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The Impact of Internationalization and Externalization on the Technology Acquisition Performance of High-Tech Firms

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ABSTRACT

The internationalization and externalization of the technology acquisition of business firms is globally increasing. The impact of these strategies on the technology acquisition performance of firms however has not been studied yet sufficiently. An analysis of 165 questionnaires from R&D managers of 16 leading pharmaceutical and semiconductor business units in Germany and Japan reveals that the internationalization of internal technology leads to an improvement of technology acquisition performance. Unlike internationalization, the externalization of technology acquisition exerts no significant influence on the performance of the surveyed business units. For the success of externalization strategies in technology acquisition, the maintaining of internal technological strength appears to be indispensable.

1 Introduction

In recent decades, the field of technology and innovation management has gained increased attention in the overall context of analyzing business firms' competitiveness. Due to a speeding up of technological progress in many relevant fields for business applications, the development of new products and processes has moved to the forefront of strategic management.

Business researchers have developed a variety of tools to support managerial efforts in this field. Such analytical methods include portfolios for the selection of technologies and products to be developed (Kamm, 1986), concurrent engineering and lean development (Åhlström and Karlsson, 1996) in order to increase the speed and efficiency of development processes, and recently, the application of knowledge management (Nonaka and Takeuchi, 1995). For a long time however, technology and innovation management, and in particular the acquisition of new technological knowledge has been viewed in the frame of two implicit assumptions. Firstly, the R&D function, and namely the acquisition of new technologies which is a central part within the field of R&D, was regarded mainly as an *internal* function of business firms. Secondly, even in the case of large corporations, the core of new technologies was mostly developed *domestically*, i.e. by the main R&D units in the home country of a firm. Without neglecting the importance of external and of international sources of technology, their role appeared to be a secondary one in the total business process of acquiring knowledge for the development of new products and processes.

This conventional wisdom has gradually weakened since the 1980s. R&D consortia, as well as external sources of technology in general, and the internationalization of industrial R&D have received increasing attention in the context of technology and innovation management (von Hippel, 1988; Granstrand, Håkanson and Sjölander, 1992). Correspondingly, business firms have certainly increased the weight of external and of international sources of technology in their R&D process, as will be discussed in detail in the next section.

These developments can be explained with a number of structural changes in the technological competition between firms. Due to an increase in the amount of technological knowledge and in the number of competitors in many industries, competition on the development of new products and processes generally seems to have intensified between firms. This has also resulted in a higher importance of speed vis-à-vis cost in the field of technological competition. Therefore, it has become inevitable for competing firms to make better use of technological knowledge outside their former institutional and geographical boundaries.

In this perception, the externalization and internationalization of technology acquisition is viewed as a sheer necessity the management of business firms has to comply with in order maintain its technological competitiveness. It may be due to this prevailing view, and also to the general difficulties to measure business firms' performance in the field of technology acquisition, that the actual impact of externalization and internationalization on the performance of firms in this field has not been scrutinized sufficiently until now. Although it seems plausible that firms cannot circumvent the externalization and internationalization of technology acquisition due to changes in their competitive environment, it still remains an open question whether firms which have externalized and internationalized their technology acquisition really show a better performance in this field than other firms which still mainly rely on internal and domestic sources of technological knowledge.

This gap of empirical research will be addressed by the subsequent analysis of a detailed survey of leading high-tech manufacturing firms in Germany and Japan. The results show that there are wide differences between the firms concerning externalization and internationalization of technology acquisition. In general, the technology acquisition is found to be more externalized and internationalized in most German firms than in most Japanese firms. The self-assessment of technology acquisition performance by German managers is also significantly higher than by Japanese managers. These findings seem to confirm the conventional view that externalization and internationalization of technology acquisition is inevitable to maintain technological competitiveness. A detailed analysis of the survey data reveals however, that while the internationalization of the firms' R&D can be identified as an important factor improving the technology acquisition performance, the impact of the externalization of technology acquisition on the firms' performance in this field is less clear.

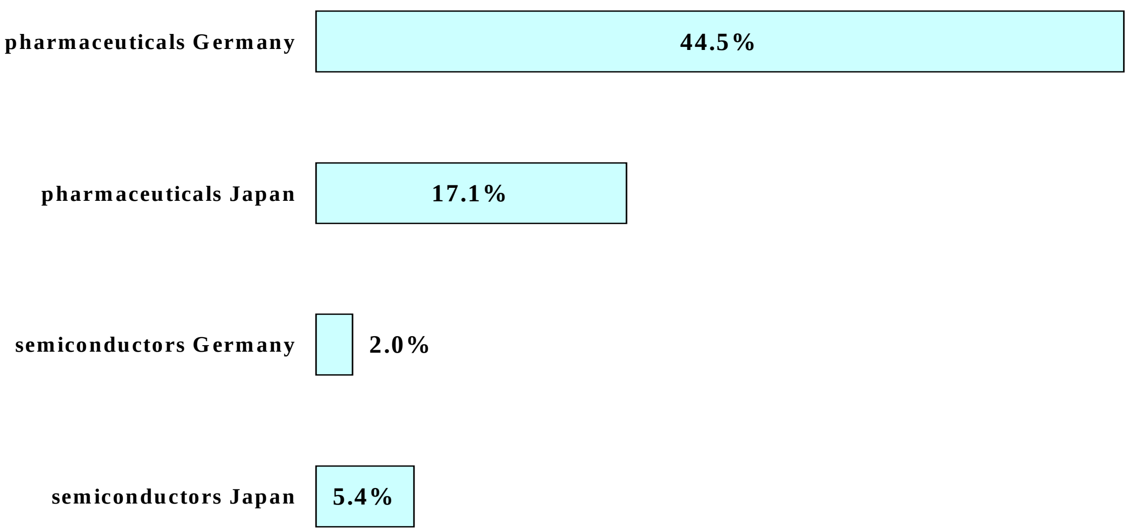
2 Internationalization and externalization of technology acquisition in high-tech firms: an overview

2.1 Internationalization

With the exceptions of a few multinational firms originating from small home countries in Europe, the R&D even of very large manufacturing firms has been dominated by the main R&D units in their home countries at least until the 1980s. An international analysis of patent data until 1986 revealed that at that time the R&D activities of large firms were still dominated by the operations in their home countries (Patel and Pavitt, 1992). The results of recent surveys indicate however, that the importance of overseas R&D is gradually increasing in large manufacturing firms (Gassmann and von Zedtwitz, 1998; OECD, 1999; Reger, 1999).

Statistics on the overseas R&D spending of US manufacturing firms confirm this view (Figure 1). The pace of internationalization, as measured by this indicator, is rather slow, however. In some industries like electrical equipment the relative share of overseas R&D spending has even decreased in the 1990s. Among the R&D-intensive industries, only in the pharmaceutical industry the overseas R&D accounted for more than 20% of the total R&D spending of US firms in the second half of the 1990s.

Figure 1: Part of total R&D expenditures of US manufacturing firms spent abroad



Source: National Science Foundation, 2000.

Other statistical data reveal that the relative importance of international R&D is higher for firms from other countries. In Germany, international R&D accounted for an estimated 20% of the total R&D spending of German manufacturing firms in 1997 (BMBF, 2000). In the cases of other countries like Ireland, Australia, Canada, the UK and Spain this share is even higher and reaches a level of more than 30% (OECD, 1999). The opposite extreme is the case of Japan, where the overseas R&D of industrial firms was a mere 3% of total R&D spending in 1997, up from an almost negligible 0.7% in 1989 (Tsūshō Sangyōshō, 2000). These statistical findings match with survey results about the internationalization of the R&D of US, European and Japanese firms (Roberts, 1995).

Micro-level research on the international R&D management of high-tech manufacturing firms from different countries has shown that the number of overseas R&D units has steeply increased since the 1980s (Kuemmerle, 1997). In the pharmaceutical industry, the internationalization of R&D appears to be most advanced among high-tech industries (Taggart, 1991; Beckmann, 1997).

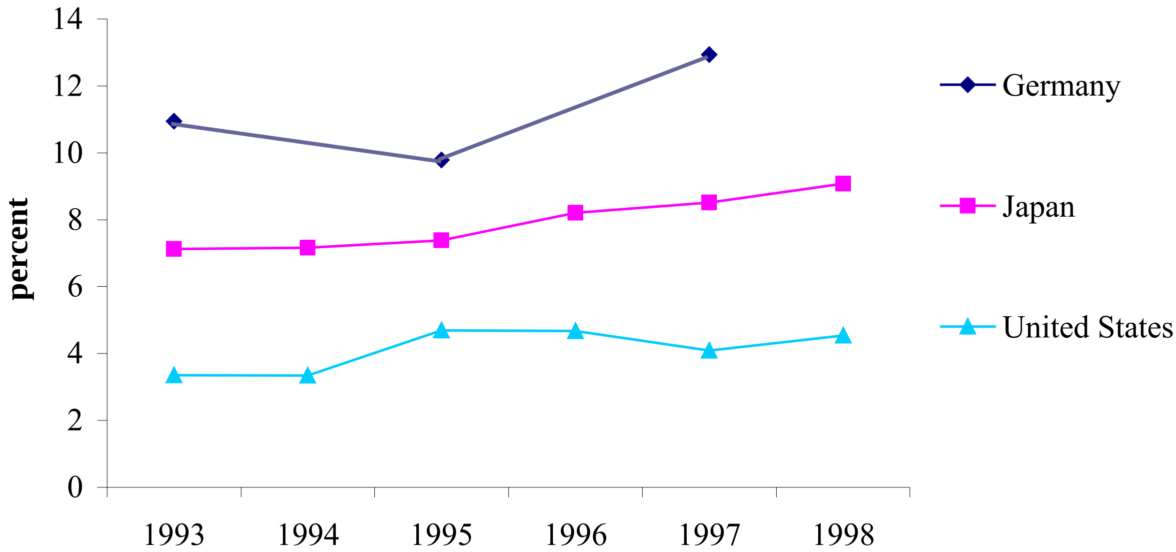
Altogether, recent empirical data support the common view that the internationalization of R&D and of technology acquisition of business firms has significantly increased in recent years. The data also indicate however, that on the aggregated level (1) the pace of this internationalization is rather slow, (2) the relative importance of international R&D is still limited when compared with the total amount of R&D and (3) there are wide differences between industries and countries. These observations are consistent with the findings of Patel (1996), who stresses the point that the R&D of most manufacturing firms is still concentrated in their home countries.

