Swedish Rotor was included in the sample, as a particular case of a small (with fewer than 100 employees) and extremely technology-sales-intensive company throughout its fairly long life (over 50 years). Thus, the sample covered most strategy combinations in Table 1. In all, around 30 technology and business managers were interviewed. The interviews had three main foci – history, strategy, and organisation of technology trade in the company. The approach was mainly exploratory and qualitative, although some quantitative data were gathered when possible. The contents of individual technology trade agreements were not studied.

3.3 Empirical findings

3.3.1 Macro level

At the macro level, R&D costs, company size by number of employees, and inter-company technology trade were significantly correlated as shown in Table 2. Thus technology trade was a complement to, rather than a substitute for, R&D and product trade. That internal R&D and product trade to some degree constituted a necessary condition for technology trade to bear fruit was also supported by the interviews in the micro-study (see below). On the other hand, technology sales do not necessarily have synergies with technology purchasing or vice versa, and on average there was a low correlation between these two activities at company level. (For more detailed results from the macro study, see [15].)

Table 2 Correlations between technology trade, R&D and company size for Swedish industrial sectors (1997)[1]

	Chemical[2] *(n=69)*			*Engineering*[3] *(n=229)*			*Total industry*[3] *(n=453)*		
Sector	*R&D*	*C*	*R*	*R&D*	*C*	*R*	*R&D*	*C*	*R*
S	0.54	0.45	0.65	0.92	0.54	0.55	0.79	0.41	0.40
R&D		0.79	0.62		0.69	0.49		0.64	0.49
C			0.51			0.18			0.20

Notation:
S = Company size in number of employees; R&D = Research and development costs
C = Costs for technology bought; R = Receipts for technology sold; n = Number of companies

Notes:

[1] Covers all companies with R&D and/or technology trade and more than 49 employees. Only a sample of sectors is shown here. For a full presentation, see Granstrand [15].

[2] All correlations are significant on 0.001 level.

[3] All correlations are significant on 0.01 level but not on 0.001 level.

Source: Compiled from unpublished primary data from SCB [14]

3.3.2 Company history of technology trade

On the whole, acquisition of foreign technology had been highly important in the stage of founding of all four industrial companies Alfa-Laval, Ericsson, Nobel and Perstorp. Inventors and company founders had by and large been well-educated and had studied or travelled abroad in the large industrialised countries of the late 19th century, often with a conscious aim to transfer technology to Sweden. An acquisitive technology-transfer stage and a subsequent stage of build-up of internal R&D could be discerned in the company histories [16]**.** Internal R&D then became product- or process-focused, and also in some cases took a lead in certain areas of the product technology. However, technology acquisitions did not wane over time in absolute terms as internal R&D gradually grew. On the contrary, technology purchases grew, especially after World War II, as did internal R&D, thereby co-evolving. Mostly, purchased technology was of direct importance for product diversification rather than for internationalisation. Moreover, purchased technology was considered in most companies to be behind the company's large technology leaps, whilst internal R&D had been behind the incremental component of the company's technological development. Most of the radical innovations of the companies had their sources mainly outside the companies.

Technology sales, on the other hand, have not been important historically, at least not until 1960. The large engineering companies Alfa-Laval and Ericsson were internationalised early, mainly through foreign direct investments, whilst the chemical companies Nobel and Perstorp were late internationa1isers. Technology sales have not been especially important in the internationalisation process on the whole, although there are instances of licensing on distant and/or protected markets and/or licensing as an intermediate stage in further integration forwards into direct product trade.

In the 1960s and 1970s technology sales grew. The chemical companies had divisions which considerably exploited internal technology through licensing and joint ventures because of high transportation costs, capital-intensive production and protected markets.

The engineering companies, both selling high-technology systems, had found themselves subjected to protectionism and had been forced into licensing and joint ventures. (Earlier the Russian revolution in 1917 had a similar effect on Swedish engineering companies in general, many of which had subsidiaries and production plants in Russia, e.g. Alfa-Laval and Ericsson. Also the trading companies developed much trade with the Soviet Union over the years.) In the 1960s and 1970s the trading companies also tried the business idea of technology trade.

Behind these increased efforts to sell technology was also an internal force. Most of the companies had experienced problems with intra-company technology transfer from central R&D units to existing or new divisional operations. Alfa-Laval, Ericsson, Nobel, Perstorp, and also the Johnson Group, had had large central R&D units in the 1960s. In the early 1970s Nobel and Perstorp almost shut them down and decentralised R&D, and in the late 1970s Alfa-Laval did the same, followed by Ericsson. Also the central R&D unit in the Johnson Group ceased to exist as such but was converted into a business unit.

Thus, central R&D fell into disrepute in the 1970s and the term ‘central R&D’ became almost a dirty word, which aroused bad feelings in the companies. Responses to intra-company transfer problems around earlier central R&D units included the initiation of efforts to licence out the corresponding technology. Also the Salén Group had made efforts at corporate level during the 1970s to purchase and sell technology but without success. However, the latter efforts were not triggered by problems with central R&D but rather by external opportunities. The emphasis was on purchasing technology at corporate level and transferring it to the business divisions, which in no case succeeded.

