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**THE ACQUISITION OF TECHNOLOGY
AND SMALL FIRMS BY LARGE FIRMS**

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Ove Granstrand and Sören Sjölander

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ABSTRACT

This paper describes how large, typically multi-technology corporations build up and exploit their technological capability by purchasing small, technology-based firms in order to acquire their technology. The frequency, possible causes and economic effects of this phenomenon are elaborated, based on empirical studies of Swedish industry. A new mechanism for trading technology through the trading of small firms among large firms is proposed.

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1. Introduction

The output and resource use of the world's science and technology (S&T) system has grown fast and steadily with no signs of decline. Seven- to ten-year doubling times in the stock of knowledge, as indicated for example by bibliometric data or R&D expenditures, are common, corresponding to growth rates of about 7 to 10%.

By contrast, industrialized production tends to grow more slowly, as does the number of innovations, with average annual growth rates of roughly 3% and 5% respectively for Sweden between 1945 and 1980. This suggests the possibility of an expanding set of unexploited technological opportunities, especially in the light of results indicating that technology accounts for a very large part of output growth.¹⁾

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Given the growth differential, is there a deficient demand for technology? Could there be overcapacity in the S&T system that is protected on non-economic grounds? Or is there an undercapacity in the technology management system in the form of managerial bottle-necks regarding the exploitation of technology (Penrose 1959)? It is well known that the nature of R&D leads to underinvestment (Arrow 1962). On the other hand, a number of factors, such as a tendency to look at R&D as a kind of insurance premium or a lottery ticket, could cause overinvestment. The complexity of modern technology, requiring interaction of many highly specialized scientists and engineers, poses special problems for both markets and management to organize efficient innovation and diffusion processes. The matching of specific financial assets with human assets of various kinds is critical. The problem is exacerbated by the pace of knowledge accumulation noted above. For example, with a 40-year working lifetime for an average individual and a 10-year doubling time of knowledge in a given field, roughly 94% of the existing stock of S&T knowledge will be produced by scientists and engineers still alive and active. Moreover, a very small and declining share of that growing stock of knowledge could be acquired and mastered by a single individual during his or her working lifetime and then with a considerable lag. Thus, the current stock of technological knowledge is embodied in and fragmented among human assets to a very high degree and the matching of the different pieces of knowledge is also critical, given the increasing complexity of industrial production.

The emergence of corporations that exploit several technologies is one response to these problems. Externalization of technology sourcing and the creation of "technology markets" is another (Granstrand and Sjölander 1989). Even with these developments there is a need to develop new methods of technology management and new market mechanisms for translating technological developments into widely deployed innovative products and processes. All in all, one can speculate that a rise of quasi-integrated (or hybrid)

organizational and market forms is most efficiency-inducing in innovation (Granstrand 1982, pp. 196-200).

Given this, the present contribution intends to show how small technology-based firms (STBFs) are acquired by large technology-based firms (LTBFs), typically multi-technology corporations. Such acquisitions constitute a fairly recent phenomenon and the paper gives results based on case studies and a pilot survey. These results indicate that structural changes in the form of such acquisitions generate growth under certain conditions. A new mechanism or system is therefore proposed whereby STBFs are traded in the sense of being created, possibly as a spin-off from another firm, and then being acquired by LTBFs immediately or later. This would correspond to a very special market for corporate control, typically not involving hostility and management displacement. (Cf. Marris 1963.) This form of trading technology, "packaged" in small firms, is to be compared with other forms of trading technology, e.g. trading licenses or R&D resources. At present there are no empirical data available about the functioning and comparative advantages of such a complete acquisition and spin-off system. However, some theoretical rationales are indicated here, and further research may develop a full theoretical justification.

2. Acquisition and Exploitation of Technology

The **technology-base** of a company is the technological competence or capability (knowledge and skills) that the company possesses. It would ideally appear as an asset on the balance sheet of the company, although this is not easy to accomplish. Nevertheless, the asset is in effect valued in practice, for instance when a company is a target for acquisition. The asset can be built up, maintained and exploited in various ways. Granstrand (1982, p. 66) and Granstrand & Sjölander (1989) suggest the following typology-based on the contractual form used to build up and exploit technological competence. In falling order of

organizational integration, technological capabilities thus could be built up through internal R&D (including recruitment and training), acquisition of innovative firms (or business units), joint ventures (including inter-firm R&D cooperation in general), technology purchasing (contract R&D, licensing in, etc.), and finally technology scanning (including legal and illegal forms of acquiring technological know-how from outside without any direct purchasing from the original source). Similarly, in falling order of organizational integration, technology could be exploited through direct investments in production and/or marketing of products, creation of innovative firms (or business units), joint ventures (including inter-firm cooperation in general), technology sale (performing contract R&D, licensing out, etc.), and total divestment. In addition, there is a residue of unexploited or unappropriated technology, possibly leaking to competitors through their technology-scanning or hire-over efforts.

These different strategies for acquiring and exploiting new technologies may be combined. For example, both Swedish and Japanese firms have absorbed foreign technology and then combined it with internal development and subsequently exploited it through direct investments in production and international marketing. Strategies may also evolve, as in Japan's and recently South Korea's shifts of relative emphasis from technology-scanning to licensing and subsequently to internal R&D.