2.2 Externalization

Similar to the concentration of the R&D activities of business firms to their domestic sites, the view that the generation of new technology is predominantly conducted inside each firm prevailed for a long time, but has gradually changed since the 1980s. During the last two decades, a variety of organizational modes for acquiring technological knowledge from outside the firm has been under intensive discussion: R&D consortia, strategic alliances, collaborative R&D with suppliers and customers, venture nurturing, informal information exchange with outsiders, and many others (Roberts and Berry, 1985; von Hippel, 1988; Pisano, 1990; Aldrich and Sasaki, 1995; Appleyard, 1996; Sakakibara, 1997; Chiesa and Manzini, 1998).

In the 1990s, the part of manufacturing firms' R&D spent externally which may serve as a good proxy for the degree of externalization of the R&D activities, has gradually increased in the three largest industrial economies (Figure 2). According to these statistics, the importance of external R&D is relatively highest in Germany, somewhat lower in Japan, and lowest in the US. The data also suggest that on the aggregated level, the role of external sources of technology is still limited when compared with the volume of internal R&D efforts.

Figure 2: Part of total R&D expenditures of US, Japanese and German manufacturing firms spent externally



Source: Grenzmann, Marquadt and Wudtke, 2000 (and earlier editions); National Science Foundation, 2000; Sōmuchō Tōkeikyoku, 2000 (and earlier editions).

A considerable amount of research has been conducted in recent years to explore the trends of and the motives behind the externalization of R&D in general and of technology acquisition in particular. Concerning the US, Corey (1997) observes a significant rise of the importance of R&D consortia since the 1980s. Hicks, Isard and

Martin (1996) and Cockburn and Henderson (1998), who analyze the co-authoring behavior in the publications of business firms' researchers, conclude that the role of collaborative R&D has generally increased for large business firms. Hagedoorn (1995) observes a considerable increase of the number of strategic alliances between large international firms. He also reports on wide differences concerning the frequency of such alliances between single industries, with the highest number of them in the chemical industry and the lowest in the heavy electrical equipment industry. Tapon and Thong (1999) analyze data from 22 large pharmaceutical firms and find an increasing importance of collaborative R&D over time.

The findings concerning the externalization of technology acquisition are very similar to the ones concerning its internationalization. During the last two decades, external sources of technology have significantly gained importance for the technology acquisition of business firms. Compared with the amount of internal R&D however, they still play a minor role in quantitative terms. Moreover, in analogy to the issue of internationalization, significant differences between firms from different countries and industries can be observed.

2.3 Merits and demerits of internationalization and externalization of technology acquisition

The previous overview of empirical data has shown that concerning internationalization and externalization of technology acquisition of business firms, similar tendencies could be observed during the last two decades. Their relative importance has certainly increased, but at least from a quantitative point of view, domestic and internal technology acquisition still play a dominant role. Moreover, the role of international and external technology acquisition largely differs between firms from different countries and industries.

Both the internationalization and the externalization of technology acquisition can be regarded as strategies to gain access to technological knowledge that hitherto has been out of the reach of a firm. Through the internationalization of technology acquisition a firm tries to overcome geographical borders to technological knowledge, while the externalization of technology acquisition can be regarded as an effort to overcome institutional barriers to gain access to such knowledge.

Therefore, a potential merit of the internalization and externalization of technology acquisition apparently lies in the increase of the amount of available technological knowledge. Moreover, the quality of available technological knowledge may be improved as well through the internationalization and externalization of a firms' technology acquisition.

At the same time, there also a number of possible demerits of the internationalization and externalization of technology acquisition. One such demerit lies in higher transaction cost because of the geographical and institutional dispersion of a firms' activities. Such an increase of transaction cost has two facets. Firstly, the direct transaction cost, like the cost of transportation and of using telecommunication equipment, can be expected to increase when a firm establishes overseas R&D units or cooperates with external institutions in the field of technology acquisition. Additionally, the indirect transaction cost which are caused by behavioral uncertainty may also increase as a consequence of the internationalization or externalization of technology acquisition. In the case of externalization, the arguments of transaction cost theory concerning behavioral uncertainty when dealing with external partners (Williamson, 1975) can be directly applied (Pisano, 1990). In the case of internationalization, the partners to be dealt with are not external in an institutional sense. They are located at foreign sites, however. Under the assumption that the cultural differences between the sites of a firm in different countries are significant, an increased behavioral uncertainty compared with transactions between domestic sites of a firm may occur.

Another potential demerit of the internationalization and externalization of technology acquisition may derive from economies of scale, i.e. the insufficient divisibility of a firms' resources. It is assumed that in the field of technology acquisition, a certain amount of personal and financial resources have to be concentrated at one site of a firm to enable efficient operations. In high-tech industries like semiconductors where the development of new technologies require a very significant investment into each site (e.g., clean rooms), this aspect appears to be particularly important (Inoue, 1998).

In the case of internationalization of technology acquisition, additional sites have to be set up or acquired. When the minimum scale of such an additional site is significant (Kuemmerle, 1997), its establishment may be restrained by the overall organizational and financial capabilities of a firm. As a consequence, the optimal scale of the international site may not be reached, resulting in a relatively high cost and low efficiency of this site.

In case of externalization of technology acquisition, the underlying argument is more subtle since the cooperation with external institutions does not necessarily require the establishment of additional sites. In the course of such external cooperation, it seems plausible however that a certain amount of personal and financial resources has to be devoted to make it feasible, thereby reducing the amount of available resources available for other ongoing operations. Under the resource based view of a firm, there is only a limited amount of resources available at a given point of time (Penrose, 1959). Therefore, the organizational dispersion of work which occurs due to the externalization of technology acquisition may also decrease the overall efficiency of technology acquisition activities since it reduces the amount of available resources for each ongoing operation or project.

3 Technology acquisition of German and Japanese high-tech firms: empirical evidence

3.1 Hypotheses

The above discussion has shown that the internationalization and externalization of technology acquisition do not necessarily have to improve the performance of business firms in this managerial field. Rather they have potential merits and demerits, and their overall effect on technology acquisition performance depends on the actual relevance of these merits and demerits for each firm or business unit.

Subsequently, the results of an empirical survey about these issues covering high-tech firms from two countries (Germany and Japan) and two industries (pharmaceuticals and semiconductors) are reported. Prior to this analysis however, the results of the previous discussion about the possible impact of internationalization and externalization on technology acquisition performance will be made explicit in four hypotheses to be tested by the empirical data.

It was assumed that the internationalization and externalization of technology acquisition bears the potential for improved access to external technological knowledge.

Such improved access to external knowledge may result in a better market fit of newly developed products or processes, or lead to more innovative products or products. In other words: the output performance of technology acquisition may be improved as a consequence of the internationalization and externalization of the firms' or business units' activities in this field.

Hypothesis 1: The more internationalized the technology acquisition of a firm or business unit, the better the output performance in this field.

Hypothesis 2: The more externalized the technology acquisition of a firm or business unit, the better the output performance in this field.

The potential demerits of the internationalization and externalization of technology acquisition may materialize, as discussed above, in higher cost and lower efficiency of technology acquisition activities. Such aspects concern, in contrast to the expected merits of these strategies, primarily the input performance of technology acquisition.

Hypothesis 3: The more internationalized the technology acquisition of a firm or business unit, the worse the input performance in this field.

Hypothesis 4: The more externalized the technology acquisition of a firm or business unit, the worse the input performance in this field.

3.2 Research methodology

The empirical survey the subsequent analysis is based on was conducted during the second half of 1999. Since a substantial part of the technology acquisition activities in high-tech industries is concentrated in a few large firms, it was decided to focus the research on a detailed analysis of the technology acquisition of these leading firms instead of conducting a large scale survey. In order to assess the impact of different institutional environments and of different technologies and markets, it was also decided to cover firms from different countries and industries. This was attained by a survey of firms from two large industrialized countries (Germany and Japan) and two high-tech industries (pharmaceuticals and semiconductors).

In each country and industry, the top six to seven firms (as measured by their R&D and sales volumes in the respective industries) were contacted, resulting in a total of 26 firms which participation in the survey was requested. In order to reduce reservations among the firms about the disclosure of strategically relevant information to competitors, the whole survey was conducted anonymously. Out of the number of contacted firms, 16 firms eventually participated in the survey. The study therefore covers a large part of the leading firms in the respective countries and industries.

