Available online at www.sciencedirect.com

SCIENCE DIRECT®

ELSEVIER

Research Policy 33 (2004) 1019–1039

research policy

www.elsevier.com/locate/econbase

The influence of institutional factors on the technology acquisition performance of high-tech firms: survey results from Germany and Japan

Martin Hemmert*

Korea University Business School, Anam-dong, Sungbuk-gu, Seoul 136-701, Korea

Received 1 October 2002; accepted 16 April 2004

Available online 25 June 2004

Abstract

The technology acquisition performance of firms is influenced by a variety of institutional factors which include access to R&D personnel, access to external sources of knowledge (firms and research institutions), the political, legal and administrative environment and the organization of knowledge transfer. A detailed analysis of the influence of these factors on the technology acquisition performance of German and Japanese pharmaceutical and semiconductor business units reveals that it (1) generally varies to a large extent between different factors and (2) also differs between countries and industries to a considerable degree.

Keywords: Technology acquisition; Innovation systems; Science and technology policy; R&D collaboration; Knowledge transfer

1. Introduction

This paper deals with the influence of institutional factors on the technology acquisition performance of firms. Technology acquisition can be broadly defined as the acquisition of technological knowledge for the development of new products and processes. It may be conducted (1) by firm-internal activities, typically R&D efforts, (2) by collaborative activities with outsiders, such as joint R&D projects, or (3) by acquiring technology from outside, e.g. by licensing agreements or contract R&D. Therefore, on the one hand, technology acquisition extends beyond R&D, as it also covers the collaborative and external acquisition of technology. On the other hand, it does not cover the storage and utilization of technologies which are also part of the R&D function.

Institutional factors, understood as those circumstances which are rooted in the institutional and economic environment of firms, may influence their technology acquisition in different ways. First, these factors may influence their structure. Specifically, it can be expected that the balance between internal, collaborative, and external technology acquisition is determined by them. For instance, when a firm has access to cutting-edge technological knowledge in external research institutions, it may increase its relative share of collaborative and external technology acquisition. Second, institutional factors may also influence the performance outcome of technology acquisition activities. In the same example, the technology acquisition performance of a firm may improve due to its collaboration

* Tel.: +82 2 3290 2605; fax: +82 2 922 7220.
E-mail address: mhemmert@korea.ac.kr (M. Hemmert).

doi:10.1016/j.respol.2004.04.003

with excellent research institutions. The discussion in this paper is focused on these performance effects.

The function of technology acquisition is receiving increased attention from the management of firms for two reasons. First, the importance of collaborative and external technology acquisition, as compared with firm-internal R&D, has been increasing throughout the last two decades. There is a growing awareness that important sources of technology are often located beyond the boundaries of a firm (von Hippel, 1988; Corey, 1997; Niosi, 1999). Correspondingly, many firms have indeed increased the proportion of external sources of technology in their R&D process (Hagedoorn, 1995; Tapon and Thong, 1999; Hagedoorn, 2002). Second, the internationalization of R&D is also progressing, whereby the aim of seeking technological knowledge in host-country locations plays a prominent role (Granstrand et al., 1992; Brockhoff, 1998; OECD, 1999a; Niosi, 1999). As a result of intensified competition and of the increasing quantity and complexity of technologies to be considered for commercial R&D, it has become essential for firms to tap into technological knowledge outside their former institutional and geographical boundaries.

In response to the increased recognition of the function of technology acquisition and its determining institutional factors, a considerable amount of literature has been published on these topics, particularly since the 1990s. This paper contributes to the literature by examining (1) general differences in the relative importance of various institutional factors for the technology acquisition performance of firms and (2) country- and industry-specific differences concerning the importance of these factors. The analysis is based on empirical data from two countries (Germany and Japan) and two industries (pharmaceuticals and semiconductors).

This paper is structured as follows. First, the influence of various institutional factors on the technology acquisition performance of firms in general as well as in specific countries and industries is discussed from a theoretical standpoint. With reference to the literature on innovation systems and on R&D management, hypotheses concerning the general and the country- and industry-specific influence of institutional factors on performance are developed.

Thereafter, these hypotheses are tested using survey data on the technology acquisition of German and Japanese pharmaceutical and semiconductor firms. The findings suggest pronounced differences in the relative importance of different factors for technology acquisition performance, i.e. the competitive performance of a firm in the specific area of technology acquisition. While some of the factors are identified as being highly important, others appear to be far less relevant. Moreover, in some areas, considerable country- and industry-specific differences are to be observed. Finally, some implications of the results for science and technology policy are presented.