Now consider an LTBF's strategy to acquire innovative firms (STBFs), add value to them through capital and/or management and/or technology contributions, and then after a suitable period of time integrate them or divest them in various ways. This is how many venture capital firms and venture development units attached to a parent firm operate.²⁾ A given firm may acquire another firm or a product development project at a certain stage in its product and business development process. The internal growth is usually increased if this acquisition occurs at a

late stage, but then the price will be high. Experience has shown that a higher probability of failure is associated with acquisitions made before the acquired firm or project has its new product on the market, rather than afterward. It is also difficult to disengage from an unsuccessful STBF with lingering profit prospects.

In what follows we focus on the acquisition by large technology-based firms of small technology-based firms in general, not necessarily for the sole purpose of divesting them at a later stage, and we will try to assess the effects of that strategy, especially on growth. First we briefly consider a Japanese sample, then a Swedish one in more depth.

3. Acquisition of Small Technology-Based Firms by Japanese Large Firms

As part of an ongoing study of multi-technology corporations in Japan, Sweden and the US, 14 large Japanese manufacturing corporations were interviewed in April-May 1988. In general these corporations were diversifying both their technology-base and product base. 10 of them were strengthening their R&D in absolute terms and in 5 of these cases also relative to sales. 10 of them considered technological diversification and technology fusion of increasing importance. Within five years 8 of them had significantly increased, or will increase, their investments in basic research, and 6 of them were seriously considering, or already in the process of, internationalizing their R&D.

Japanese large firms acquire STBFs much less frequently than do Swedish and US firms, and this technology acquisition strategy ranks low in comparison with other possible means of acquiring technology (in-house R&D, joint ventures, licensing in, etc., as described above). Only 3 out of the 14 firms had acquired technology through takeovers, and then to a minor extent, often in an ad hoc

manner. Also, technology-based spin-offs from universities and large firms are very rare in Japan.

These facts could be attributed mainly to a traditional mentality among owners and managers. Also, there are few small technology-based firms to acquire. The rate of technology-based start-ups has been low, and existing firms seldom sell a subsidiary to another firm.³⁾ Lifetime employment and strong company loyalty imply low inter-firm mobility of engineers and managers. A social stigma seems also to be associated with the personnel of an acquired firm.

Things are changing, however. The number of acquisitions, start-ups and spin-offs is increasing. A Japanese venture capital market is developing. Investment by large Japanese firms in small, high-tech US firms linked up with universities and other basic research institutions is increasing. This creates concern and confusion in the US, since buying high-tech firms, perhaps also with university links, could be an efficient way of getting access to a nation's S&T system. The same possibilities do not exist in Japan for US firms, since Japanese universities and small firms are comparatively less important in the Japanese basic S&T system. However, these investments, according to one high-ranking Japanese company and government representative interviewed, should be looked upon not primarily as a way to get research results in the short run, but as a way for Japanese industry to learn more about the American S&T system and this mode of technology acquisition at the cost of "losing" much talented personnel to the US at present.

Of course, overly wealthy Japanese firms and a high-valued yen could be perceived by the US as constituting a new kind of "threat" to the appropriation of the American S&T base by US industry, which in turn relies much more on its domestic universities and small, high-tech firms for building up its technological capability. (Note how Japanese companies earlier bought inexpensive licences from

the US, by some called "the biggest bargain ever". The further development and exploitation of this technology later gave rise to severe trade friction between the US and Japan. Currently investment friction arises when Japan invests part of her trade surpluses in US assets, including S&T assets.) A similar perception of asymmetry could develop in Europe, in those few areas where Europe has an edge in basic S&T. It seems that there is an increasing S&T protectionism rather than a development of international markets for science and technology that results from differences in the national technology supply structures such as the ones described above. This S&T protectionism among nations and trade blocks could be a temporary phenomenon, but chances are that it will thrive on perceptions of problems with appropriating the benefits of private and public investments in R&D.

4. Acquisition of Small Technology-Based Firms by Swedish Large Firms

4.1 Previous research

Many studies have claimed that small companies have a stage-specific or total advantage over their larger counterparts, in regard to innovative activities. Williamson (1975, pp. 196-207) divides the innovation process into three stages - invention, development and final supply - and argues that no single size or form of organization has optimum properties with respect to all stages. Rather a system in which large firms acquire small ones at some point is optimal, he argues. Small firms are then considered to have comparative advantages at early stages of the innovation process, while large firms have advantages at later stages, for example by providing financial or managerial resources or an already established sales organization for international marketing.

However, there are few if any systematic empirical studies of how large companies acquire small ones with the primary motive of acquiring their technology. Utterback and Reitberger (1982, p. 23) found that of all Swedish manufacturing firms with 5-20 employees in 1975, about 10% had been acquired by larger firms by 1980. For a sub-sample of 60 STBFs formed between 1965 and 1980, the situation in the early 1980s was that 50% of the firms were wholly owned, 72% majority-owned, and 8% minority-owned by their original founders (op.cit. p. 33). 20% of the firms were wholly owned by others than the original founders. Of the 17 firms (28%) majority-owned by others, 12 had been taken over by large manufacturing firms (i.e. firms with more than 1,000 employees). A further analysis of the Utterback-Reitberger data shows that the average age at the time of acquisition for those 17 firms that had been acquired by 1982 was 5.8 years, and that the rate of acquisitions made by large firms had been radically increasing during 1965-1988 (cf. Table 4.1 below).