As can be seen from Table 1, the size and the structure of the surveyed firms from the respective countries and industries are similar in most respects. With the exception of the Japanese pharmaceutical firms, which sales are highly concentrated on the pharmaceutical business, the sales volume of the surveyed business units (pharmaceuticals and semiconductors) accounts on the average only for a minor fraction of the total sales of the firms. As might be expected from general observations of these industries in the two countries, the average size of the respective high-tech business units of the German firms is larger in the pharmaceutical industry and the size of the Japanese firms is larger in the semiconductor industry. However, the average size is in all countries and industries in the range between 2.5 and 5.5 billions US-$ of annual sales, indicating a high structural similarity of the surveyed business units. The average R&D intensity is well above 10% in all countries and industries, which confirms the classification of the business units as 'high-tech'.[1] It is in both industries somewhat higher for the German firms than for the Japanese firms, which might be due to different accounting standards in the two countries (Brockhoff, 1999).

Prior to the survey, its actual contents were discussed with the firms' managers in order to gain a maximum acceptance from the participants. Pretests were also conducted with R&D managers from four firms – one in each country and industry – which were not participating in the main survey.

1 In German R&D surveys, industries with a R&D intensity of above 8.5% are defined as high-tech (BMBF, 2000).

Table 1: Structural indicators of the surveyed firms and business units by country and industry, 1998

indicator \ country/industry	semicon-ductors Japan n = 5	semicon-ductors Germany n = 4	pharma-ceuticals Japan n = 4	pharma-ceuticals Germany n = 3
A average annual sales of the firms (millions of US-$)	42,337	44,776	3,406	20,057
B average annual sales of the business units for pharmaceuticals / semiconductors (millions of US-$, including firm-internal sales)	5,457	2,778	2,663	4,342
C average part of the business units sales for pharmaceuticals / semiconductors of the firms' sales (B / A x 100)	12.9	6.2	78.2	21.6
D average annual R&D expenditures of the business units for pharmaceuticals / semiconductors (millions of US-$)	680	403	336	734
E average R&D intensity of the business units for pharmaceuticals / semiconductors (D / B x 100)	12.5	14.5	12.6	16.9

Source: Author's calculations based on data from the firm's annual reports, information directly obtained from the firms and from Semiconductor World, 1999.

Note: Currency conversion from local currencies into US-$ based on average foreign exchange rates released by the Federal Reserve Board.

The main study was conducted in three steps. Firstly, various quantitative data about the externalization and the internationalization of technology acquisition was collected from the pharmaceuticals or semiconductor business unit within each participating firm.

Secondly, assessments concerning the internationalization, the externalization and the performance of technology acquisition activities were requested in a questionnaire addressed to the high-tech business unit's R&D managers of each firm. In order to gain a precise picture of the technology acquisition, numerous questionnaires were sent to each business unit, each one to be responded by another R&D department head within the business unit.

A total of 235 questionnaires was sent out to the firms. Out of this number, 165 usable responses were returned to the author. Therefore, the total response rate was 70.2%.

Thirdly, based on a preliminary analysis of the questionnaire responses, additional interviews with the firms' managers concerning the internationalization and externalization of their technology acquisition activities were conducted. As in the questionnaire survey, the assessments of several respondents from each firm were sought to gain a detailed picture concerning the overall situation within the high-tech business units. Between September and December 1999, 44 R&D managers from 15 firms[2] were interviewed altogether.

The questionnaire survey and the interviews were exclusively conducted in the native languages of the respondents (German and Japanese). All respondents were home-country based, i.e. located in Germany or Japan.

3.3 Evidence on the field level

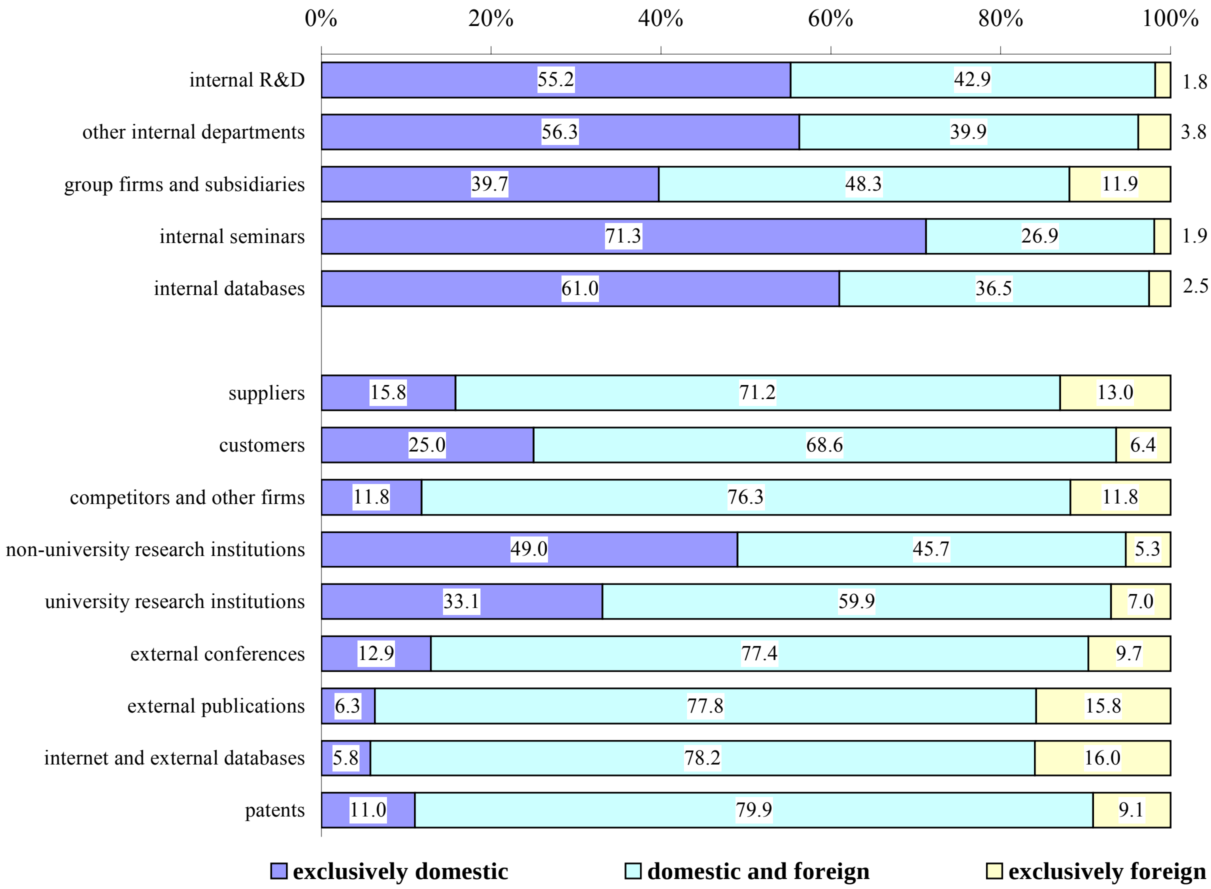
In this section, the results of the questionnaire survey concerning internationalization, externalization and performance of technology acquisition are analyzed. As mentioned above, each questionnaire was responded by a R&D manager representing one technological field within the surveyed firms. Therefore, each case in the subsequent statistical analysis represents not a whole firm or business unit, but one technological field within these business units.

The internationalization of technology acquisition was measured by indication whether a technology was acquired (a) exclusively from domestic sources, (b) from domestic and foreign sources or (c) exclusively from foreign sources. A list of five internal and nine external technological sources was provided to measure the degree of internationalization in each case. The distribution of responses (Figure 3) shows that while external technological sources are located domestic as well as abroad in most cases, internal technological sources with the exception of subsidiaries and group firms are in a majority of cases located exclusively domestic. This result suggests that the

2 One Japanese semiconductor firm limited its participation to the first two parts of the survey due to internal circumstances.

internationalization of firm-internal technology acquisition is even in large high-tech firms not progressed as far as might have been expected from the findings of previous research, as discussed above.

Figure 3: Location of technological sources of the questionnaire respondents



Source: Author's calculations.

In order to allow a calculation of average values and a measurement of the significance of country- and industry-specific differences concerning the internationalization of technology acquisition, for each technological source an 'internationalization variable' was created and depicted on a standardized scale by assigning a value of 0 for the alternative (a), a value of 0.5 for the alternative (b) and a value of 1 for the alternative (c). These values were interpreted as interval data rather than as ordinal data.

Table 2: Degree of internationalization of technological sources in the fields of the questionnaire respondents: average values and differences by country and by industry

technological source	country			industry		
	Germany	Japan	significance level of difference	pharmaceuticals	semiconductors	significance level of difference
internal R&D	0.442 n=52 sd=0.235	0.135 n=111 sd=0.223	0.000	0.297 n=69 sd=0.247	0.186 n=94 sd=0.274	0.009
other internal departments	0.400 n=50 sd=0.226	0.162 n=108 sd=0.280	0.000	0.297 n=69 sd=0.313	0.191 n=89 sd=0.256	0.020
group firms and subsidiaries	0.424 n=46 sd=0.235	0.333 n=105 sd=0.365	0.124	0.446 n=65 sd=0.265	0.297 n=86 sd=0.320	0.006
internal seminars	0.291 n=51 sd=0.268	0.087 n=109 sd=0.214	0.000	0.228 n=68 sd=0.265	0.098 n=92 sd=0.225	0.001
internal databases	0.347 n=49 sd=0.233	0.146 n=110 sd=0.265	0.000	0.275 n=69 sd=0.291	0.156 n=90 sd=0.245	0.005
suppliers	0.500 n=41 sd=0.119	0.481 n=105 sd=0.310	0.702	0.542 n=60 sd=0.249	0.448 n=86 sd=0.277	0.037
customers	0.462 n=39 sd=0.135	0.386 n=101 sd=0.299	0.132	0.373 n=55 sd=0.259	0.429 n=85 sd=0.269	0.218
competitors and other firms	0.500 n=44 sd=0.153	0.500 n=108 sd=273	1.000	0.531 n=65 sd=0.248	0.477 n=87 sd=0.240	0.180
non-university research institutions	0.370 n=46 sd=0.222	0.243 n=105 sd=0.319	0.016	0.386 n=66 sd=0.288	0.200 n=85 sd=0.280	0.000
university research institutions	0.350 n=50 sd=0.232	0.379 n=107 sd=0.314	0.567	0.424 n=66 sd=0.252	0.330 n=91 sd=0.309	0.043
external conferences	0.490 n=48 sd=0.126	0.481 n=107 sd=0.274	0.842	0.477 n=65 sd=0.224	0.489 n=90 sd=0.248	0.758
external publications	0.510 n=48 sd=0.072	0.564 n=110 sd=0.272	0.184	0.592 n=65 sd=0.232	0.516 n=93 sd=0.227	0.041
internet and external databases	0.500 n=45 sd=0.000	0.572 n=111 sd=0.268	0.074	0.582 n=67 sd=0.240	0.528 n=89 sd=0.218	0.144
patents	0.500 n=46 sd=0.000	0.486 n=108 sd=0.269	0.727	0.531 n=64 sd=0.216	0.461 n=90 sd=0.228	0.056

Source: Author's calculations.