Thus various forms of acquisition of technology, especially foreign technology, have been important to the growth and diversification of the companies in the sample. Exploitation of technology through technology sales, on the other hand, has been of marginal importance to company development. However, this may be because the sample consists of large companies and technology sales do not contribute to growth more than marginally. The case of Swedish Rotor, a small company, illustrates that it is possible to carry the business idea of technology sales to the extreme of wholly substituting for product trade during a long period of time. The company was founded in the late 1900s on a product invention. Licensing for foreign markets was initiated in the early 1910s and a production subsidiary was started for the local market. Through a peculiar series of events the company was stripped of its production operations by a large company (ASEA, later merged into ABB), acquiring them in the mid-1910s. Swedish Rotor then became engaged solely in licensing out, after a short period of negative experience with other production operations. The company built up an inventive tradition and continued to rely on licensing out when ‘the money started to pour in.’ Subsequent owners also put priority on profitability rather than on growth as a strategy. As of 1980 the company had strong internal R&D (R&D cost was over 50% of total sales) and did not purchase any technology, but naturally tried to use grant-back licences and other mechanisms for technology feedback from its large family of licensees.

3.3.3 Company strategy and technology trade

Reasons why technology was not bought and sold more

Despite the decisive importance of some purchased licences to the historical development of at least three companies (Alfa-Laval, Nobel, Perstorp) [17] and the long involvement of a majority of the companies in licensing, technology trade was in general a poorly recognised and elaborated technology strategy. Since technology trade had traditionally been only a marginal and temporary activity by and large, it had developed into an issue of only marginal and temporary strategic concern. The explanations given in the interviews for why the companies in general did not purchase and sell technology to a larger extent were consequently rather superficial. Reasons mentioned as to why the companies did not purchase more technology included self-sufficiency among technologists and company R&D people (including not-invented-here effects), the long inventive tradition in the companies, and the belief that one was working on technology frontiers. Stated reasons were less frequently referring to external factors, such as an insufficient supply of suitable technology for sale. At the same time, systematic efforts to search the market for new technologies ('technology scouting') were not substantial.

Reasons mentioned as to why the companies did not sell more technology generally referred to the perception that the economic returns associated with selling products were higher, plus the tradition of selling primarily products and the resulting availability of production and marketing facilities. Thus, the kinds of reasons given indicated that the low level of technology trade was both cause and consequence of lacking technology strategies. However, several companies mentioned that strategy-making efforts were underway in this area.

Growth and profitability

The impact of technology trade on the four standard strategic variables profitability, growth, product diversification (including vertical integration), and internationalisation, could be assessed as described in Section 2. Technology sales were generally considered to generate less long-term growth than product trade, but could be more profitable than selling products, if less money then had to be invested in production and marketing. Swedish Rotor was a case in point. Founded on the basis of a product invention and with a long history of a steady stream of commercialisable technology developments since, the company could very well have developed into still another one of the large, invention-based, Swedish multinational corporations. However, as mentioned above, profitability had been emphasised over growth through the years. The company had also, from time to time, been one of Sweden's most profitable companies. Nevertheless, in 1980 the company believed it would be more difficult and risky to live solely on licensing in the future. R&D was getting increasingly expensive at the same time as technology-based international competition was intensifying and technological advances were becoming more incremental and interdependent. Licensing also resulted in too long a distance to the final product market. Thus, downstream integration into production and marketing was considered for the future (as of 1980).

The central R&D unit in the Johnson Group, having been engaged solely in pure licensing, had in fact embarked on a route of downstream integration. The unit had started to sell products in the mid-1970s in order to get reference plants for the licence objects and in order to improve the total economy of the unit. Similar 'creeping' into downstream operations has also been experienced by start-up R&D companies when the demand for their early R&D-stage licences has dried up.

Thus, whilst extreme reliance on technology sales may yield high profitability, although low growth, the strategy preferred by the companies was to combine technology sales and product sales and make a trade-off between growth and profitability. Needless to say, there are many contingencies, such as the availability of production or marketing facilities, the competitive situation, premiums on speed to market, and the strength of internal R&D.

Product diversification

All the companies in the sample had product diversification as a strategy at least in some business division. In general, product diversification was achieved through internal development, joint ventures, or acquisition of companies or licences, with a common preference for company acquisitions. For technologies new to a company but existing outside, the general belief was that purchasing and/or imitation was a less expensive and more speedy way than building up internal R&D. To build up R&D in new areas was thought of as very expensive, which could be a proper step only at a later stage after an entry into the new area had been achieved through other means. To buy a licence could then be a faster and cheaper way, which also could serve as an intermediate stage to closer collaboration with the out-licensing company or to acquiring the whole company in the future.

Complementarity to internal R&D

Concerning the development of existing technologies within existing product areas in the companies, none of the companies relied solely on a technology purchasing strategy. Their internal R&D was often strong, and licensing in was at most a complement, unless possibly when new technologies 'invaded' existing product areas. Internal R&D also gave access to international science and technology in the field and opened up other possibilities for technology transfer. Imitation, almost to the point of espionage, was in some cases a clearly recognised strategy instead of buying licences. Such a technology scanning or technology intelligence strategy seemed to work in certain sectors of industry with a well-developed informal network for the exchange of technological information on a kind of informal barter basis. Other sectors (rather than companies) were much more closed in this respect.

The presence or absence of internal R&D in an area also affects the outcome of a licence bought. As a rule, much work remains to be done after a licence has been bought (i.e. 'buy and make' rather than 'buy or make'), and the licensee has to have an absorption capability for which internal R&D is often needed. The list of all purchased licences in the chemical company Perstorp totalled 16 major items. Six of these concerned entirely new product areas where the company had no R&D experience of its own, and four of these six failed in the sense that activities were discontinued. Six items concerned existing product areas or areas where the company had its own R&D experience, and all were rated considerably successful. Thus, the complementarity between internal R&D and technology purchasing was strong through the capability provided by internal R&D to access, absorb, adapt and further develop externally acquired technologies.