A main conclusion from the above-mentioned study is that the importance of large firms in the development of small firms in Sweden has been increasing through take-overs, customer pre-payments, R&D collaboration, and provision of a general breeding ground for new firms. In some of the critical stages of the development process of STBFs, the creation of a symbiotic relationship with a large firm has to be contemplated by the small firm. With respect to financing, an alternative or a complement would be to turn to a stock market or a venture capital market in general. However, the latter alternative might not always provide the necessary extensions of management, marketing, production and R&D capabilities of the small firm. Transactional cost considerations often make the small firm entrepreneur favor the resource-rich large firm over the various input markets.

The important role played by large firms in the Swedish economy is further emphasized by looking at the type of firms that generate and exploit Swedish innovations. McQueen and Wallmark (1983) have shown that 80% of the 100 greatest (in terms of generated sales) civilian, patented innovations in Swedish industry in the period 1945-1980 were carried out by large firms. Of the 20 innovations carried out by new firms, 5 had been acquired by large firms in 1983, and 10 in 1988. Moreover, of these 20 innovations, 11 actually originated in existing firms where they did not fit in, and the corresponding 11 new firms could be regarded as directly or indirectly spun-off from existing firms. All in all, only 6 new firms of the 20 were neither spin-offs, nor had they been acquired by 1988. Thus, the importance of large firms in the innovation and business development processes in Swedish industry is even further increased by their role in spin-offs and acquisitions. For further empirical analysis of these samples, see Section 4.3.

4.2 Summary of the case study

This section summarizes a first study of the phenomenon of LTBFs acquiring STBFs as reported by Granstrand and Jacobsson (1983) and further developed by Jacobsson (1984). The study was exploratory since no previous studies of this type of acquisitions had been found, either in Sweden or abroad. Its empirical part consisted mainly of 5-10 interviews about each of 13 acquisitions. These were chosen from the acquisitions made by four LTBFs, covering the two most R&D-intensive industrial sectors in Sweden on a 2-digit ISIC level. The 13 acquisitions were also selected as extreme cases with respect to a compound success-failure variable related to the outcome of the acquisition in various technological commercial and economic respects.

In general, the following factors were found to be more or less related to the outcome of a large firm's acquisition of a small, technology-based firm:

- a) The seller's motives
- b) The buyer's motives
- c) The acquisition strategy of the acquiring firm
- d) The handling of key personnel
- e) The post-acquisition organization of the acquired firm
- f) The transaction time
- g) The stage of business development (stage of innovation) of the acquired firm
- h) The position of the person urging the acquisition
- i) The type and degree of diversification of the acquiring firm
- j) The nationality of the acquired firm

The most important of these factors will be commented upon below. Regarding (a) it was found that when the owners of a small firm were selling mainly because they needed capital for private consumption, there was a strong tendency towards opportunistic behavior. Since the market for corporate control in the particular cases of acquisitions considered here was characterized by a high degree of monopolistic power, the seller often had possibilities to withhold or even distort data which were necessary for evaluation of the firm. Thus, there was an increased risk that the buyer did not know what he was buying, which of course would increase the risk of post-acquisition failure.

Regarding (d) the managers and key personnel in the acquired firm were of crucial importance for a successful outcome, since the managers in the acquiring firm had little or no experience in the technology or the market. To retain key personnel was thus crucial. In all cases where R&D key personnel left within a year after the acquisition, and in 60% of the cases where the general manager left the firm, the acquisition led to a failure.

(e) The way in which the small firm **should** be integrated depended on the type of the acquisition. If the intention of the large firm was to diversify radically, the study indicated that the acquired firm should be organized at the corporate level or in a new venture development unit and left with a large amount of autonomy. If the acquisition was horizontally or vertically related, one usual motive for making the acquisition was to establish synergies in one or more areas. The best way to organize the acquired firm then seemed to be to integrate it in the division with which primary synergies were sought, despite the common risks of NIH (Not-Invented-Here) effects and unproductive internal competition.

Synergies were most often found in marketing and R&D. However, when large efforts were made to realize synergies, internal competition sometimes resulted between corresponding functions in the large firm and the small firm. This competition occasionally prevented synergies, but in other cases it stimulated both firms to make progress without cooperation and thus attain greater benefits in total. The mixed verdict regarding the effects of internal competition in general emphasizes the need for adequate attention to the post-acquisition management of acquired STBFs.

(f) Acquisition of an innovative firm not only involves an evaluation of the economic position and market strength of the target firm. It also involves evaluation of a new technology, which is not an easy task. Since the market was often characterized by a small-numbers condition in combination with opportunism, there were strong reasons for the buying firms to spend time in evaluating acquisition candidates. The average time of the acquisition transaction in the sample was 10 months. The failures in the sample all had a transaction time of 6 months or less. This indicates that a longer transaction time is associated with a successful outcome of the acquisition, although the postponement of a decision to acquire may lead to missing a good opportunity.

(g) Of the failures in the sample, 67% were found among the firms that had only an idea developed to a prototype level or had just introduced the first product generation on the market. These firms failed in further developing and marketing their products, and the large firm was never able to sell the small firm further. This indicates that the risk of failure is greater if the firm being acquired has not reached a later stage in the business development process.