2. Theory and hypotheses

2.1. General influence of institutional factors on technology acquisition performance

Since the 1990s, a large amount of conceptual and empirical research has been conducted to identify those factors which influence the technology acquisition performance of firms. One stream of literature which is particularly concerned with identifying the full scope of factors relevant for this field is the research on innovation systems.

In their well-known work (Lundvall, 1992; Nelson, 1993), Lundvall and Nelson created the analytical framework for national innovation systems which is based on an economic perspective, but which also has the potential to identify many factors relevant for the technology acquisition performance of firms. The concept of innovation systems has also been applied to the regional (Saxenian, 1994; Braczyk et al., 1998) and the sectoral levels (Breschi and Malerba, 1997). Moreover, the concept of national innovative capacity has been proposed as a further extension to the concept of innovation systems (Porter and Stern, 2001; Furman et al., 2002).[1]

Lundvall (1992) mentions the internal organization of firms, inter-firm relationships, the role of the public sector, the institutional structure of the financial sector, and the organization of R&D as elements of national

[1] For a comprehensive overview of the development and the diffusion of the concept of innovation systems throughout the last decade, cf. Lundvall et al. (2002).

innovation systems. In an OECD study (1999b), factor market conditions, product market conditions, the education and training system, the macro-economic and regulatory context, and communication infrastructures are identified as institutional factors which determine the innovative performance of firms and countries. Furman et al. (2002) mention factor conditions, demand conditions, the context for firm strategy and rivalry as well as related and supporting industries as indicators for the innovation orientation of national industry clusters.

In total, a wide range of institutional factors has been identified by the literature on innovation systems as being relevant for the technology acquisition performance of firms. From a firm's perspective, these factors may be grouped into the following categories:

(1) the availability and quality of internal resources (personnel and capital),
(2) the availability and quality of external technological knowledge (from research institutions and from other firms),
(3) the political, legal and administrative environment,
(4) the organization of knowledge transfer activities by the firms.

Thus, the innovation systems approach proves very useful for identifying the range of institutional factors which are potentially relevant for the technology acquisition performance of firms. However, the work based on this approach relates to innovation activities in general and does not permit therefore detailed insights into the relative importance of single factors for the particular field of technology acquisition.

There have also been a large number of empirical studies which have focused on the impact of specific factors on technology acquisition performance. In some of these contributions, the importance of internal knowledge transfer has been emphasized within the context of R&D (Clark and Fujimoto, 1991; Pisano, 1997) or of knowledge management (Nonaka and Takeuchi, 1995). In other empirical research, the strength of the technological ties with other firms for technology acquisition is emphasized alongside the resources that are accumulated internally (e.g., Shan et al., 1994; Mowery et al., 1996). Various contributions are mainly concerned with the relevance of the access to external technological knowledge from research institutions for the technology acquisition of firms (e.g., Beise and Stahl, 1998; Cockburn and Henderson, 1998; McMillan et al., 2000) or the technological success of publicly funded R&D consortia from the viewpoint of the participating firms (e.g., Irwin and Klenow, 1994; Teichert, 1997).

Altogether, in the studies focusing on certain aspects of technology acquisition, all the factors identified as relevant in the literature on innovation systems have been confirmed as exerting a significant impact on the technology acquisition performance of firms. Moreover, the relatively abstract categories in the literature on innovation systems are transformed by these contributions into more concrete, measurable factors. Because of the mostly narrow focus of these studies, however, they provide little information on the *relative* importance of different factors as compared with other factors which have not been considered.

This aspect of relative importance has been addressed by the literature on the determining factors of firms' international R&D site selection from a slightly different viewpoint. A large amount of research was conducted on this topic throughout the 1990s. However, not all the findings of this research are relevant from the specific viewpoint of technology acquisition.

Some overseas R&D units are primarily directed to technological access in host countries, whereas others are targeted at market access or market adaptation in order to exploit firm-specific capabilities. The former can be qualified as home-base augmenting R&D units and the latter as home-base exploiting R&D units (Kuemmerle, 1999; Le Bas and Sierra, 2002). Likewise, the motives for establishing R&D units overseas can be grouped into technology-related and market-related aspects. Concerning some issues, like the collaboration with lead users on overseas markets, both technology- and market-related aspects may play an important role (Gerybadze and Reger, 1999). In the context of technology acquisition, however, attention should be focused on the motives that are exclusively or primarily related to the access to technology at overseas locations since they are directly related to this function.