Internationalisation

All the companies studied were highly dependent upon product sales on foreign markets. The general strategy in the companies was to sell their own manufactured products all around the world in their own subsidiaries. If this was not feasible, then they resorted to joint ventures, and as a last resort to licensing out. Thus, there were three different market spheres – markets covered by the companies' own local production plants and sales subsidiaries, markets covered by jointly owned sales subsidiaries in combination with licensing out, and markets covered by pure licensing out.

There were several motives and factors behind the composition of these market spheres and their corresponding technology exploitation strategies. Important factors were transportation costs, size of investments in production plants and marketing facilities, stage in the company's internationalisation process, stage of technology development, degree of product differentiation with respect to different markets, trade barriers, and requirements from local authorities.

Thus, for example, a company in an early stage of internationalisation may use licensing out on a specific market as an intermediate stage towards internationalising operations on that market, whilst a company in a late stage with its own subsidiaries around the world has to face local demands for partnership, which may force the company into joint ventures in combination with licensing.

Stage of technology development

The stage in the technology development process and the age of a technology were important to the prospects of licensing out the technology as described in Section 2. Most of the companies had experienced problems with purchasing or selling technology in early phases of its development process, and the need to have reference plants was repeatedly emphasised. To sell technology that had not been tested, used, and produced, preferably in their own plants, was considered both difficult and unprofitable. It was also considered unprofitable from the buyer's point of view to purchase technology in its early stages. The possibility of purchasing undeveloped technology and developing it with their own R&D was not utilised and was considered a poor strategy because of the risk involved, for example the risk of not-invented-here effects. Also there were many fortune hunters and 'horse traders' in the licence-selling business, selling poor objects with no will or ability to back up a licensee.

3.3.4 Company organisation of technology trade

Table 3 shows the organisation of R&D and technology trade in the company sample. As can be seen from the Table, technology trade (as well as R&D) within existing areas of business is a divisional responsibility in all companies studied. It was also considered a strategic issue for the divisions and should therefore not be interfered with by corporate management.

Table 3 Company organisation of R&D and technology trade (as of 1980)

	Company					
	Engineering		*Chemicals*		*Trading*	
Variable	*Alfa-Laval*	*Ericsson*	*Nobel*	*Perstorp*	*Salén*	*Johnson*
Central R&D	Y,N	Y,P[c]	Y,N	Y,N	N	Y,N[b]
Divisional R&D	Y	Y	Y	Y	P	Y
Central innovation company for corporate venturing	N	N [g]	Y	Y	Y	N
Central technology-trade unit[a]	P[d]	Y[e]	P[h]	N	Y,N	Y,N
Technology trade within existing area of business a divisional responsibility [f]	Y	Y	Y	Y	Y	Y
Patent and legal unit at corporate level	Y	Y	Y	Y	Y	Y

Notation: Y = Yes, N = No,
Y,N = Existed around 1970 but not in 1980
P = Partial or minimal existence

Notes:

[a] Apart from legal assistance which was centralised in all companies.

[b] Discontinued in 1980 and converted to a business unit.

[c] Decentralisation ongoing in 1980 and later fully accomplished.

[d] Initiated 1980. Oriented around selling spin-off technology. Later abandoned.

[e] Largest unit in the sample. In 2001 Ericsson created a new central licensing organisation for licensing out technology platforms for mobile phone systems.

[f] Sometimes with approval needed from corporate management.

[g] An innovation company was created in the 1990s.

[h] Later abandoned.

Ericsson

Ericsson had once had separate technology purchasing and sales units but had then reorganised, adopting a high degree of centralisation with a unit at the corporate level strongly coordinating both technology purchasing and selling in the entire company (as of 1980). The need for centralised and integrated technology trade was due to Ericsson's production and marketing being highly internationalised with R&D being mostly domestic, to the systems nature of technologically sophisticated products, and finally to the complexity of transactions with advanced technology customers.

The Johnson Group

In the 1970s both the trading companies had initiated and later discontinued central efforts to engage in technology trade. The Johnson Group, which made the most substantial and organised effort, thus created a unit at the corporate level in the early 1970s. Since the company was involved in trading and had a well-developed international organisation, it seemed proper to engage in technology trade as well. General ideas about the increasing future role of 'knowledge industries', articulated by Peter Drucker and others, gave an intellectual stimulus in the company. These ideas also fitted well into the concrete situation of the company with a central R&D unit having internal technology transfer problems. A basic idea of this R&D unit, as encompassed by top management, was that the unit should be devoted to R&D and not engage in business activities (as opposed to the organisational ideas of corporate venturing). The proposal to have a central technology trade unit as a counterpart to the central R&D unit was therefore well received in the company. These were the starting conditions, and rather soon the ideas were entertained that the technology trade unit could develop into a fully-fledged broker, providing services in the process of purchasing technology from inside and outside the company and selling it inside and outside the company, with or without an intermediate ownership of the technology. However, the unit was dissolved in the late 1970s without having achieved the anticipated success, although it did not really result in economic losses. Interrelated reasons behind the termination of the central technology trade unit were:

- There were inadequate communication and integration with the central R&D unit, which was geographically as well as organisationally separated from the central technology-trade unit.
- It was difficult to find licence objects outside the central R&D unit and outside the company.
- The central R&D unit had needed to change its exploitation strategy and to start selling products as reference orders.
- Difficulties arose in making transactions in the early stages of the innovation process.
- Some key individuals had left the company and internal communications had deteriorated.
- The trading tradition was not entirely suitable for technology trade, resulting in misjudgement of requirements specific to technology trade regarding time spans, costs, synergies and competence.