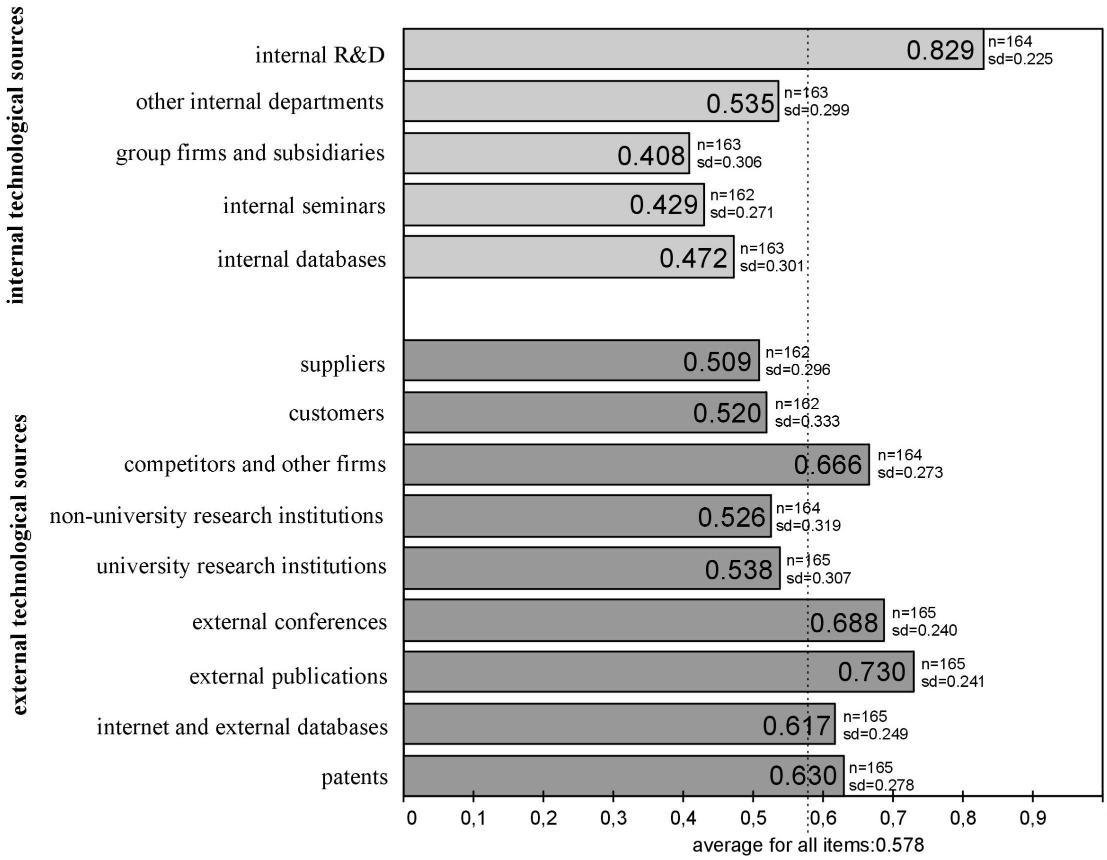
The country- and industry-specific results are summarized in Table 2. The internationalization of firm-internal technological sources is much higher among German respondents than among Japanese respondents. The country-specific differences are significant at 0.001-level for all items related to internal technological sources with the exception of group firms and subsidiaries. However, in the cases of external technological sources the differences between German and Japanese respondents are much smaller. Although concerning most items the average values for internationalization of the German respondents are also higher here than of the Japanese respondents, the differences mostly have only a very low level of significance.

In industry-specific perspective, the internationalization of technology acquisition was generally found to be higher in the pharmaceuticals industry than in the semiconductor industry. This tendency is particularly strong concerning internal technological sources, where the significance level of the difference is above 0.01 for four items and above 0.05 for the remaining item. However, for a number of external technological sources (suppliers, non-university and university research institutions and external publications) the average internationalization values were also significantly higher in the pharmaceutical industry than in the semiconductor industry.

The externalization of technology acquisition was measured by providing a five-point scale in the questionnaire for indicating the importance of internal and of external sources of technology. In analogy to the data on the internationalization of technology acquisition, the results were interpreted as interval data and depicted on a standardized scale by assigning a value of 1 for the highest importance, a value of 0 for the lowest importance, and values of 0.25, 0.5, 0.75 for the intermediate degrees of importance.

An analysis of the total results (Figure 4) shows that the respondents regard the internal R&D on the average by far as the most important technological source. However, the perceived importance of some external technological sources like competitors and other firms, external conferences, external publications, the internet and external databases, and patents is also rated above the average value for all items, whereas other internal technological sources except for the internal R&D are regarded as relatively unimportant for technology acquisition. These results therefore confirm on one hand the traditional view that the internal R&D is the most important technological source for business firms. But on the other hand they also suggest that external technological sources play a very important role for the technology acquisition of high-tech firms.

Figure 4: Importance of internal and of external technological sources in the fields of the questionnaire respondents



Source: Author's calculations.

The country- and industry-specific results are shown in Table 3. In country-specific perspective, the Japanese respondents rate other internal departments, group firms and subsidiaries and internal seminars as more important than the German respondents. Concerning the first and the last item mentioned, these differences are significant at the 0.01-level. The German respondents regard the internal R&D and internal databases as more important than the Japanese respondents, although these differences are not significant on a high level. External technological sources are, with the exception of research institutions, generally perceived as more important by the Japanese than by the Germans. Concerning competitors and other firms, this difference is significant on the 0.01-level, and concerning suppliers and customers, it is significant on the 0.05-level.

Table 3: Importance of technological sources in the fields of the questionnaire respondents: average values and differences by country and by industry

technological source	country			industry		
	Germany	Japan	significance level of difference	pharmaceuticals	semiconductors	significance level of difference
internal R&D	0.875 n=52 sd=0.201	0.808 n=112 sd=0.233	0.075	0.819 n=69 sd=0.234	0.837 n=95 sd=0.218	0.614
other internal departments	0.438 n=52 sd=0.328	0.581 n=111 sd=0.274	0.004	0.467 n=68 sd=0.308	0.584 n=95 sd=0.284	0.013
group firms and subsidiaries	0.365 n=52 sd=0.311	0.428 n=111 sd=0.302	0.224	0.485 n=68 sd=0.323	0.353 n=95 sd=0.281	0.006
internal seminars	0.348 n=51 sd=0.279	0.466 n=111 sd=0.260	0.009	0.493 n=67 sd=0.275	0.384 n=95 sd=0.260	0.012
internal databases	0.500 n=52 sd=0.328	0.460 n=111 sd=0.287	0.424	0.577 n=68 sd=0.300	0.397 n=95 sd=0.279	0.000
suppliers	0.422 n=51 sd=0.318	0.550 n=111 sd=0.278	0.010	0.508 n=66 sd=0.310	0.510 n=96 sd=0.288	0.952
customers	0.436 n=51 sd=0.353	0.559 n=111 sd=0.318	0.030	0.384 n=67 sd=0.296	0.616 n=95 sd=0.326	0.000
competitors and other firms	0.544 n=51 sd=0.258	0.721 n=113 sd=0.263	0.000	0.677 n=68 sd=0.263	0.659 n=96 sd=0.281	0.685
non-university research institutions	0.534 n=51 sd=0.332	0.522 n=113 sd=0.314	0.822	0.724 n=68 sd=0.270	0.385 n=96 sd=0.274	0.000
university research institutions	0.591 n=52 sd=0.267	0.513 n=113 sd=0.322	0.129	0.717 n=69 sd=0.271	0.409 n=96 sd=0.264	0.000
external conferences	0.635 n=52 sd=0.245	0.712 n=113 sd=0.234	0.053	0.761 n=69 sd=0.225	0.635 n=96 sd=0.238	0.001
external publications	0.721 n=52 sd=0.225	0.735 n=113 sd=0.248	0.742	0.837 n=69 sd=0.226	0.654 n=96 sd=0.222	0.000
internet and external databases	0.567 n=52 sd=0.258	0.639 n=113 sd=0.243	0.084	0.714 n=69 sd=0.258	0.714 n=96 sd=0.219	0.000
patents	0.587 n=52 sd=0.317	0.650 n=113 sd=0.258	0.171	0.688 n=69 sd=0.301	0.589 n=96 sd=0.254	0.023

Source: Author's calculations.