It is often claimed by managers in both small and large firms that the innovativeness in a small firm will disappear after the acquisition. The study found no support for this hypothesis. Both multi-innovative firms (with more than one innovation) and single-innovative firms show the same tendency to innovate after the acquisition as they did before. On the other hand, single-inventive firms (at most in a prototype stage at the time of the acquisition) were not always able to fully develop or successfully launch the product on the market after the acquisition. This indicates a significant risk in buying single-inventive firms.

In summary, the empirical findings of the study indicate that the market on which STBFs are traded is typically a seller's market, often characterized by monopoly. Thus, contrary to common belief, the small firm appears to have an advantage over the large company in the transaction. The market gives rise to a small-numbers condition, where sellers can behave opportunistically. When more than one large firm shows an interest in acquiring the small firm, competition arises and not seldom an acquisition takes place only to prevent a competitor from buying. The competition in general among buyers of small firms may then lead to younger and younger STBFs being acquired, aside from driving up the prices of them. However, the early-stage firms, whose products often need much additional development work before market introduction, are more difficult to evaluate and the outcome of the acquisition is far more uncertain. Competition among buyers also tends to shorten the transaction time, again increasing the risk of failure. Of course, an increasing failure rate in turn tends to dampen subsequent competition among buyers for STBFs, implying a self-regulating feature of the system of LTBFs acquiring STBFs.

4.3 Growth among acquired and non-acquired STBFs

Now let us analyze the occurrence and effects of acquisitions of STBFs by LTBFs mainly for the purpose of strengthening the large firm's technology base. How many firms are acquired when and why? Do they grow faster and more profitably than non-acquired firms? Do acquired firms grow faster and more profitably after acquisition than before acquisition? What factors can explain differences in growth and profitability? These are questions that the case study could not address in any depth. A subsequent study focusing on some of these questions is now in progress, and the results of a pilot study concerning the effects on STBFs rather than on LTBFs are presented here.

Three samples of small technology-based firms have been analyzed in the present pilot study. The first consists of the 20 new firms based on one of the 100 greatest, civilian, patented innovations in Sweden during 1945-1980 as identified by Wallmark and McQueen (1983). Of these innovations, 20 gave rise to a new firm, and the rest were exploited by predominantly large firms through corporate entrepreneurship.

The second sample is identical to that of 60 STBFs in the CPA (Centre for Policy Alternatives at MIT) study of Swedish technology-based firms established during 1965-1980 and operating independently with at least 20 employees in 1980 (see Utterback and Reitberger, 1982). The third sample consists of the technology-based firms spun off from Chalmers University of Technology in Sweden between 1945 and 1980.

Primary data has been collected by questionnaires and phone interviews for all three samples, complementing some available secondary data for the first two samples. In general, reliable data on profitability have not been available for the acquired firms after acquisition. Usually the acquired firm does not remain as a comparable profit center in the large firm after acquisition, especially not after the integration process that tends to take place soon after acquisition of the type studied here. Moreover, there are no stock market prices for the STBFs that could be used to measure effects of acquisitions. Thus acquisition effects on growth of the STBF's sales and employment have been focused upon. Sales figures have been adjusted for inflation using consumer price indexes. Business cycle effects have not been removed since it is unclear what kinds of cyclic effects, if any, pertain to the different technology-based businesses, many of which seem rather insensitive to such cycles.

Table 4.1 in about here

Table 4.1 presents some sample statistics. As can be seen, between 38% and 63% of the STBFs in the samples had been acquired by May 1988. More than 80% of the acquired STBFs had been bought by LTBFs. The average age of the acquired firms ranged from 14 to 25 years. The indicators show considerable managerial integration and owner control of the acquired firm at the board level, with 45% to 68% of the board members appointed by the acquiring firm. At the managerial level the results are less conclusive. In the CPA sample 38% of the management team members were appointed by or recruited from the acquiring firm, while the corresponding figure was only 4% and 6% in the two other samples.

Do acquired firms grow faster than non-acquired firms? Table 4.2 gives three indicators: the total growth of sales during the lifetime of an STBF, total growth of the number of employees during that time, and the average annual growth of sales, that is total growth of sales during lifetime, divided by age.

Table 4.2 in about here

Our analysis clearly indicates that acquired STBFs grew faster than non-acquired STBFs. But is this due to post-acquisition effects, or do LTBFs tend to buy STBFs already growing at a relatively high rate? Does acquisition induce high growth or the other way around? A t-test showed that there were no significant differences between acquired and non-acquired STBFs regarding their average annual growth of sales during the period when the STBFs were not acquired (Prob (F' > t) = 0.78). Moreover, a t-test showed that among acquired STBFs, post-acquisition growth was significantly (6-8% level) higher than pre-acquisition growth for all three growth indicators (Prob (F' > t) = 0.05-0.08, see Table 4.3 below.)

One may also ask whether the results presented here are affected by a search-induced bias in that the buying companies deliberately search for STBFs not necessarily with a past record of high growth but with clear potential for future growth. To answer this question, the growth pattern among STBFs that had received an offer to sell but rejected it was investigated. Among the 14 firms so identified, no significant difference in growth compared to other non-acquired firms was found.

Table 4.3 in about here

So a reasonable conclusion is that STBFs are not bought by LTBFs because they are growing at a relatively high rate, but possibly because their resource base is complementary to that of the LTBFs and their integration with these can reap the potential benefits. More than 50% of the interviewed firms in the pilot survey reported resource synergies, especially marketing and financial ones (cf. Section 4.2).