In a number of empirical surveys, a wide range of technology-related determinants of foreign R&D has been considered. Caluori and Schips (1991), who surveyed the determining factors for the location of overseas R&D sites of leading Swiss firms, observed that there are strong differences in the relative importance of the various factors. They found the availability of skilled personnel and the access to external technological knowledge to be most important, and governmental subsidies and regulations as least important. von Boehmer (1995) analyzed the location factors of host country R&D sites in American, British and German firms. According to his findings, the availability of R&D personnel has been assessed as most important, whereas access to external knowledge, factor cost and regulatory and administrative issues have been regarded as far less relevant. Additionally, he points to the relevance of the organization of firm-internal knowledge transfer between sites in different countries as an important factor. In contrast, Kumar (2001), who analyzed the determining factors of overseas R&D locations of US and Japanese multinationals, found that the relative cost of labor and the availability of external knowledge are most important.

The studies on the factors which influence the selection of international R&D sites have a number of limitations for the identification of the determining factors of technology acquisition performance. They refer to the function of R&D which is not identical to technology acquisition, as has been pointed out above. Additionally, they take the specific perspective of the site selection in host countries, which is not necessarily identical with the home country or the overall perspective of a firm.

Nevertheless, the studies on the determining factors of international R&D sites also cover the whole range of institutional factors which have been identified above as relevant for the technology acquisition performance of firms. Whereas their specific findings are partly controversial, they unanimously indicate that there are considerable differences in the relative importance of the various factors in this context. Therefore, such differences may also be expected with regard to their influence on the technology acquisition performance of firms.

Hypothesis 1. Institutional factors influence the technology acquisition performance of firms to a varying degree.

2.2. Country- and industry-specific differences

In the following, arguments on country- and industry-specific differences regarding the influence of institutional factors on the technology acquisition performance of firms will be developed. They are set in direct relation to the countries (Germany and Japan) and industries (pharmaceuticals and semiconductors) that are covered by the empirical survey whose results are reported later.

One category of institutional factors for which country-specific differences may be expected are internal resources. Apparently, there are considerable differences between countries concerning their endowment with production factors, these being internal resources from the firms' point of view. Furthermore, since production factors can be substituted for each other only to a limited extent, it can be expected that the perceived relevance of each production factor increases with its relative scarcity in the respective country. In the context of national innovation systems, the relevance of this aspect becomes clear, for instance, in the necessity for catch-up countries to increase their still relatively small R&D workforce (OECD, 1999b). However, it can be expected that such differences on the national level are reflected by the perceptions of each individual firm as well.

In case of Germany and Japan, significant differences appear to exist with respect to R&D personnel as a main category of internal resources. The relative density of R&D personnel has been observed to be much higher in Japan than in Germany (Ernst and Wiesner, 1994). In addition, Germany has experienced a particular scarcity of R&D personnel in recent years (Ebling et al., 2000).

Hypothesis 2. The influence of the availability and quality of R&D personnel on the technology acquisition performance of firms is stronger in Germany than in Japan.

Furthermore, since knowledge is now widely perceived as being a production factor alongside personnel and capital, the same argument as the one concerning R&D personnel may be applied on the basis of its different country-specific relevance which correspond to its relative scarcity in different countries (Guerrieri and Tylecote, 1997). From a firm's point of view, external knowledge is particularly relevant as a separate factor, whereas internal knowledge is already highly incorporated in its R&D personnel.

As regards the two countries being considered here, the relative endowment with external knowledge appears to be higher in Germany than in Japan where the technological level of research institutions appears to be relatively low when compared with leading Western countries due to lower public investment in this field and to organizational barriers within research institutions (Sakakibara, 1995; Barker, 1998).

Hypothesis 3. The influence of the availability and quality of external knowledge on the technology acquisition performance of firms is stronger in Japan than in Germany.

As in the case of R&D personnel and external knowledge, the relevance of the political, legal and administrative factors for the technology acquisition performance of firms also very probably differs between countries. In countries that are catching up technologically, the governments have a relatively strong influence on the technology acquisition of firms (Kim, 1997), whereas in the technologically most advanced countries, their role tends to be less important.

Japan is currently no longer regarded as a country which is catching up technologically with Western countries. However, some institutional arrangements from its previous catch-up period appear to remain in part (Hemmert and Oberländer, 1998). Specifically, the political, administrative and legal interference in the field of technology acquisition appears to be stronger in Japan than in Germany and other Western countries. Investigations into governmental agencies in Japan have been carried out over a long time with respect to their efforts to exert a strong direct influence on the technology acquisition activities of firms through administrative guidance, particularly in collaborative R&D projects (Callon, 1995). Moreover, the administrative regulation of activities which are relevant for technology acquisition activities, such as university-industry collaborations, appears to be much stronger than in the leading Western countries, including Germany (Barker, 1998).

Hypothesis 4. The influence of political, legal and administrative factors on the technology acquisition performance of firms is stronger in Japan than in Germany.