The Salén group

The central effort in the Salén Group was on a much smaller scale than in the Johnson Group. It was not coupled to a central R&D unit. The emphasis was rather on transferring technology from the outside to the company. In both the Salén and Johnson cases, there was optimism about the possibilities of economising on the company's international organisation as well as the appeal of technology trade as a new business idea for a trading company. Some reasons for the termination of the central effort in Salén were similar to the ones in Johnson, for example, the fallacies involved in transacting early-stage technologies and the risks of over-reliance in technology trade on product trading competence and tradition.

Centralisation and integration

The experiences gained in the trading companies indicate the difficulties with central integrated technology trade units. Nevertheless, central technology trade units have existed in some companies, although not always at corporate level. (They have also existed at national level in some socialist countries.) In addition, the circumstances were special in the trading companies, which were trying to act more as brokers, following their trading tradition.

Integration between internal R&D and technology sales may be desirable, on the other hand. At the same time, not-invented-here effects, so often encountered in technology trade, would make it desirable organisationally to separate technology purchasing from R&D and rather integrate it with marketing and general management, especially when buying product rather than process technologies. Besides, good buyers are not necessarily good sellers and vice versa. However, some interviewees claimed that technology purchasing and sales should be integrated. For legal matters, 'difficult' countries, and systems technologies, the advantages of internally integrated technology trade units might supersede the advantages of differentiated centralisation and integration of technology purchasing and sales activities.

Besides the synergies or economies of scope in connection with integration, there are also economies-of-scale effects to consider. Dynamic ones arise from learning and more efficient accumulation of knowledge in technology trade through a high frequency in handling agreements, thereby lowering transaction costs. There is also a risk that technology trade activities would fall below a critical minimum level if decentralised, thereby jeopardising any static economies of scale. It was a common and simple but indicative answer that people in the divisions did not have or take the time to engage in technology trade matters. These were mostly 'a quarter-to-five kind of activity'. Finally, economies-of-speed considerations give a mixed verdict as to the virtues of decentralisation. Decentralisation may make decision-making faster in response to technology trade opportunities, usually first appearing locally in the organisation. On the other hand, licensing activities are long-term commitments and create relations to outside parties who potentially become competitors. Thus, coordination is called for across interdependent technologies and businesses in a large company, especially for technology sales. A quick and carelessly sold licence may sooner or later be regretted, and more so than a carelessly bought licence, for which the potential loss is limited to the acquisition cost.

3.4 Summary

For Swedish industry as a whole, before the advent of the pro-patent era, both technology purchasing and technology selling were marginal in official monetary terms, technology purchasing amounting to 4.9% of total R&D and technology selling amounting to 0.08% of total sales as of 1980. Sweden's technology trade was highly internationalised and more so than product trade, but less confined to large companies than were R&D costs. Moreover, technology trade was positively correlated with company size and size of company R&D for most industrial sectors, indicating a complementarity in companies between technology purchasing and R&D, and between selling technology and selling products. On the other hand, purchasing and selling technology were not strongly correlated.

In the case study of a sample of six large companies, a set of technology acquisition strategies and a set of technology exploitation strategies were identified. The marginal role of technology trade and its complementarity to internal R&D and product trade were further evidenced. Technology purchasing did not and presumably could not substitute for R&D in the long run. The large trading companies in the sample had failed in efforts to adopt technology trade as a business idea, indicating lack of economies of scope between ordinary trading and technology trade. No categories of companies relying heavily on technology trade strategies were found among small companies, and a single case was found of a small and highly profitable company having relied solely on licensing and internal R&D for over 60 years. This was then an exceptional case of sustainable stand-alone licensing, i.e. licensing out as a major business without being a complement to selling products.

Acquisition of foreign technology through imitation and technology purchasing had been of decisive importance in the founding and later diversification of the large industrial companies [7,18–20]. Initial technology acquisition was then usually followed by a stage of build-up of internal R&D. In most companies, external acquisitions of technology accounted for most of the radical changes in the company's technology base, whilst internal R&D had been more associated with the incremental changes. Thus, technology purchasing had been marginal in terms of cost but not in terms of effects.

Technology sales had hardly been important at all for growth and internationalisation of the large companies, compared to foreign direct investment and exports. Technology sales had mostly been resorted to for spin-off technology or for distant or protected markets, sometimes as an intermediate stage to further internationalisation. However, more recently various circumstances had forced some of the companies into an increasing use of joint ventures and licensing out.

The companies organised for R&D, innovation and technology trade in various ways with a trend towards decentralisation. Central corporate R&D units had been abolished almost everywhere. Innovation companies for corporate venturing, and central technology trade units existed in some companies but the trading companies had discontinued centralised technology trade.