Next we analyze growth after the STBFs have been bought. Table 4.3 shows the results. There is a significant (at the 6-8% level) difference between growth rates before and after acquisition, with faster growth after the acquisition.

Moreover, Table 4.3 shows that the standard deviation for the growth indicators increases after acquisition. This may be due to the intervening management factor. In some acquisition and integration processes the large firm's management principles were forced onto the STBF in a way that caused counter-productive conflicts and was thus a management failure. On the other hand, some more experienced large firms had developed management skills applicable to the integration process and hence had a better chance to contribute to the growth of the STBF by means of its resources. If such differences in post-acquisition managerial skills are present for a given level of resource complementarity, the standard deviation in the sample should increase for post-acquisition indicators.

The next question is to what extent populations and vintages of small firms shrink because of acquisitions. In other words, how long will a new firm live on average as an independent firm? Does the number of non-acquired firms in a vintage decrease towards an asymptotic level as they grow older? To investigate this in the three sub-samples, the percentage of non-acquired firms of all STBFs of a certain age is shown in Figure 1.

Figure 1 in about here

The distribution indicates an asymptote for the percentage of non-acquired firms in the total sample at roughly the 49% level. The distribution above the asymptote is nearly exponential⁴⁾.

In the total sample, 11% of the STBFs were acquired during their first 5 years, 19% before an age of 10 years, and 50% before 32 years. If the time from initiation to market introduction of a new product generation is about 10 years, one may conclude from the distribution that 20-30% of STBFs do not enter a subsequent development of their second major product generation as independent firms. Many of the young acquired STBFs stated that the reason for selling the small firm actually was to gain access to a large firm's financial, marketing and technological resources, which were needed to strengthen the STBF's own R&D and sales. Among the old non-acquired STBFs, three problems often created crises in their post-innovation process: (a) financing and managing international marketing, (b) financing and managing the development of a second major product generation, and (c) bridging a subsequent generation shift in the top management team.

4.4 A tentative growth model

We have paid special attention to growth factors associated with age, size, technological diversification, ownership and managerial control. Table 4.4 shows the results from a regression analysis performed on the linear model:

$$\text{GROWTH} = k_0 + k_1 \times \text{ACQ} + k_2 \times \text{AGE} + k_3 \times \text{IBL} + k_4 \times \text{MC} + k_5 \times \text{SIZE} + k_6 \times \text{TDIV}$$

In order to control for size, GROWTH has been operationalized as average annual growth in sales as in Table 4.2, divided by sales in 1987. ACQ is a binary variable = 1 if more than 50% of stock was acquired, else it is = 0. SIZE is measured by number of employees in 1987. Operationalizations of the other variables in the model are as shown in Table 4.1, where IBL is a measure of relative changes in ownership and MC a measure of relative changes in management.

Table 4.4 in about here

As can be seen from Table 4.4 acquisition, age, size, management control and technological diversification all contributed significantly to the relative annual growth of sales. Integration at the board level did not. Thus, the results indicate that changes in ownership contribute to growth but not primarily through large personnel changes at the board level but rather through contributing managerial and technological resources to the acquired firm. This is not inconsistent with the finding from the case study that continuity in top management and key R&D personnel of the acquired firm is important (cf. Section 4.2). The strong influence of technological diversification on growth of STBFs indicates the importance of building a broad technology base and matching different technological competences as mentioned in Section 1. This result for STBFs is also consistent with the finding in Granstrand and Sjölander (1989) that technological diversification was associated with high growth among Swedish LTBFs.

The results presented in this section are far from conclusive. However, the analysis favours a continued effort to develop and test growth models for STBFs along the above lines. Several questions deserve further probing. What is the causal relationship between technological diversification and growth? What factors can help to explain the increased growth of STBFs after they have been acquired? What kinds of integrative mechanism are most effective for enhancing growth? What is the nature of the synergetic potential of the LTBF and the STBF? How is this potential identified and its benefit realized? These are some of the topics that should be addressed in future studies.

5. Discussion and Speculation

5.1 Empirical summary

Empirical studies of acquisitions of small technology-based firms (STBFs) by large technology-based firms (LTBFs), reported in Sections 4.2 and 4.3, show among other things that:

Case study

- o The market for corporate control involving such acquisitions is mainly a seller's market, characterized by monopolistic power. Competition among buyers leads to reduced transaction times, higher prices, and "underdeveloped" firms with unfinished technology being acquired. These three factors are associated with acquisition failure at the buying LTBF end.
- o Technological innovativeness of the STBF is not normally slowed down by an acquisition, on the contrary.
- o Continuity in top management and key R&D personnel of the small firm before and after acquisition is associated with the latter's success.

Pilot survey

- o The post-acquisition growth of STBFs is significantly higher than pre-acquisition growth.
- o Non-acquired STBFs grow at roughly the same rate as do acquired STBFs before acquisition. Thus, there is no evidence that high-growth firms are primary targets for acquisition.
- o The number of independent STBFs with the same age shrinks rapidly due to acquisitions, 19% of firms being acquired before the age of 10 years. The acquired firms' lifetimes as independent firms were nearly exponentially distributed.
- o Management control exerted by the LTBF and technological diversification of the small firm contributed significantly to its post-acquisition growth, while integration at its board level with the large firm did not.