Additionally, it can also be expected that the importance of different categories of institutional factors for the technology acquisition of firms varies between industries. Pavitt (1984) distinguished in a widely acknowledged taxonomy of industries based on their technological regimes and innovation patterns between ‘supplier dominated’, ‘specialized supplier’, ‘scale intensive’ and ‘science-based’ sectors. However, there is still a considerable variety observable within these four groups, namely, within the science-based industries.

As previously discussed, the external knowledge that firms may seek access to in the course of their technology sourcing may be categorized into knowledge from other firms and knowledge from research institutions. There are clear empirical indications that in some industries external knowledge from research institutions plays a particularly important role, whereas in other industries external knowledge from other firms (suppliers, customers and competitors) is relatively more important (Reger et al., 1999). As regards the two industries considered here, the pharmaceutical industry appears to be a particularly research-oriented industry (Gambardella, 1995), whereas in the semiconductor industry the propensity to acquire knowledge from other firms seems to be stronger (Kimura, 1997; Reger et al., 1999). Therefore, external knowledge from research institutions can be expected to exert a stronger influence on technology acquisition performance in the former industry, whereas the influence of external knowledge from other firms may be stronger in the latter.

Hypothesis 5. The influence of the availability and quality of external knowledge from research institutions on the technology acquisition performance of firms is stronger in the pharmaceutical industry than in the semiconductor industry.

Hypothesis 6. The influence of the availability and quality of external knowledge from other firms on the technology acquisition performance of firms is stronger in the semiconductor industry than in the pharmaceutical industry.

Finally, there are some industries in which political, legal and administrative issues can be expected to be much more influential on technology acquisition performance than in other industries because of the nature of the products developed.

The pharmaceutical industry appears to represent a strong case of such a highly regulated industry. It is widely perceived as an industry where the interference of political, administrative and legal issues is particularly high (Helms, 1996; Kuemmerle, 1999), whereas in the semiconductor industry the influence of such aspects on technology acquisition performance appears to be less strong.

Hypothesis 7. The influence of political, legal and administrative factors on the technology acquisition performance of firms is stronger in the pharmaceutical industry than in the semiconductor industry.

3. The empirical survey

3.1. Research methodology and sample

During the second half of 1999, a detailed empirical survey of the influence of institutional factors on the technology acquisition performance of R&D-intensive firms was conducted. In order to analyze the relative importance of these factors, a questionnaire containing a large number of items was prepared for assessment by the firms' R&D managers, as will be elaborated on in detail in the next section. Furthermore, firms from the two countries (Germany and Japan) and industries (pharmaceuticals and semiconductors) were surveyed to assess the international and inter-industrial differences.

Because of scale requirements, a substantial part of the technology acquisition activities in the two R&D-intensive industries chosen concentrates on a few large firms. Therefore, it was decided to conduct a detailed analysis of the technology acquisition of the semiconductor and pharmaceutical business units[2] within these leading firms instead of a large-scale survey of small- and medium-sized firms.

In each country and industry, all the leading business units (as measured by their R&D and sales volumes in the respective industries) were contacted, resulting in a total of 26 business units whose participation in the survey was requested. In order to reduce reservations about the disclosure of strategically relevant information to competitors, the whole survey was conducted anonymously. Out of the total number of business units contacted, 16 eventually participated in the survey. Despite the relatively small sample size, the business units surveyed represent a substantial part of the total R&D activities in the countries and industries surveyed as a result of the high concentration on a few leading firms.[3]

The characteristics of the business units surveyed are reported in Table 1. Their sizes and structures are similar in most respects. In all countries and industries the average size is within the range of 2.5–5.5 billion US$ annual sales, indicating a high structural similarity between them. All the business units surveyed, with the exception of two somewhat smaller German semiconductor units, exceeded one billion US$ annual sales. The average R&D intensity was well above 10% in both countries and industries, confirming the classification of the business units as R&D-intensive, as revealed by a comparison with the average values for those industries regarded by the OECD as 'high-tech' (Hatzichronoglou, 1997).

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

Two principal sources of data were used in the survey:

- Standardized assessments of institutional factors and the performance of technology acquisition activities, as provided by numerous R&D managers, typically sub-department or group heads, within each business unit surveyed.

[2] In many cases, the activities in the semiconductor and pharmaceutical business are not conducted by single-business firms, but by business units which are part of large, diversified electronics or chemical firms. The survey focused exclusively on these semiconductor and pharmaceutical business units.

[3] In Japan, for instance, the five largest firms accounted for 53.9% of the total R&D expenditures in the micro-electronics/telecommunications industry in 2000. The figure for the pharmaceutical industry was 31.1% (Sōmuchō Tōkeikyoku, 2000).