The overall impression concerning the country-specific results on the importance of technological sources is that the Japanese respondents perceive external sources of technology as more important than the German respondents. Even regarding firm-internal sources, the Japanese seem to rely to a high degree on technological sources other than R&D, whereas the Germans focus very much on the internal R&D.

In industry-specific perspective, the respondents from the pharmaceutical industry regard group firms and subsidiaries, internal seminars and internal databases as more important than the respondents from the semiconductor industry who in turn assign a higher importance to other internal departments than R&D. Concerning external technological sources, customers are regarded as more important in the semiconductor industry than in the pharmaceutical industry, with the difference significant on the 0.01-level. At the same time, the respondents from the pharmaceutical industry view most other external technological sources as much more important than the respondents from the semiconductor industry. In the cases of most items, these difference are significant at a level of 0.01. These results point to a comparatively higher externalization of technology acquisition in the pharmaceutical industry than in the semiconductor industry, with the notable exception of customers as technological sources.

The technology acquisition performance was also measured on a five-point scale where the questionnaire respondents rated the performance in their respective fields concerning six specific performance criteria relative to their competitors. By three of these criteria (low cost of input factors, efficiency of technology acquisition, and speed of technology acquisition) input performance of technology acquisition was measured, while the other three (newness of technologies, market fit of technologies, and transferability of technologies) were provided as indicators of output performance. Additionally, the respondents were asked for a total rating of their technology acquisition performance. The highest rating was assigned to a much better, the lowest to a much worse performance when compared with competing firms. As in the previous cases, the data were treated as interval data and measured on a standardized scale between 0 and 1.

Table 4 shows the results by countries and industries. In country-specific view, the average assessment of technology acquisition performance of the German respondents was generally higher than that of the Japanese respondents. With the exception of the criterion of transferability of new technologies, the country-specific differences are significant for all items on the 0.001-level.

Table 4: Technology acquisition performance in the fields of the questionnaire respondents: average values and differences by country and by industry

performance measure (compared with competitors)	country			industry		
	Germany	Japan	significance level of difference	pharmaceuticals	semiconductors	significance level of difference
low cost of input factors	0.590 n=47 sd=0.198	0.470 n=84 sd=0.180	0.001	0.491 n=56 sd=0.178	0.530 n=75 sd=0.205	0.258
efficiency of technology acquisition	0.645 n=50 sd=0.232	0.474 n=96 sd=0.187	0.000	0.520 n=62 sd=0.223	0.542 n=84 sd=0.216	0.558
speed of technology acquisition	0.640 n=50 sd=0.253	0.462 n=106 sd=0.192	0.000	0.508 n=64 sd=0.227	0.527 n=92 sd=0.230	0.604
newness of technologies	0.688 n=48 sd=0.203	0.546 n=104 sd=0.180	0.000	0.574 n=61 sd=0.179	0.602 n=91 sd=0.211	0.398
market fit of technologies	0.760 n=49 sd=0.169	0.572 n=101 sd=0.185	0.000	0.593 n=59 sd=0.196	0.659 n=91 sd=0.199	0.048
transferability of technologies	0.585 n=47 sd=0.204	0.541 n=92 sd=0.163	0.166	0.561 n=57 sd=0.166	0.552 n=82 sd=0.187	0.757
total technology acquisition performance	0.745 n=50 sd=0.164	0.538 n=98 sd=0.184	0.000	0.608 n=60 sd=0.213	0.608 n=88 sd=0.196	0.991

Source: Author's calculations.

The differences concerning the assessments of technology acquisition performance are not as large between industries as between countries. For most items, the average rating is somewhat higher in the semiconductor industry than in the pharmaceutical industry. However, with the exception of the market fit of technologies, where the industry-specific difference is significant at a level of 0.05, the observed differences between the two industries are rather small. Moreover, the average assessments of the total performance of technology acquisition are almost identical in both industries.

After having analyzed internationalization, externalization, and performance of technology acquisition one by one, the impact of internalization and externalization on technology acquisition performance is now assessed through a correlation analysis. Due to the non-metric input data, Spearman's Rho correlation coefficients have been calculated.

All indicators of the internationalization of internal technological sources show a positive correlation with all indicators of technology acquisition performance (Table 5). Concerning efficiency, speed, newness, market fit and total performance, most of the correlation coefficients are significant. This means that Hypothesis 1 which presupposes a positive impact of internationalization of technology acquisition on its output performance is supported concerning internal technological sources. At the same time Hypothesis 3 which suggests a negative impact of internationalization on input performance is falsified by the results since the input oriented performance indicators are positively correlated as well with the internationalization of internal technological sources.

At the same time, the correlation between the internationalization of external technological sources and the performance indicators is generally very weak and only in very few cases significant. Therefore, neither Hypothesis 1 nor Hypothesis 3 is clearly supported by the results concerning external technological sources.

The correlation between the perceived importance of technological sources and technology acquisition performance is shown in Table 6. The importance of external sources of technology is in most cases not significantly correlated with technology acquisition performance. Among the indicators of output performance, only the transferability of technologies is in most cases positively correlated with the importance of external technological sources, and only two among the observed correlation coefficients between these variables are significant. At the same time, the correlation between the importance of external sources of technology and the newness and market fit of technologies is weakly negative in a majority of cases. Therefore, Hypothesis 2 which suggested a positive impact of the externalization of technology acquisition on output performance is not supported concerning newness and market fit and only weakly supported concerning transferability.

Table 5: Correlation between the internationalization of technological sources and the technology acquisition performance in the fields of the questionnaire respondents

performance indicator / technological source	input performance			output performance			total technology acquisition performance	intervals for numbers of cases n
	low cost of input factors	efficiency of technology acquisition	speed of technology acquisition	newness of technologies	market fit of technologies	transferability of technologies		
internal R&D	0,005	0,077	0.101	0.208**	0.220***	0,049	0.170**	131-155
other internal departments	0,116	0.241***	0.197**	0.148*	0.204**	0,129	0.261***	127-150
group firms and subsidiaries	0,097	0.157*	0,111	0.151*	0,123	0,109	0,125	123-145
internal seminars	0,031	0.243***	0.182**	0.309***	0.238***	0.090	0.316***	129-152
internal databases	0,039	0.216**	0.160**	0.270***	0.253***	0,119	0.305***	128-152
suppliers	0.281***	0,058	0,045	–0.059	0,021	0.060	0,104	117-140
customers	0,073	0,059	0,093	0,134	0,085	0,079	0,078	113-135
competitors and other firms	–0.033	–0.081	–0.126	–0.048	0,033	–0.026	–0.042	124-146
non-university research instit.	0,088	0,035	0,042	0,107	0.100	0,031	0,157	122-144
university research institutions	–0.042	–0.014	–0.053	–0.005	–0.049	0,002	0,026	126-149
external conferences	0,127	0,044	0,003	–0.079	–0.094	0,011	0,015	127-148
external publications	0,044	–0.108	–0.194**	–0.122	–0.058	0,015	–0.058	128-152
internet and external databases	–0.003	–0.103	–0.193**	–0.033	–0.091	0.148*	–0.020	126-149
patents	0,122	0,042	–0.085	0,065	0,089	0,026	0,043	124-147

Source: Author's calculations.

*Note: Spearman's Rho correlation coefficients. *: significant at 0.1 level, ** significant at 0.05-level, ***: significant at 0.01-level.*

The indicators of input performance are generally very weakly correlated with the importance of external technological sources. Not even one statistically significant correlation was observed. Therefore, Hypothesis 4 concerning a negative impact of externalization on input performance of technology acquisition receives no support from the survey data on the field level.

Table 6: Correlation between the importance of technological sources and the technology acquisition performance in the fields of the questionnaire respondents

performance indicator / technological source	input performance			output performance			total technology acquisition performance	intervals for numbers of cases n
	low cost of input factors	efficiency of technology acquisition	speed of technology acquisition	newness of technologies	market fit of technologies	transferability of technologies		
internal R&D	0,084	0.198**	0.202**	0,123	0.256***	0,139	0.159**	130-155
other internal departments	0,032	0,041	0,067	–0.016	–0.012	0,132	–0.059	130-155
group firms and subsidiaries	0,000	–0.139*	–0.026	–0.074	–0.157**	0,065	–0.116	130-154
internal seminars	0,033	0,053	0,074	0,047	–0.087	0,126	–0.053	130-154
internal databases	0,103	0,095	0.179**	0.206**	0.172**	0.208**	0.229***	130-154
suppliers	0,085	–0.043	0,052	0,008	–0.127	0,088	–0.008	130-154
customers	–0.050	–0.073	–0.079	–0.046	0,006	–0.027	–0.067	131-154
competitors and other firms	–0.015	–0.066	–0.040	–0.029	–0.124	0,068	–0.091	131-156
non-university research instit.	–0.088	–0.042	–0.031	–0.138*	–0.081	0,049	–0.036	131-156
university research institutions	0,000	0,020	0,100	0,069	–0.024	0.170**	0,073	131-156
external conferences	0,032	0,070	–0.011	0,000	–0.167**	0.197**	–0.002	131-156
external publications	–0.008	–0.092	0,018	–0.020	–0.156*	0,103	0,067	131-156
internet and external databases	–0.080	–0.103	0,016	–0.065	–0.131	0,053	–0.022	131-156
patents	0,078	–0.067	0,048	0,070	0,009	0,029	0,120	131-156

Source: Author's calculations.