Thus, the empirical evidence available so far gives some indication of the 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 contributes little to an understanding of the special "entrepreneurial" type of acquisitions considered in this paper. (See for instance Salter and Weinhold, 1979; Singh, 1984; Addanki, 1986; Ravenscraft and Scherer, 1987 a, b; and Scherer, 1985.) Studies of acquisitions and mergers generally focus on larger acquisitions than considered here, on acquisitions with more available data on stock prices, profits, assets and the like, and on acquisitions made with other primary purposes. Still, comparison of results may be useful. For instance Ravenscraft and Scherer (1987 b, p. 212) found no strong support for the common view that acquisitions are efficiency-inducing through their displacement of inefficient managers. In the study reported in this paper, acquired firms were not especially ill-managed and to retain key managers and supplement them through additions to a management team was often crucial to a successful outcome of the acquisition. Moreover, Ravenscraft and Scherer (1987 a, b) found no significant positive effects of acquisitions on the acquired firm's profitability, which was influenced by asset value write-ups resulting from the acquisition, neither did they find a positive effect on the post-acquisition growth of R&D efforts. This is in contrast to the present study, where positive effects of acquisitions on sales growth as well as on innovativeness were indicated.

However, the particular type of acquisitions considered in this paper is a relatively recent phenomenon and any evidence is weak at best. As the number of such entrepreneurial acquisitions increases and managerial systems evolve to handle them, it will become easier to accurately assess their outcome and potential value as an innovation and growth-inducing mechanism in an economy, thereby possibly contributing to institutional evolution (cf. Day 1988). Certainly, the common belief that the large non-innovative firm is preying on the small innovative firm to the detriment of its owners and eventually choking its innovativeness is not at all supported by the empirical studies presented here. Instead, the evidence suggests that the large acquiring firm releases a technology exploitation potential for the small firm.

5.2 An acquisition and divestment system for trading STBFs

As mentioned in Section 4.1 Williamson (1975, p. 196) proposes a "systems approach" to creating efficient innovation processes in an economy, whereby small firms specialize in early stages of the innovation process for subsequent acquisition by large firms specializing in late stages. We now propose an extended "system" to include also the mechanism by which LTBFs spin off STBFs for possible acquisitions so that a market for STBFs is created as a supplement to other forms of technology markets.

There are several reasons for believing that the latter mechanism would be efficiency-inducing as well. First of all, since it presents a new degree of managerial opportunity, it has in principle potential benefits just as a pure acquisition mechanism has. More importantly, large firms operating in many technological areas become increasingly important as sources of new technologies and inventions with a potential for innovation outside their existing product areas. Since large and old firms, with age sometimes more important than size in this context, may have early-stage disadvantages, they could create new "firms" within the firm, thereby decreasing managerial integration and changing ownership and capital structure, possibly to the point of spinning off a fully independent new firm (or it can be kept at arm's length for later re-integration). Moreover, in vertically integrated firms, new or almost new technologies could be more efficiently improved as well as economized if a firm is spun off to exploit them on non-captive markets as well. In such cases, there are also possible benefits for the large firm's remaining businesses since they might not have to cater to captive suppliers or compete with customers.

At present there are few, if any, empirical studies that go beyond anecdotes in examining benefits from such spin-offs. We may add to the anecdotal evidence that the diversified auto manufacturer Volvo was legally started 1915 as a wholly owned subsidiary to the specialized bearing manufacturer SKF and was spun-off in the early 1930s. Today (1989) Volvo ranks as the largest spin-off firm in Swedish industrial history, and a close examination of the corresponding business histories shows that Volvo would probably never have developed so successfully if it had remained a wholly-owned subsidiary of SKF.

Eliasson and Granstrand (1982) report four cases of Swedish large firms trying to organize, in a semi-autonomous way, venture development units within the firm which could serve as vehicles for both acquisitions and spin-offs. This organizational idea, at least two decades old, has not been extensively applied in Swedish industry and several unsuccessful attempts are known. However, a large firm can organize both acquisitions and spin-offs of small firms in ways which are yet to be experienced.

While awaiting more empirical studies, some speculations and theorizing are worthwhile. Consider a system with technology-based and technology-generating firms, consisting of a population of large firms that acquire and spin off small firms, and a population of small firms with entries from and exits to the population of large firms in addition to entries and exits to and from the environment. Both acquisitions and spin-offs could be made with varying degrees of ownership and control, and thus we could also regard the system as a collection of large firms with clusters of small firms attached to them in a dynamically changing quasi-integrated manner.

Such a quasi-integrated system might be innovation-inducing, since it has a potential for combining advantages of managerial and market mechanisms while mitigating many of their disadvantages. This could be argued in a transaction cost framework in line with Williamson's proposed "systems approach". It could more specifically be argued on the grounds that technology, through its information nature (Arrow 1974), gives rise to classic market failures on the one hand. On the other hand, technological information has peculiar features compared with other types of information, e.g. being more possible to codify, through e.g. mathematical and chemical formula, drawings, nomenclature and patent specifications,

and thereby more possible to transfer and accumulate. Technological information is also to some extent divisible and less subject to Arrow's information paradox (Arrow, 1974). Besides, there is the legal framework of intellectual property rights which, despite well-known criticism, is to some extent harmonized and functioning internationally as a basis for creating a market for technology. The special technology strategy of acquiring and spinning off small firms may then, as a result of counteracting influences, be a suitable way of packaging technology and transacting it and/or managing it.