The motives in the companies for buying and selling technology were similar to traditional motives found in studies in other countries (see e.g., [21–24]) Motives explaining why companies did not buy more technology, despite historical successes with this strategy, pointed at effects of building up internal R&D, such as self-sufficiency and prestige attached to pioneering, implying negative attitudes towards licensing in

(NIH-effects). Motives explaining why companies did not sell more technology pointed especially at the perceived risk of future competition and decreased competitiveness through loss of firm-specific technological advantages. Moreover, a technology sales strategy was not as compatible with a long-term growth strategy as it could be with a profitability strategy.

4 Trading of technology-based firms

A particular type of technology trade is to trade technology embedded in small technology-based firms (STBFs) rather than to trade technology disembodied in the form of licences. This type of trade corresponds to the use of technology strategies for acquisition and creation of innovative firms in the framework presented in Section 2. A study of this so far fairly small but increasingly important type of technology trade is reported in [25] and briefly summarised here, as follows:

- The market for trading STBFs was mainly a seller's market, characterised by monopolistic powers. Competition among buyers led to reduced transaction times (with less time for careful evaluation), higher prices, and 'underdeveloped' firms with unfinished technology being acquired. These three factors were associated with acquisition failure at the buying end, usually a large technology-based firm (LTBF).
- Technological innovativeness of the STBF was not normally slowed down by an acquisition, on the contrary.
- The post-acquisition growth of STBFs was significantly higher than pre-acquisition growth.
- Non-acquired STBFs grew at roughly the same rate as did acquired STBFs before acquisition. Thus, there was no evidence that high-growth firms were primary targets for acquisition.
- The number of independent STBFs with the same age shrank rapidly due to acquisitions, 19% of firms being acquired before the age of ten years. The acquired firms' lifetimes as independent firms were nearly exponentially distributed.
- Continuity in top management and key R&D personnel of the small firm before and after acquisition was associated with success.
- Management control exerted by the LTBF and technology diversification of the STBF contributed significantly to its post-acquisition growth, whilst integration with the large firm at the board level of the STBF did not.

Thus, the empirical evidence indicated benefits of large firms' acquisitions of small firms, made with the main purpose of acquiring technology. It may be noted that the literature on acquisitions in general so far has had little to contribute to an understanding of the special 'entrepreneurial' type of acquisition considered here.

STBFs may also be spun off by LTBFs and offered for sale, thereby creating a supply of STBFs in addition to independent start-ups. A new technology trade mechanism is thereby created with potential benefits for innovativeness and growth, as described in [25] and further studied empirically in [26].

5 Technology acquisition strategies in Japan, Sweden and the USA

5.1 Country comparisons

After the study of the role of technology trade in Swedish companies in 1980 it was natural to make an updated study, broader in scope and extended to other industrialised countries as well. A sample of 14 Japanese, 16 US and 12 Swedish large corporations was then studied in many technology management aspects through questionnaires and interviews. Some results pertaining to technology trade are summarised here. (For further details, see [27,28]). There were no significant (at 5% level) country differences between the perceived degrees of importance of various technology acquisition strategies among companies in different countries, as shown in Table 4. R&D was decentralised into various divisions and business units to a much larger extent in Swedish companies (with 8% of R&D centralised at corporate level) compared to US companies (with 21%) and especially compared to Japanese companies (with 40%).

5.2 Trends 1982 – 1987

As seen from Table 4, internal R&D was still considered to be the most important technology acquisition strategy for the companies, regardless of nationality. However, there was an increase in perceived importance of all strategies for external technology acquisition, except for technology purchasing in the form of licensing in. Technology scanning was perceived to be the second most important technology acquisition strategy in all countries for both years, and had, moreover, grown significantly in importance. This was in turn connected with a growth in the use of patent information for technology and competitor scanning purposes. The joint venture strategy increased most in importance in general, and especially among the companies in the USA and Japan (see also [29]). In some companies it had in fact become a major strategic issue whether they were becoming too dependent on external technology acquisition. For example, one electronics company reported (in the interviews) that only 20–30% of its total cost of technology acquisition was associated with internal (in-house) R&D, whilst 70–80% was associated with external acquisition.

Table 4 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)

	Total			*Japan*			*USA*			*Sweden*		
	1982	*87*	*p*	*1982*	*87*	*p*	*1982*	*87*	*p*	*1982*	*87*	*p*
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
Acquisition of innovative 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 techn. 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
Licensing in	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 so as to represent a falling order of organisational integration, or equivalently an increasing order or degree of external acquisition (sourcing), based on contractual considerations. Assuming, admittedly boldly, equidistant strategies on a 0-1 scale of degree of external technology 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 equidistant categories, and T-EXTB for five separate equidistant categories, where the strategies of contract R&D and licensing in have been lumped together since they have a similar degree of organisational integration.

Source: Granstrand *et al.* [28]

5.3 Externalisation of technology acquisition and use of technology markets

As described in Section 2, the strategies in Table 4 have been ranked in increasing order of externalisation (or falling order of organisational integration). The strategies and their corresponding contracts also correspond to different forms of technology markets, even for the technology scanning strategy if barter-oriented markets are included. It is now desirable to operationalise, on a metric scale, some aggregate measure of the degree to which technology is acquired externally through various technology market transactions or otherwise. However, as described in [28], it turned out to be extremely difficult to extract financial data systematically for each strategy from accounting data and interviews.