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

Indicator	Country/industry	Semiconductors Japan ($n = 5$)	Semiconductors Germany ($n = 4$)	Pharmaceuticals Japan ($n = 4$)	Pharmaceuticals Germany ($n = 3$)
A	Average annual sales of the business units (in millions of US$, including firm-internal sales)	5457	2778	2663	4342
B	Average annual R&D expenditures of the business units (in millions of US$)	680	403	336	734
C	Average R&D intensity of the business units for pharmaceuticals/semiconductors ($B/A \times 100$)	12.5	14.5	12.6	16.9

Source: Author's calculations based on data from the firms' annual reports, information directly obtained from the firms and from Semiconductor World (1999). *Note*: Currency conversion from local currencies into US$ based on the average foreign exchange rates released by the Federal Reserve Board.

- Qualitative assessments of the importance of institutional factors for the technology acquisition performance of the business units, as provided by several R&D department heads from each business unit.

Because of the wide range of the technology acquisition activities of the business units surveyed, one questionnaire response was requested from an R&D manager within each business unit responsible for a different field of activity. This approach was chosen in order to gain a precise overall picture of the technology acquisition activities of each business unit which was not biased by the personal views of single individuals.

A total of 235 questionnaires was sent out to the business units. Out of this number, 165 usable responses were returned to the author. Therefore, the total response rate was 70.2%. The number of responses and the response rates by country and industry are summarized in Table 2.

In the interview survey, the assessments of several respondents from each business unit were again sought in order to gain a detailed picture of the overall situation. Between September and December 1999, a total of 44 R&D department heads from 15 business units was interviewed. These department heads were responsible for different areas of R&D activities within the business units. Only one Japanese semiconductor business unit limited its participation to the questionnaire survey due to internal circumstances.

The questionnaire survey and the interviews were conducted exclusively in the native languages of the respondents (German and Japanese). All respondents were home-country based, i.e. located in Germany or Japan. Therefore, in contrast to previous studies that were primarily interested in the factors that influence the performance of overseas R&D units, this survey focused on the home-country perspective. This perspective is highly relevant since, despite ongoing internationalization, the majority of R&D activities of most large firms is still centered on their home countries (Patel, 1996).

3.2. Measurement of variables

In the questionnaire survey, the relevance of institutional factors for the technology acquisition of the business units surveyed was measured by an assessment of the R&D managers belonging to these business units concerning (a) the *general importance* of and (b) the *actual situation* regarding a wide range

Table 2
Number of responses and response rates of the questionnaire survey by countries and industries

	Pharmaceuticals	Semiconductors	Total number by country
Japan	49 (70.0%)	64 (85.3%)	113 (77.9%)
Germany	20 (41.7%)	32 (76.2%)	52 (57.8%)
Total number by industry	69 (58.5%)	96 (82.1%)	165 (70.2%)

of institutional factors which might have an influence on the technology acquisition activities within their fields of responsibility. Both assessments were given on five-point Likert scales, with the general importance assessments ranging from ‘very unimportant’ to ‘very important’ and the assessments of the actual situation ranging from ‘very bad’ to ‘very good’.

The list of institutional factors was initially generated from the results of prior research on the field of technology acquisition and therefore covered the whole range of aspects discussed in Section 2 of this paper. Thereafter, it was revised as a result of the pretests and of preliminary discussions held with the R&D managers of the participating business units before the actual survey was conducted. Specifically, the items concerning the availability and quality of capital were eliminated from the survey due to the fact that these aspects were assessed as not being relevant for the technology acquisition of the business units by the R&D managers. This outcome is consistent with indications in the literature that the availability and quality of capital is primarily relevant for the technology acquisition of small and medium-sized firms (Shan et al., 1994; Janz and Licht, 1999), but not for business units belonging to large firms which were subject to the survey reported in this paper.

Therefore, the list that was eventually used in the questionnaire survey contained: (a) nine items relating to the availability and quality of R&D personnel, (b) fourteen items relating to the availability and quality of external sources of knowledge, among which seven items referred to external knowledge from other firms and the remaining seven items referred to external knowledge from research institutions, (c) seven items relating to political, legal and administrative factors, and (d) four items relating to the organization of knowledge transfer. These items are listed in full in Table 3.

Whereas general differences in the influence of the institutional factors on technology acquisition performance were measured by analyzing the R&D managers’ assessments for the whole survey sample, the country- and industry-specific differences were measured by comparing the results for Germany versus Japan and for pharmaceuticals versus semiconductors.