Let us next assume that growth impulses arise - at least in the small firms - from gradual or radical changes in ownership and control of the two major types considered here, acquisition and spin-off. The question then is which characteristics of this fission/fusion pattern contribute to overall growth and innovativeness. Important characteristics are the stage of innovation (roughly corresponding to the age of the STBF) and the size of firm, at least on a first level of analysis. In addition, the STBF is mostly characterized by technological competence, its most valuable asset (cf. Eliasson 1988). An acquisition of the type considered here is attempted only if complementarities are perceived between the technological competences of the LTBFs and STBFs. Similarly, a substitute technology might be better developed in a small, spin-off firm due to impeding factors in large organizations, having to do with persistence, procurement bias, lack of entrepreneurial incentives etc.

Continual developments in different technologies especially generic, pervasive ones such as materials technology, information technology, automation technology, bio-technologies and subsequent product/process improvements make, together with market fluctuations, any identification of stages of innovation somewhat haphazard and artificial. Similarly, the concept of size of the firm refers back to the question of what levels and types of ownership and control should define a firm. However, as a first approximation, age, size and competence may be used as rather easily operationalized variables to characterize the fission/fusion pattern in the total population of LTBFs and STBFs. (A firm's technological competence in various technologies could in principle be measured by number of engineers of different qualities or degrees and also to some extent by number of valid patents in various areas.) A formal modelling of populations of LTBFs and STBFs interacting through acquisition and spin-

off (divestment) processes of the kind presented here is outlined by Gyllenberg (1988), building on the theory of structured population dynamics.

What are the relevant questions then to ask such a model? Important ones concern asymptotic behavior and stability. For example, is there a stable age-size distribution towards which all distributions converge? Under what conditions will steady-state dominance of old, large firms appear or disappear (cf. the old Schumpeter in Schumpeter 1976)? Especially - under what conditions will there be a stationary (periodic or non-periodic) co-existence of large and small firms? Such a co-existence would then mean the coexistence of the young and the old Schumpeterian regimes, or Schumpeter Mark I and Mark II respectively (see Day and Eliasson 1986, pp. 199 and 372). Intuitively it seems likely that there is a (non-trivial) range of initial conditions and model specifications that would produce persistently recurring time periods (all with lengths exceeding some possibly small but positive number given beforehand) of co-existence with probability one. However, for the time being this must be left as a hypothesis.

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Footnotes:

1) Of course, military R&D accounts for roughly half of the world's R&D, and the growth pattern of the world's military expenditures and "output" (national or international security?) could in principle explain the possible growth differential between growth in S&T knowledge and economic growth, but this is unlikely (unless there are some peculiar interactions between the military and civilian R&D and economy). Other possible explanations of the growth differential relate e.g. to the incentives to publish in the non-commercial part of the S&T system (typically universities but also government labs) or to the possibility that knowledge growth rates are high in those fields that have not yet become commercially exploited to any high degree, or that a declining share of produced knowledge could yield positive RoIs (a slow-down of "real" R&D productivity), or that time to exploitation increases in general. In any case, the notion of even a temporary exhaustion of opportunities to invest in new technology seems unrealistic not only to any active engineer but also to the perhaps less romantic entrepreneur.

2) For example in the way Pernovo is attached to the Swedish chemical firm Perstorp.

3) ("You don't sell a member of the family".) Acquiring a firm is almost considered piracy, as when material-maker Kyocera acquired camera-maker Yashica, as a step in a long-range plan for Kyocera's technological diversification rather than a short-range move for product diversification.

4) Exponential interpolation was performed for the total sample with five classes: 0-5 years, 6-9 years, 10-17 years, 18-32 years and 33 years or more. $F(x) = 1 - e^{-\lambda x}$ and 49% non-acquired companies after 32 years gives $0.49 = e^{-\lambda 32}$ and $\lambda = 0.0223$ and $\chi^2_{obs} = 4.90$, which corresponds to a significance level of 0.093. Thus one may conclude that the distribution is exponential on the 10% level but not on the 5% level.

FIGURE 1

Distribution of Life-times of STBFs as Independent Firms in the Three Samples

(N=100)