Thus a simple Likert-type scale of perceived importance of each strategy was used. Weights for different strategies, reflecting their degree of external technology acquisition, were then (boldly) assumed to be equidistant on a scale from zero for internal R&D to one for technology scanning. This assumption could be justified to some extent in a first approximation, based on a kind of 'principle of indifference' [30]. Sensitivity analysis is obviously required, and the following two measures or indices for the degree of external technology acquisition have been used, where PI(X) is the perceived importance of strategy X:

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

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

Thus the two indices differ in that licensing in and contract R&D have been split up or lumped together, respectively. This is due to the uncertainty about the difference in degree of integration for these two strategies, as described in Section 2.

Based on the T-EXT indices as indicators of degree of externalisation of technology acquisition, Table 4 further shows that such externalisation and thereby use of technology markets has increased significantly in general, and for the USA and Sweden in particular. Japanese companies had a similar but not as significant increase. However, Japanese companies had a higher degree of external technology acquisition and use of technology markets than US and Swedish companies in the first place for both 1982 and 1987. Again, no country differences were significant at the 5% level.

Further analysis of data from this study showed that the T-EXT indices were positively correlated with importance of internal R&D, indicating a complementarity, albeit significant only at the 12 % level. The T-EXT indices were, moreover, significantly positively correlated with the importance of the corporate development strategies growth, product diversification and R&D investments [31]. A regression showed that the degree of technology externalisation was primarily explained by strategic emphasis on R&D investments, whilst growth and product diversification only added about 5% to the explained variance. However, the quantitative analysis could not be stretched very far in this direction due to small samples.

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 as of 1992 and 1987 (adding a university collaboration strategy) was asked to an extended sample of 24 Japanese and 23 Swedish large corporations, allowing a study of possible differences in the chemical, electrical and mechanical engineering sectors [32,33]. The results for 1992 are shown in Tables 5–6. Some highlights are:

1 Internal R&D definitely remained the main strategy regardless of country and sector. However, external technology acquisition by various strategies was increasingly important, somewhat more so in Japan. Collaborative R&D and technology scanning were especially important on average after internal R&D.

2 University collaboration grew rapidly in importance from 1987 to 1992 for both Japanese and Swedish corporations. The Japanese corporations regardless of sector preferred US universities, whilst the Swedish corporations by far preferred collaboration with domestic universities.

3 The importance of licensing in, relative to other strategies, increased between 1987 and 1992 in Sweden but not significantly in Japan.

4 On direct questions about trends, the Japanese corporations reported that during 1987–92 their propensity to licence in as well as out and to cross-licence had increased, increasing R&D costs had increased the propensity to licence out, royalty sales had increased, and patents were increasingly sought to generate licence incomes. Overall, the strategic role of licensing had increased significantly in the corporations. (See further [7].)

Finally, Table 7 shows the importance attached to various technology exploitation strategies by the Japanese corporations. As seen, internal exploitation dominates by far, and technology selling – which ranks next to joint ventures – has the strongest upward trend in importance totally and especially in mechanical engineering corporations. One may also observe an overall externalisation of technology exploitation through an increasing use of other exploitation strategies than internal exploitation, and notably through technology selling.

Table 5 Perceived importance of technology acquisition strategies in Japanese large corporations 1992[1]
(Scale: No importance = 0, 1, 2, 3, 4 = Of major importance)

Strategy	*Chemical (n=9)*	*Electrical (n=10)*	*Mechanical (n=5)*	*Total (n=24)*
Internal R&D	$\overline{3.89}$	$\overline{3.70}$	$\overline{3.80}$	$\overline{3.79}$
Acquisition of innovative firms (or business units)	$\underline{1.88}$	$\underline{1.40}$	2.40	$\underline{1.78}$
Joint venture and other forms of cooperative R&D	2.89	2.40	2.80	2.67
Contract R&D	2.25	1.70	$\underline{2.20}$	2.00
Licensing in	2.75	1.90	2.40	2.30
Technology scanning	2.88	2.70	3.00	2.83
University collaboration	3.00	2.56	2.00	2.60
University collaboration with universities in:				
Japan	2.78	2.56	2.80	2.70
USA	3.13	2.67	3.20	2.95
Sweden	1.29	1.13	1.20	1.20

Note: [1] The highest and lowest values for each industry are overlined and underlined respectively.

Table 6 Perceived importance of technology acquisition strategies in Swedish large corporations 1992[1])
(Scale: No importance = 0, 1, 2, 3, 4 = Of major importance)

Strategy	*Chemical (n=8)*	*Electrical (n=3)*	*Mechanical (n=12)*	*Total (n=23)*
Internal R&D	$\overline{3.63}$	$\overline{4.00}$	$\overline{3.58}$	$\overline{3.65}$
Acquisition of innovative firms (or business units)	$\underline{1.13}$	$\underline{1.33}$	$\underline{0.92}$	$\underline{1.04}$
Joint venture and other forms of cooperative R&D	2.38	2.33	1.83	2.09
Contract R&D	1.75	1.67	2.25	2.00
Licensing in	1.14	1.33	1.08	1.14
Technology scanning	2.25	2.00	2.42	2.30
University collaboration	2.17	$\underline{1.33}$	2.17	2.00
University collaboration with universities in:				
Japan	0.29	0.00	0.67	0.44
USA	1.00	1.50	1.09	1.10
Sweden	2.75	2.00	2.42	2.48

Note: [1] The highest and lowest values for each industry are overlined and underlined respectively.