*Note: Spearman's Rho correlation coefficients. *: significant at 0.1 level, ** significant at 0.05-level, ***: significant at 0.01-level.*

3.4 Evidence on the business unit level

Following the discussion of the results on the field level of technology acquisition, an additional analysis of findings on the business unit level is provided subsequently. This analysis is conducted in two ways: firstly by reviewing the quantitative data on technology acquisition collected from the surveyed firms, and secondly by transposing some of the results on the field level to the business unit level.

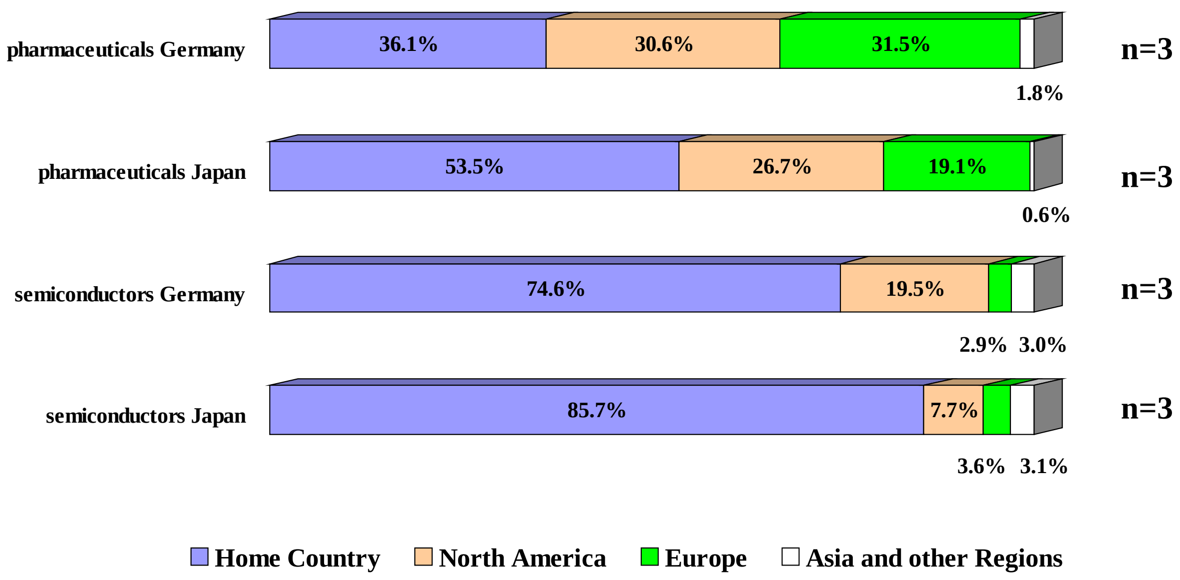
As a part of the quantitative data on technology acquisition, information on the geographic distribution of R&D in the surveyed business units was collected. However, these data were not supplied by two Japanese semiconductor and one pharmaceutical business unit. Moreover, the data of one German semiconductor business unit were excluded from this part of the analysis since the global headquarters of this business unit were not located in Germany and the data concerning geographic distribution of R&D therefore were not fully comparable with those of the other business units. Therefore, twelve business units were left for analysis: three in each country and industry. The R&D budgets for all respective business units in each country and industry were added, and their geographic distribution was subsequently calculated. Therefore, each business unit is, as shown in Figure 5, weighted in the results according to the amount of its R&D.

The results clearly indicate that the R&D (and therefore, supposedly the technology acquisition) is much more internationalized in the pharmaceutical industry than in the semiconductor industry and in the German business units than in the Japanese ones. The industry- and country-specific differences concerning the internationalization of technology acquisition which were observed on the field level are therefore confirmed by the business unit data on R&D.

Compared with the industry-level data for US firms shown in Figure 1, the part of R&D spent outside the home country by the surveyed business units is substantially higher. This indicates that the R&D of large firms or business units, which were subject to the author's survey, is probably much more internationalized than the R&D of small and medium-sized firms which also contribute to the industry-level data. With the exception of the German pharmaceutical business units, more than half of the total R&D of the surveyed business units was spent domestically, however. This result suggests that even in large high-tech business units, R&D activities are still often concentrated to a high degree in the home countries.

The data in Figure 5 also show that while in the semiconductor industry the main part of the international R&D is spent in North America, in the pharmaceutical industry it is quite evenly split between North America and Europe. Asia and other regions play only a minor role.

Figure 5: Geographic composition of the R&D expenditures of the surveyed business units



Source: Author's calculations.

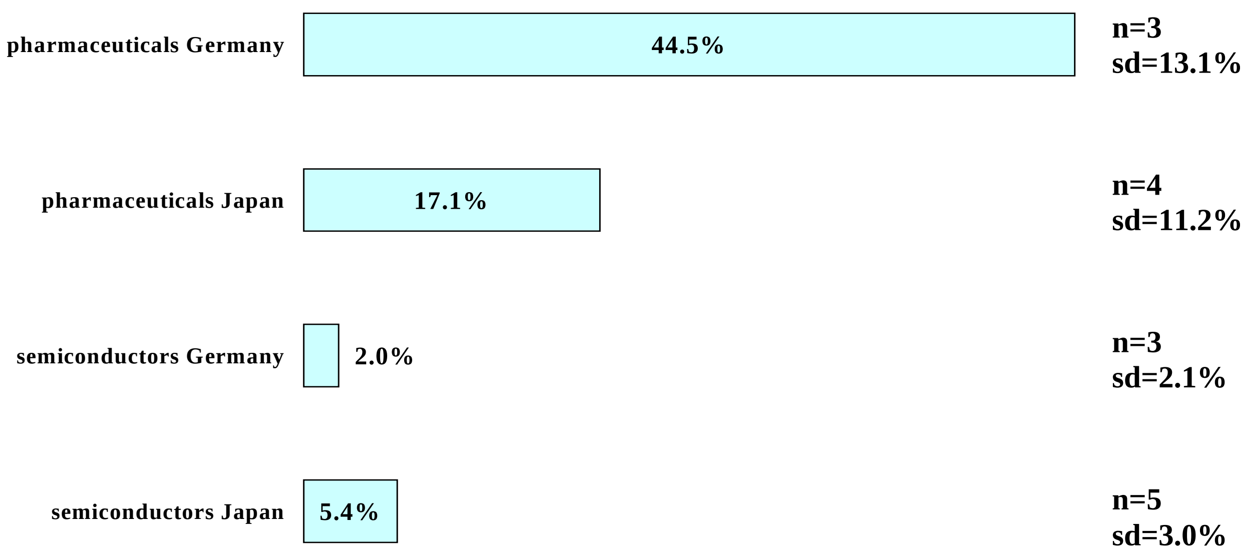
Most of the surveyed business units supplied additional information about the international location of their R&D functions. An analysis of this additional information revealed that the R&D functions closest to the final product (product development in the semiconductor industry, clinical development in the pharmaceutical industry) are most internationalized due to the need to develop and design products separately for markets in different countries.

It became also clear from the additional information supplied by the firms that all German business units in the pharmaceutical industry and some German business units in the semiconductor industry are maintaining R&D activities covering the full scope from research to product development, respectively clinical development in one or two foreign locations. Unlike to this structure, the functions of the foreign R&D locations of the Japanese firms are in both industries limited to specific fields like product development or research. In other words: foreign locations covering the whole scope of R&D do not exist in the surveyed Japanese business units.

Additionally, the surveyed business units were asked for the part of their total R&D budget spent externally, i.e. outside the firm. As discussed above, this information may serve as an indicator for the externalization of R&D and therefore, of technology acquisition.

All surveyed business units supplied the necessary information concerning this issue. The results are given in Figure 6. Again, the German semiconductor business unit which has its headquarters outside Germany was excluded because of the limited comparability of the data. As with the data on the internationalization of R&D, the calculation is based on an aggregation of the R&D spending of all surveyed business units.

Figure 6: Part of the R&D expenditures of the surveyed business units spent externally



Source: Author's calculations.

It becomes very clear from the results that the externalization of R&D is much higher in the pharmaceutical industry than in the semiconductor industry. This is partially due to the extensive outsourcing of clinical development by many pharmaceutical business units, as became apparent in the subsequent interview survey conducted by the author. Clinical development accounts for up to half of the R&D spending of the surveyed business units.

In country-specific perspective however, the results are less homogenous. In the pharmaceutical industry the R&D of the German business units is much more externalized than that of the Japanese ones. In the semiconductor industry however, the part of the R&D spent externally is smaller among the German than among the Japanese business units.

Alongside with the analysis of quantitative data on the business unit level, the field level data which are discussed above were aggregated to the business unit level. The focus of analysis is to identify predominant patterns concerning internationalization and externalization of technology acquisition in each surveyed business unit. Therefore, a cluster analysis of technology acquisition patterns on the field level was conducted prior to the aggregation on the business unit level. Because of the large number of items in the questionnaire survey however, factor analysis was applied in a first step in order to reduce the complexity of the data.

In the factor analysis, an orthogonal factor rotation with the varimax rotation method was applied. Missing values of variables were substituted by average values.

From the 14 items measuring the internationalization of technology acquisition, two factors were extracted (Table 7). The first factor expresses the internationalization of external technological sources, the second one the internationalization of internal technological sources.

The factor analysis of the items concerning the importance of technological sources led to the extraction of three factors (Table 8). The first factor can be interpreted as the importance of external technological sources related to science (or 'external scientific technology'), the second as the importance of internal technological sources (or 'internal technology'), and the third as the importance of external technological sources related to other firms (or 'external applied technology').