In addition to their assessments of the general importance and current situation of institutional factors, the R&D managers rated the technology acquisition performance in their fields of activity for the following criteria: ‘low cost of input factors’, ‘efficiency of technology acquisition’, ‘speed of technology acquisition’, ‘newness of technologies’, ‘market fit of technologies’ and ‘transferability of technologies’. The list thus includes input-, throughput- and output-related yardsticks and therefore covers a wide range of self-assessments of technology acquisition. The assessments were given on a five-point Likert scale ranging from a ‘much worse’ to a ‘much better’ performance in comparison to that of competitors.

In the interviews, the importance of the whole range of institutional factors for the technology acquisition activities of the business units surveyed was indicated by R&D department heads on a qualitative, non-standardized basis.

The results are reported in the following two sections. First, the results of the questionnaire survey and the interviews concerning the general importance of institutional factors for the technology acquisition performance of the business units are analyzed. Thereafter, the influence of institutional factors on technology acquisition performance is measured by analyzing the influence of the assessments of the current situation of institutional factors on performance by using a regression analysis.

3.3. Results: the general importance of institutional factors for technology acquisition performance

The results of the importance assessments given by the R&D department heads are summarized in Fig. 1 on a standardized scale between 0 and 1. Strong differences in the average importance rating can be observed between the items. Among the factors related to R&D personnel, the items reflecting the qualifications of the R&D staff are viewed as being the most important ones. This applies particularly to the ‘professional skills of R&D personnel’ which received the highest average score among all the items surveyed.

In the group of knowledge-related factors, the quality of external knowledge, as measured by the technological level of external organizations, was also perceived as being fairly important, particularly concerning other firms. In contrast, the R&D managers regarded the spatial proximity to other firms and to research institutions as relatively unimportant.

Table 3
Survey items relating to institutional factors which influence the technology acquisition performance of firms

Items relating to the availability, cost and quality of R&D personnel	Items relating to the availability, cost and quality of external knowledge	Items relating to political, legal and administrative factors	Items relating to the organization of knowledge transfer
'Recruitment conditions for R&D personnel'	*(a) External knowledge from other firms*	'Price regulation for final products' (included only for the pharmaceutical industry)	'Freedom of the internal exchange of information'
'Recruitment potential through R&D collaboration with universities'	'Business ties with supplier firms'	'Spatial proximity to the drug administration' (included only for the pharmaceutical industry)	'Strength of the internal communication network'
'Cost of R&D personnel'	'Business ties with customer firms'	'Impediments to R&D by administrative and legal barriers'	'Freedom of the external exchange of information'
'Lay-off conditions for R&D personnel'	'Business ties with competitors and other firms'	'General R&D subsidies'	'Strength of the external communication network'
'General education level of R&D personnel'	'Spatial proximity to other firms'	'Subsidies for collaborative R&D'	
'Professional skills of R&D personnel'	'Technological level of supplier firms'	'Protection of intellectual property rights'	
'Spatial mobility of R&D personnel'	'Technological level of customer firms'	'Governmental demand for final products' (included only for the semiconductor industry)	
'Networking of R&D personnel with other firms'	'Technological level of competitors and other firms'		
'Networking of R&D personnel with research institutions'	*(b) External knowledge from research institutions*		
	'Potential for information exchange at external conferences'		
	'Access to external technological databases and publications'		
	'Conditions for R&D collaboration with non-university research institutions'		
	'Conditions for R&D collaboration with university research institutions'		
	'Spatial proximity to research institutions'		
	'Technological level of non-university research institutions'		
	'Technological level of university research institutions'		