Source: Adapted from Granstrand [32]

Table 7 Perceived importance of technology exploitation strategies in large Japanese corporations 1992[1])
(Scale: No importance = 0, 1, 2, 3, 4 = of major importance)

Strategy	*Chemical (n = 9)*	*Electrical (n = 10)*	*Mechanical (n = 5)*	*Total (n = 24)*
Internal exploitation 1992	$\overline{3.89}$	$\overline{3.50}$	$\overline{4.00}$	$\overline{3.75}$
Growth ratio 1992/1987	1.00	1.01	1.07	1.02
Creation of innovative firms 1992	2.00	$\underline{2.00}$	$\underline{2.40}$	$\underline{2.09}$
Growth ratio 1992/1987	1.25	1.04	1.50	1.19
Joint ventures 1992	2.44	2.50	2.60	2.50
Growth ratio 1992/1987	1.40	1.33	1.40	1.37
Technology selling 1992	$\underline{1.89}$	2.50	$\underline{2.40}$	2.25
Growth ratio 1992/1987	1.24	1.43	1.90	1.46

Note: [1] The highest and lowest values for each industry are overlined and underlined respectively. The growth ratio is the importance assessed for 1992 divided by the importance assessed (in 1992) for 1987.

Source: Granstrand [7]

6 Technology acquisition at product level – case studies

In order to find out the role of external technology acquisition, not only at country, sector and company level but also at detailed product level, a number of product case studies were carried out as reported in [28,34]. Three product areas were chosen with clear product generation shifts, allowing a study of trends, and a substantial number of interviews were carried out in the corresponding Swedish corporations: Ericsson for phones and cables, and Electrolux for refrigerators. Table 8 summarises the findings regarding external technology acquisition for the three product areas.

Table 8 Number of technologies and technology acquisition patterns for different product generations in three product areas

	Number of important technologies				*R&D costs index with generation*	*Number of technologies acquired externally*[d]		*Main engineering categories for R&D*[g]	*# Patent classes*[h]
Product	Old[a]	New[b]	Tot	Obsoleted[c]	1=100				
1. Cellular phones									
- Generation 1 – NMT 450	-	-	5	-	100	0.6	(12%)	E	17
- Generation 2 – NMT 900	5	5	10	0	200	2.8	(28%)	E,F,M	25
- Generation 3 – GSM	9	5	14	1	500	4.0	(29%)	E,F,M,C	29
2.Telecommunication cables									
- Generation 1									
Coaxial cables	-	-	5	-	100	1.5	(30%)	E,K,M	14
- Generation 2									
Optical cables	4	6	10	1	500	4.7	(47%)	E,F,K,M	17
3. Refrigerators									
- Current generation	-	-	5e	-	n.a.	0.1	(2%)	n.a.	n.a.
- Next generation	3	4	7e	2	n.a.	1.7[f]	(24%)	n.a.	n.a.

Notes:
- a No. of technologies that also existed in the preceding generation.
- b No. of technologies that did not exist in the preceding generation.
- c No. of technologies in the preceding 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), mechanical (M) and computer (C) engineering categories respectively.
- h Number of IPC-classes at 4-digit level.

Source: [27]

The main conclusion was that, in all three product areas, the number of technologies in the technology base of the products increased between the consecutive product generations; that is, technology diversification increased. The main factors behind these increases appeared to be technology 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 fibre systems. One effect of the technology transitions and the resulting increase in number of technologies and R&D costs was increased external technology acquisition. In all three product areas, the majority of new technologies needed were acquired externally, mainly from Japan and the USA. Despite increased internal R&D within the firms, firms still had to acquire technology externally to a significant and increasing degree, both absolutely and relative to internal R&D. There were several factors at play behind this. Firstly, external technology acquisition mainly concerned new (to the firm) technologies that were so complex that they required large R&D efforts – including time – if developed internally. Secondly, if the firms had wanted to develop new technologies internally, finding sufficient R&D competence would have been problematic even within large time and cost bounds. Thirdly, the efficiency of internal R&D was highly dependent on the external inflow of information. Thus, as was often pointed out in the interviews, there were strong complementarities between internal R&D and external technology acquisition.

Hence, several factors may stimulate a demand for new technologies, but then there has to be a matching supply of them at feasible prices in order for technology trade to take place. Several factors stimulate a competitive supply of new technologies – such as high R&D costs for the supplier in combination with lack of competition between supplier and buyer, cross-licensing opportunities, and availability of even newer substitute technologies at the supplying end. A competitive supply is moreover stimulated by proliferation of technologies, R&D capabilities, and duplicate R&D, creating multiple sources of suppliers (firms, universities, institutes etc.), who believe someone else is able and willing to sell the new technology off the shelf or on order ('If we don't sell, someone else will').

In the product cases, the supply of externally available technology was stimulated by product specialisation among component suppliers, many of which were highly specialised suppliers of a single, very complex technology in the products.

7 Summary and conclusions

This paper has focused on the development of technology trade and markets in industry from the 1980s onwards, and probed whether a pro-licensing era in some sense is emerging in the aftermath of the emergence of a pro-patent era. An analytical framework for strategic technology management has guided a number of empirical studies, which are summarised in the paper. The studies show that technology trade is of old origins just like the patent system and has been practised by companies since industrialisation, primarily in connection with entrepreneurship and technological catch-up at the buying end and limited internationalisation at the selling end. In simplified terms: leading but local companies sold some technology to lagging non-competing companies in distant or unrelated markets. A stage of build-up of internal R&D has usually accompanied licensing in, during which the relative importance of licensing has decreased.