Finally, the application of factor analysis to the six questionnaire items expressing specific dimensions of technology acquisition performance resulted in the identification of two factors: one expressing input performance and one expressing output performance of technology acquisition (Table 9). The results of the factor analysis are therefore consistent with the interpretation of performance indicators in the analysis on the field level.

Table 7: Results of the factor analysis concerning the internationalization of technology acquisition

Factor loadings *Internationalization of...*	**factors** **1** internationalization of external technology	**2** internationalization of internal technology
internal R&D	0.002	0.790
internal seminars	0.107	0.775
internal databases	0.127	0.686
other internal departments	-0.144	0.658
group firms and subsidiaries	0.090	0.424
customers	0.201	0.359
external publications	0.773	-0.103
internet and external databases	0.773	-0.071
patents	0.715	0.022
competitors and other firms	0.673	0.141
external conferences	0.600	0.055
university research institutions	0.582	0.199
non-university research institutions	0.478	0.362
suppliers	0.431	0.209
Eigenvalues	3.369	2.690
Explained part of total variance (%)	24.06	19.22

Source: Author's calculations.

Note: Rotated factors with the varimax method. Factor loadings of 0.5 or higher are marked.

Table 8: Results of the factor analysis concerning the importance of technological sources

Factor loadings *Importance of…*	**factors** 1 external scientific technology	2 internal technology	3 external applied technology
non-university research institutions	0.776	0.087	-0.012
external publications	0.761	0.033	0.165
university research institutions	0.759	0.182	-0.181
external conferences	0.732	-0.033	0.196
internet and external databases	0.525	0.377	0.368
patents	0.298	0.274	0.276
internal R&D	-0.128	0.777	-0.203
internal databases	0.335	0.744	0.085
internal seminars	0.290	0.723	0.131
other internal departments	-0.273	0.508	0.424
customers	-0.255	0.102	0.696
competitors and other firms	0.304	-0.020	0.638
suppliers	0.158	-0.014	0.517
group firms and subsidiaries	0.042	0.414	0.416
Eigenvalues	3.130	2.380	1.889
Explained part of total variance (%)	22.36	17.00	13.49

Source: Author's calculations.

Note: Rotated factors with the varimax method. Factor loadings of 0.5 or higher are marked.

Table 9: Results of the factor analysis concerning the technology acquisition performance

Factor loadings *performance measure*	**factor**	
	1 **input performance**	**2** **output performance**
Low cost of input factors	0.826	0.032
Efficiency of technology acquisition	0.743	0.337
Speed of technology acquisition	0.746	0.420
Newness of technologies	0.199	0.778
Market fit of technologies	0.284	0.750
Transferability of technologies	0.112	0.670
Eigenvalues	1.924	1.908
Explained part of total variance (%)	32.07	31.79

Source: Author's calculations.

Note: Rotated factors with the varimax method. Factor loadings of 0.5 or higher are marked.

In the next step, hierarchical cluster analysis was applied to the five new variables generated from the factor analysis concerning the internationalization and the externalization of technology acquisition. In order to maintain a good comparability between all cases to be clustered, all questionnaire responses from general managers which do not clearly represent a specific field of technology acquisition were excluded from the analysis. This led to the elimination of 16 cases (one for each firm) out of the sample of 165 cases. Furthermore, seven outliers were identified in single-linkage clustering of the remaining cases. The inclusion of these cases resulted approximately in a doubling of the sum of squared deviations. These outliers were therefore also eliminated from the subsequent part of the analysis. This left a remaining sample of 142 questionnaire responses for the cluster analysis.

The application of the Ward method to the squared Euclidean distance between these cases resulted in the identification of five clusters. In the five cluster solution, 23 out of 25 F values were below 1, which indicates a greater homogeneity within a cluster than between all clusters for a given variable. Close to half (12) of the F values were smaller than 0.5. A series of tests confirmed that the five cluster solution shows the best performance concerning cluster homogeneity and minimization of the sum of squared deviations when compared with other clustering methods or different numbers of clusters.

Table 10 shows the t values for the five clusters and the average Z values of each cluster concerning the input and the output performance of technology acquisition. In cluster 1, the internationalization of external technology is very high and the internationalization of internal technology very low. The importance of both types of external technology is above average and the importance of internal technology is below average. In order words: the technology acquisition in these fields is highly dependent on external technology from foreign sources and may be described as ‘external sourcing of foreign technology’. Both the input and the output performance are clearly below average in this cluster.

In the fields of technology acquisition represented by cluster 2, which is much larger than the first cluster, the internationalization of internal technology is comparatively high and the internationalization of external technology is close to the average. The cases in this cluster feature a high importance of external scientific technology and internal technology and an average importance of external applied technology. The cluster may be titled with ‘international sourcing of scientific technology’. Input performance is slightly below average, output performance above average in this cluster.

Table 10: Results of the cluster analysis of the questionnaire responses concerning the internationalization and externalization of technology acquisition

	clusters				
Clustering variables (t values)	1 ‘external sourcing of foreign technology’	2 ‘internatio-nal sourcing of scientific technology’	3 ‘internatio-nal sourcing of internal technology’	4 ‘internatio-nal sourcing of external technology’	5 ‘domestic sourcing of applied technology’
Internationalization of external technology	2.391	0.037	-0.070	-0.306	-0.483
Internationalization of internal technology	-0.624	0.483	0.614	0.436	-0.751
External scientific technology	0.221	0.864	-0.749	0.617	-0.561
Internal technology	-0.277	0.741	0.150	-1.664	0.022
External applied technology	0.065	0.046	-1.121	0.443	0.420
Average performance of clusters (Z values)					
Input performance	-0.225	-0.084	0.214	0.093	-0.033
Output performance	-0.243	0.180	0.274	-0.101	-0.202
Number of cases	12	38	27	18	47

Source: Author’s calculations.

Note: Clustering of the squared Euclidean distance with the Ward method. Total number of cases: 142.

In the third cluster, the internationalization of internal technology is even higher than in the second cluster, whereas the internationalization of external technology is slightly below average. The importance of internal technology is above average and the importance of both types of external technology is very low. The cluster is therefore described by the 'international sourcing of internal technology'. Both the input and the output performance are relatively strong in this cluster.

In the cases of cluster 4, the internationalization of internal technology is relatively high and the internationalization of external technology is relatively low. The importance of both kinds of external technology is high and the importance of internal technology is extremely low. Thus this cluster may be characterized by the 'international sourcing of external technology'. Input performance is a little above average and output performance slightly below average.

Finally, in the fifth and largest cluster the internationalization of both internal and external technology is very low. The importance of external scientific technology is low, the importance of internal technology is close to average, and the importance of external applied technology is high. This cluster is therefore titled with the 'domestic sourcing of applied technology'. The input performance of the cases in this cluster is close to average and the output performance is below average.

The cluster analysis bears interesting results concerning the combined impact of internationalization and externalization on technology acquisition performance. The best input and output performance is attained by the cluster of 'international sourcing of internal technology' which is characterized by a high internationalization and a high importance of internal technology. The worst performance is shown by the cluster of 'external sourcing of foreign technology' which features a high internationalization and a high importance of external technology.

In general, the outcome of the correlation analysis that only the internationalization of internal technological sources, but not the internationalization of external technological sources leads to a good performance is confirmed. Concerning the impact of externalization on technology acquisition performance, the results are less clear. Above all, cluster 3 with a low importance of both types of external technology shows the best performance. A combination of a high importance of internal technology with a high importance of external scientific technology (as in cluster 2) results in a relatively good output performance, while a combination of a average importance of internal technology with a high importance of external applied technology (as in cluster 5) leads to a performance below average, probably also due to the low internationalization of internal technology. Interestingly, a high importance of both types of external technologies combined with a very low importance of internal technology leads also to a reasonable performance when the internationalization of internal technology is high (as in cluster 4).

Altogether, the results suggest that while the internationalization of internal technology can be clearly identified as a success factor of technology acquisition (concerning both input and output), the externalization of technology acquisition cannot generally be associated with a strong performance. Rather it may result in an inferior performance when it is not accompanied either by a high internationalization or a high importance of internal technology.