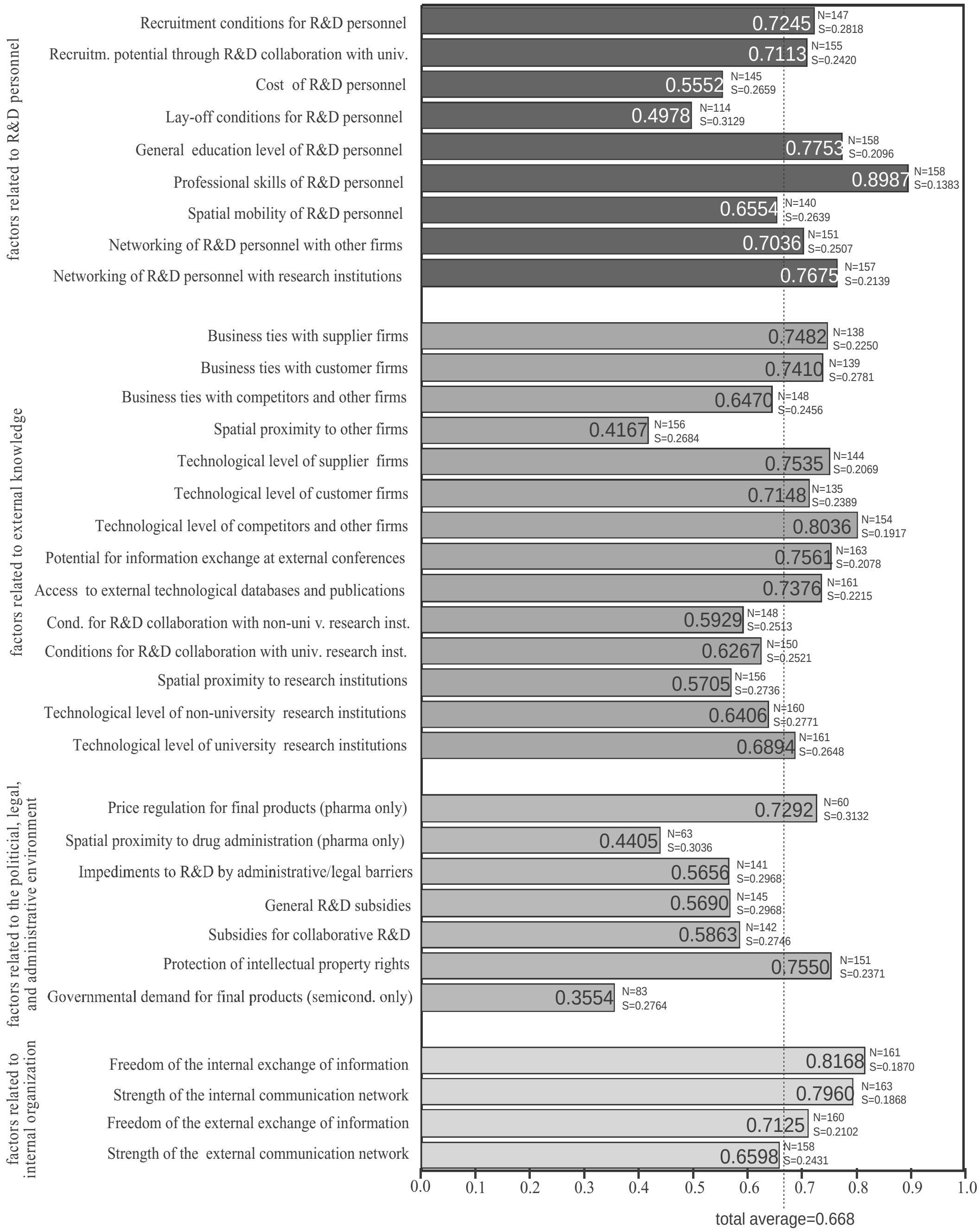

Fig. 1. Importance assessment of institutional factors for technology acquisition by R& D managers (mean values). *Notes*: $N =$ number of observations; $S =$ standard deviation.

Table 4
Country- and industry-specific differences of the importance assessments of institutional factors

Group of factors	Country-specific differences		Industry-specific differences	
	More important in Japan ($n = 113$)	More important in Germany ($n = 52$)	More important in pharmaceuticals ($n = 69$)	More important in semiconductors ($n = 96$)
Availability, cost and quality of R&D personnel	Lay-off conditions for R&D personnel ($P < 0.05$)	Recruitment conditions for R&D personnel ($P < 0.05$) Recruitment potential through R&D collaboration with universities ($P < 0.01$) General education level of R&D personnel ($P < 0.01$)	Network of R&D personnel with research institutions ($P < 0.01$)	None
Availability, cost and quality of external knowledge	Business ties with competitors and other firms ($P < 0.01$) Technological level of customer firms ($P < 0.05$)	None	Conditions for R&D collaboration with non-university research institutions ($P < 0.01$) Conditions for R&D collaboration with university research institutions ($P < 0.01$) Technological level of non-university research institutions ($P < 0.01$) Technological level of university research institutions ($P < 0.01$)	Business ties with customer firms ($P < 0.01$) Spatial proximity to other firms ($P < 0.01$) Technological level of customer firms ($P < 0.01$)
Political, legal and administrative factors	Governmental demand for final products ($P < 0.01$)	None	Impediments to R&D by administrative/legal barriers ($P < 0.01$) Protection of intellectual property rights ($P < 0.01$)	None
Organization of knowledge transfer	None	Strength of the internal communication network ($P < 0.01$)	None	None

Among the factors relating to political, legal and administrative influences, only the importance of the ‘protection of intellectual property rights’ and the ‘price regulation for final products’ (which was included in the questionnaire only for the pharmaceutical industry) was rated as being of above-average importance. Governmental R&D subsidies and other factors were regarded as being much less relevant for technology acquisition activities.