Despite the historic importance for many companies of some singular licence purchases, e.g. for diversification or radical technological renewal, licensing in has traditionally not been more than a minor complement to internal R&D, due to e.g. NIH-effects. Similarly, licensing out has been a minor complement to product sales, used more or less as a last resort on distant, difficult or protectionistic markets – sometimes in connection with joint ventures, sometimes as a 'gap-filler' in further internationalisation and internal build-up of FDIs, but always with the concern not to nurture a future competitor.

Thus, it seems reasonable to claim that licensing traditionally has played a strategic role occasionally in companies but has on average occupied only a marginal role as a complement to internal R&D and product sales, thereby as a strategy being subjected to licensing-sceptical if not anti-licensing attitudes.

In the postwar globalising context, there were large technology gaps during the 1950s within and between the first world and the more protectionistic second and third worlds, and international technology trade grew. In the 1960s and 1970s several Swedish companies experimented with new ideas for R&D, corporate venturing and technology trade, and set up corporate R&D, venturing and technology trade units. With some exceptions, these units had been closed down by the early 1980s in the absence of clear signs of success. Benefits from centralisation and diversification into new areas, and integration of licensing in and out and product trade, had been overestimated.

In the 1980s external technology acquisition in various forms grew significantly across countries and sectors, although not in particular in the form of licensing. This trend continued into the 1990s. By then the pro-patent era had emerged, triggered by developments in the 1980s in the USA, leading to significant increases in patent values, patent volumes, patent litigation and patent resources. By now many previous technological gaps had been reduced and some even reversed. Sources of new technologies had multiplied, and many new technologies – not least ICTs – had emerged, several being generic (general purpose, platform) technologies with wide ranges of applications. Technological diversification and interdependence of products and companies had increased, as had R&D costs and premiums on dominant designs, dominant standards and time to global markets.

Factors like these could be expected to be conducive to both supply and demand of new technologies on technology markets. Technology trade has also grown [35]. The functioning of such markets as well as the need for them (e.g. in assembling necessary IPRs) could also be expected to be stimulated by a strong IP regime together with managerial learning about IP and how to trade technology and the growth of people and firms specialising in technology trade. Many companies (and entrepreneurs) also started in the 1990s to experiment with new licensing strategies and business models and switched from reactive to pro-active licensing. Licensing took on new features with more cross-licensing, block-licensing, core and non-core licensing, open licensing, licensing of other IPRs than patents, stand-alone licensing, technology platform licensing, licensing between equals (rather than from leaders to laggards), university licensing and so on. Royalty rates increased, as did royalty stacking, and many companies reported that their licensing propensity had increased. The strategic role of licensing increased in many companies, not least in ICT-based industries for establishing standards and technology platforms. Royalty-free or low-royalty licensing schemes also started to be used not only for creating standards and creating large producer and user communities, but also for organising R&D and technology collaborations among many parties more efficiently. In brief, the traditional list of advantages of licensing became extended, perceptions of advantages grew and disadvantages were down-weighed [7,5,36–38].

New supporting technologies for technology trade have emerged too, in particular the internet for online technology marketing and trade, but also new software packages for technology valuation and pricing, technology and patent mapping, and negotiation and contracting support among other things. In addition, new ICTs enabled more production and distribution of information, more means for technological protection and appropriation of information benefits and lower transaction costs, thereby fostering pure information markets, including technology markets (see [39]).

The development of financial markets and the venture capital industry since the 1980s has also contributed to the emergence and growth of technology markets. Patent portfolios and licence deals in young start-ups attract venture capital, and different financing for different development stages of a start-up induces trade in company stock, which is also a form of technology trade.

Thus, various empirical studies and observations have recognised the growing importance of technology markets, the growth of technology trade and the changing nature of licensing. From an economic analysis point of view, this is also an expected effect of the pro-patent era, although there are several other contributing factors as well, such as increasing technology diversification, managerial learning, new infocom technologies and developments in the financial system. Whilst supporting evidence favours the view that a pro-licensing era is emerging, it is yet too early to draw such a conclusion, apart from the uncertainty as to what a pro-licensing era really means. Nevertheless, there are no strong signs of any reversal of the trends described, pointing towards an era of more licensing and technology trade in varied forms.

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References and Notes

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16 The four companies were founded in 1883, 1876, 1871 and 1881 respectively, with units established for testing, product and process development, and even some research within a decade or two.

17 It may be noted that Alexander Graham Bell's neglect to extend his US telephone patent of 1876 enabled Ericsson to enter the telephone business.

18 This has been found in other studies as well; see e.g. [19] and, specifically for Japan, [20] and [7].

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30 Note that the degree of externalisation is the reverse of degree of integration. The latter would have the weight zero for technology scanning and one for internal R&D, with the weights for intermediate quasi-integrated forms dispersed equidistantly in between.

31 The importance of various corporate strategies in the framework in Section 2 was assessed as well in the study. See [22] for further details.

32 This sample resulted from a response rate of 78% for Japan and 86% for Sweden, and represented over 50% of total Japanese industrial R&D and around 80% of Swedish. The sample by and large included the largest industrial R&D spenders in the two countries. For further details, see [33].

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List of abbreviations

FDI	Foreign direct investment
ICTs	Information and communication technologies
IP	Intellectual property
ISIC	International Standard Industrial Classification
LTBF	Large technology-based firm
NIH	Not-Invented-Here
R&D	Research and development
STBF	Small technology-based firm