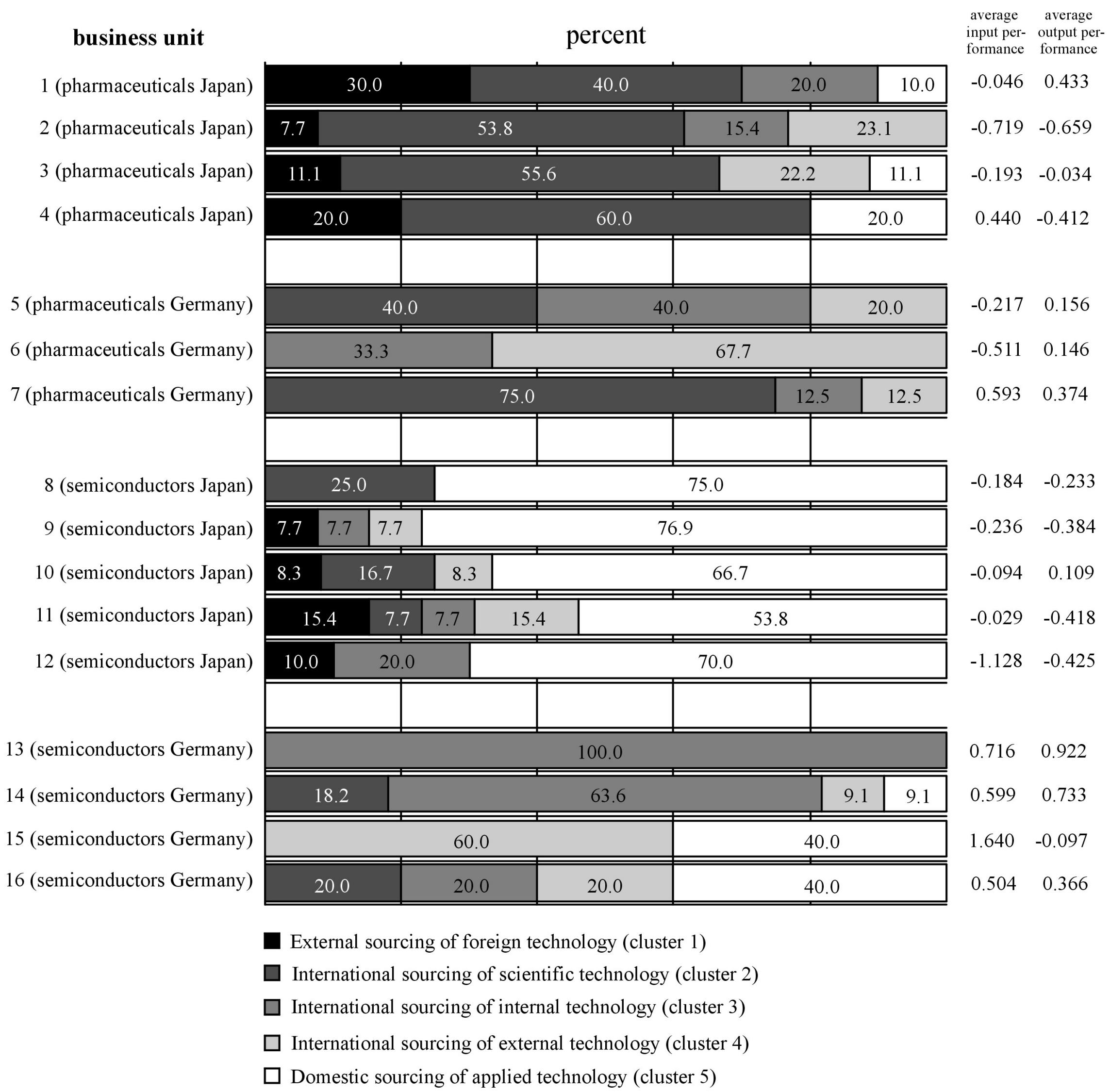
Further insights can be gained from the distribution of the five clusters among each surveyed business unit (Figure 5). It becomes apparent that the type of 'domestic sourcing of applied technology' is predominant in all five surveyed Japanese semiconductor business units, whereas it has only a limited or no importance in the German semiconductor business units and the pharmaceutical business units from both countries. This confirms the earlier finding that the internationalization of R&D is quite low in the Japanese semiconductor business units.

Another peculiarity is the total absence of the cluster of 'external sourcing of foreign technology' among the German business units. At the same time, this cluster is present in all Japanese business units except for one in the semiconductor industry.

Since both the input and the output performance of technology acquisition are below average in these two clusters, it does not come as a surprise that the Japanese business units in both industries generally have an inferior performance when compared with the German business units.

These results suggest firstly that the technology acquisition performance of the Japanese high-tech business units, particularly in the semiconductor industry, is suffering from a low level of internationalization of internal technology. Secondly, all except one of the surveyed Japanese business units are relying on the 'external sourcing of foreign technology' in some fields of technology acquisition. In other words: in these fields they have neither a strong internal base in technology acquisition, nor have they the capability to transfer foreign technology through internal channels. These features can clearly be associated with a weak strategic position. Therefore, it can be argued, strategic management should abandon the technology acquisition in such fields and rather concentrate internal resources on fields of generic strength of the business unit.

Figure 7: Distribution of technology acquisition clusters and average technology acquisition performance of the surveyed business units



Source: Author's calculations.

This interpretation matches with the findings of other empirical research where a lack of strategy, particularly a lack of ability to concentrate on core competencies, was identified as a major weakness of the management of Japanese high-tech firms (Porter, Takeuchi and Sakakibara, 2000). Aside from the aspects of internationalization and externalization, the focus of technology acquisition activities on fields of internal strength evolves as another success factor from the survey results.

3.5 Discussion

After having analyzed the survey results one by one, they are now discussed in the larger context of technology acquisition management. The issues of the validity and the significance of the results are also taken into consideration.

The results of the survey of German and Japanese high-tech business units indicate both on the field level and on the business unit level significant differences concerning internationalization and externalization of technology acquisition between firms operating in different industries and countries. This suggests that both the industry-specific (technology and market) environment and the country-specific (institutional) environment exert a strong influence on the technology acquisition of the firms.

Concerning the actual industries and countries covered by this survey, some concrete arguments on the influence of these environments can be applied. In industry-specific perspective, the higher internationalization and externalization of technology acquisition in the pharmaceutical industry than in the semiconductor industry can be explained with the relative explicitness of technological knowledge in the pharmaceutical industry, in contrast to the bigger role of tacit, implicit knowledge in the semiconductor industry (von Hippel, 1994). Since explicit, codified knowledge is easier to transfer than implicit knowledge, a higher organizational and geographical dispersion of technology acquisition may be feasible in the pharmaceutical industry than in the semiconductor industry.

In country-specific perspective, the matter of path dependency has to be taken into consideration. German manufacturing firms have a track record of strong internationalization in the field of R&D at least since the 1980s (Brockhoff, 1990). In contrast, Japanese business firms are regarded as latecomers concerning internationalization, particularly in the field of R&D (Pearce and Papanastassiou, 1996). Therefore, the observed difference between the business units from the two countries concerning internationalization of technology acquisition is not just a result of the firms current management, but also of their previous history.

Among the hypothesis proposed above, only Hypothesis 1 about a positive impact of the internationalization of technology acquisition on its output performance was supported concerning internal technological sources. The expectation that internationalization of technology acquisition may result in a negative impact on input performance (Hypothesis 3) was countered by the results which suggest that the internationalization of internal technological sources has a positive impact on input performance as well. The internationalization of external technological sources however had no visible impact on technology acquisition performance of the surveyed fields and business units.

Between the externalization and the performance of technology acquisition, no clear-cut causality could be identified. Neither a positive impact of externalization on output performance (Hypothesis 2) nor a negative impact on input performance (Hypothesis 4) could be generally observed. The results of the cluster analysis suggest however that a high importance of external technology has to be accompanied either by a high importance or a high internationalization of internal technology to bear good results. This finding is consistent with other research where the complementarity of internal and external technology (Veugelers, 1997) and a sufficient internal absorptive capacity as a prerequisite for a successful use of external technology (Cockburn and Henderson, 1998) are emphasized.

It remains to be mentioned that the empirical research discussed here covers only two countries and industries. Therefore, the applicability of its results to firms from other countries and industries cannot be assumed automatically. Additional research on the organization of technology acquisition of business firms is desirable.

Aside from this limitation that more or less applies to all empirical work, the validity of the results concerning technology acquisition performance may also be questioned. This issue seems important since performance measurement in this field is generally difficult and the performance assessments of German and Japanese respondents largely differ. It may be argued that the observed country-specific results could be influenced by cultural differences concerning such self-assessments. Therefore, they might not correctly describe the real performance situation due to a cultural bias.

During the interview survey it became clear however that the observed country-specific differences of technology acquisition performance are not simply the result of different questionnaire answering patterns in Germany and Japan, but do reflect the managers' actual opinions. German managers generally assessed the technology acquisition performance of their business units as more favorable than Japanese managers.

Additionally, a analysis of the number of patents granted to the surveyed business units the US Patent Office between 1995 and 2000 was conducted. This analysis revealed that the number of patents granted to the German business units largely increased within this period, whereas the increase of the number of patents received by the Japanese business units was much smaller. Therefore, the survey results were confirmed by the patent data in a dynamic context. They indicate a relative increase of technological competitiveness of the German business units and a relative competitive decline of the Japanese business units.

4 Implications for the technology acquisition strategies of high-tech firms

Finally, some implications of the survey results for the technology acquisition strategies of high-tech firms are briefly drawn.

The results of the empirical research strongly suggest that the degree of internationalization of internal technological sources exert a positive influence on technology acquisition performance. In contrast, the internationalization of external sources of technology seems not to contribute positively to the performance of firms in this field.

Therefore, high-tech firms managers should actively seek progress concerning internationalization of internal R&D. One instructive means to achieve a high level of internationalization might be the establishment of full scope R&D units at one or more foreign locations, as practiced by some of the German firms surveyed by the author. The actual organizational shape of the internationalization of R&D was not the main subject of this research however and may depend largely on each firms' or business units' situation.[3]

Concerning the externalization of technology acquisition, no positive impact on the fields' or business units' performance could be clearly identified. The findings rather suggest that a high reliance on external technological sources may result in an inferior performance when there is not a sufficient internal technological strength maintained.

Thus high-tech firm's R&D managers should be much more cautious with the externalization than with the internationalization of technology acquisition. Although it may have certain advantages in specific fields or projects, it appears dangerous to apply it as a general strategy. At least, measures should be taken to secure the absorptive capacity and internal technological strength of the firm when increasing the externalization of technology acquisition. This implication can also be derived from the result of the cluster analysis on the business unit level that the concentration of technology acquisition activities on fields of internal strength is an important factor for the success in this field.

3 For a detailed discussion of the advantages and disadvantages of different organizational modes of international R&D, refer to Brockhoff and Schmaul (1996) and Reger (1999).

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