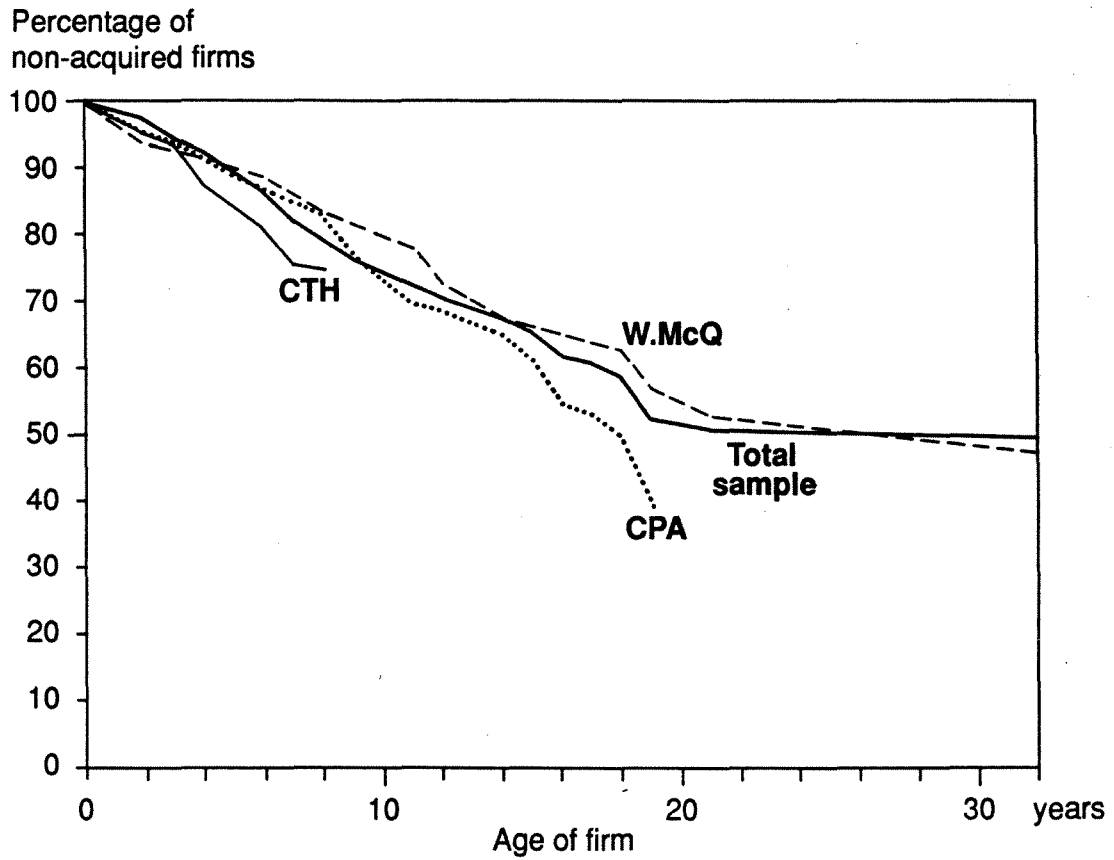


TABLE 4.1

Sample Statistics for Three Swedish Samples of Small Technology-Based Firms

Variable	Sample		
	W.McQ. ³⁾	CPA ⁴⁾	CTH ⁵⁾
Sample size	19	60	39
Number of STBFs acquired by May 1988 (>50% of stock acquired)	9	38	15
Average annual growth of sales (MSEK)	12.7	6.8	0.3
Age 1988 (in years)	25.1	18.0	14.4
T-width ¹⁾	1.57	1.31	1.22
TDIV ²⁾	0.51	0.78	0.38
FOR ACQUIRED FIRMS:			
Growth of number of persons on the board	1.3	1.9	1.4
Proportion of new members on the board (IBL)	45%	68%	61%
Growth of number of persons in the management team	1.7	1.6	1.3
Proportion of new members in the management team (MC)	6%	38%	4%

- Note
1. Sample average of the number of engineering (M.Sc.) categories (mechanical, chemical etc.) represented in the firm, i.e. width of the technology-base of the firm.
 2. Growth of T-width from the founding of the company until 1988.
 3. Sample of 20 STBFs from Wallmark and McQueen (1983) established between 1945-1980. (Data from one case is missing.)
 4. Sample of STBFs from Utterback and Reitberger (1982) established between 1965-1980.
 5. All STBFs spun off from Chalmers Univ. of Technology and established between 1945-1980.

TABLE 4.2

Growth Among Acquired and Non-acquired STBFs

Growth indicator	Non-acquired Firms			Acquired Firms			Significance Level
	N ¹⁾	Mean	Std dev	N ¹⁾	Mean	Std dev	Prob F'> ²⁾
Total growth of sales (MSEK) ³⁾	46	69.4	162.1	54	109.1	353.2	0.0000
Total growth of number of employees ⁴⁾	46	114.7	344.7	54	157.3	543.4	0.0021
Average annual growth of sales (MSEK) ⁵⁾	46	3.7	9.3	54	5.1	16.3	0.0001

1. Sample size was reduced due to missing data.
2. t-test of difference in mean values for acquired and non-acquired firms.
3. Sales in 1987 minus sales during the firm's first year adjusted for inflation using consumer price index (1980=100).
4. Number of employees at the end of 1987 minus number of employees at the end of firm's first year.
5. Total growth of sales divided by age. Adjusted for inflation using consumer price index (1980=100).

TABLE 4.3

Growth Among Acquired STBFs Before and After Acquisition

N=54 (missing data for 12 acquired companies)

Growth indicator ¹⁾	Before Acquisition		After Acquisition		Significance Level
	Mean	Std dev	Mean	Std dev	Prob F'>
Total growth of sales (MSEK)	56.3	176.2	69.8	222.8	0.050
Total growth of number of employees	70.0	270.5	111.5	349.9	0.080
Average annual growth of sales (MSEK)	4.8	16.8	6.0	18.2	0.052

1) Same as in Table 4.2.

TABLE 4.4

**Regression Model (N=98, $R^2=0.386$)
of Relative Annual Growth of STBF Sales**

Variable	Parameter estimate		Prob >/T/
Intercept	1.100	(k_0)	0.0076
ACQ	0.201	(k_1)	0.036
AGE	0.094	(k_2)	0.042
SIZE	0.141	(k_3)	0.031
IBL	0.069	(k_4)	0.102
MC	0.093	(k_5)	0.051
TDIV	1.12	(k_6)	0.042