Finally, the R&D managers perceived the factors related to the organization of internal knowledge transfer as being among the most important ones, whereas the importance of factors reflecting the management of the external flow of information was assessed as being close to the total average.

In sum, the results strongly support Hypothesis 1, according to which there is a varying importance of institutional factors for the technology acquisition performance of firms.

As regards the international and inter-industrial variance of the results, Table 4 lists those items which show significant differences. Four of the country-specific differences are concentrated on the field of R&D personnel, with three of them in the direction expected in Hypothesis 2. However, one significant difference (the higher importance of the ‘lay-off conditions for R&D personnel’ in Japan than in Germany) runs counter to this Hypothesis which therefore receives only partial support. Hypotheses 3 and 4 are only weakly supported since only two items related to external knowledge and one item related to political, administrative and legal factors respectively have been rated as being significantly more important in Japan than in Germany, as expected.

In an industry-specific comparison, significant differences concerning the importance ratings were observed mainly among those factors relating to external knowledge. Four items associated with the technological level of and the network and business ties with research institutions were regarded as being more important in the pharmaceutical industry than in the semiconductor industry. The reverse was the case concerning three items relating to the technological level of and the business ties with firms. Since for about half of the items relating to these issues significant inter-industry differences could be observed in the expected direction, Hypotheses 5 and 6 are moderately supported.

Furthermore, the pharmaceutical R&D managers assessed the impediments to R&D resulting from administrative and legal barriers and the protection of intellectual property rights as being more important than their colleagues in the semiconductor industry did. This lends some support to Hypothesis 7 since the inter-industry differences were significant for two out of four items relating to political, legal and administrative factors which were included in the questionnaire survey for both industries.

In the interview survey, most of the R&D department heads generally stressed the crucial roles of the skills of R&D workers, of firm-internal knowledge transfer, and of technological ties with external sources of knowledge. In their perception, the role of the factors relating to the political, legal and administrative environment is not as great as that of any of the three previously mentioned factors. Moreover, whereas most of the R&D department heads evaluated external knowledge as being important for technology acquisition performance, they emphasized, in agreement with the questionnaire respondents, that the geographical proximity to the sources of external knowledge is not of high relevance. Altogether, the interviews confirmed the finding from the questionnaire survey regarding the strong differences in the relative importance of different factors for technology acquisition performance and therefore support Hypothesis 1.

From a country-specific perspective, the German R&D department heads specifically emphasized the importance of the availability of skilled R&D personnel and referred to the shortage of such highly qualified personnel in Germany. The Japanese R&D managers, in contrast, emphasized the importance of the technological competence of customer firms to a higher degree than their German colleagues did. The results of the interviews therefore support Hypotheses 2 and 3. As regards the importance of political, legal and administrative factors, no large differences between the assessments of the German and the Japanese department heads were observed, however. Thus, Hypothesis 4 was not supported.

From an industry-specific perspective, the department heads in the pharmaceutical industry assessed the availability and quality of external knowledge from research institutions as being particularly important, whereas their colleagues in the semiconductor industry regarded external knowledge from other firms as being more relevant. Therefore, Hypotheses 5 and 6 were supported. Moreover, the impediments to R&D resulting from administrative and legal barriers were mentioned particularly by the R&D department heads in the pharmaceutical industry as being an important issue, lending support to Hypothesis 7.

3.4. Results: the influence of institutional factors on technology acquisition performance

On the basis of the questionnaire data, the influence of institutional factors on technology acquisition performance was analyzed using a regression analysis with the assessments of the current situation of the institutional factors as independent variables and the performance assessments as dependent variables. Prior to this step, an exploratory factor analysis was applied to both groups of items in order to reduce complexity and to identify the underlying dimensions behind the survey items.

For the factor analysis of the data on the current situation of the institutional factors related to technology acquisition, the three items surveyed in only one industry were eliminated first. Additionally, four more variables, namely the 'cost of R&D personnel', 'lay-off conditions for R&D personnel', the 'networking of R&D personnel with other firms' and the 'impediments to R&D by administrative and legal barriers', were excluded because of the unsatisfactory variable-specific MSA values which were not clearly above the commonly applied threshold value of 0.5.

In the subsequent factor analysis of the remaining 27 variables, an orthogonal factor rotation with the Varimax rotation method was applied. Missing values of variables were substituted by average values. The analysis resulted in the extraction of five factors. With reference to their loadings on the initial variables related to the questionnaire items, they were labeled as 'firms', 'research institutions', 'external network', 'R&D personnel', and 'R&D subsidies' (Table 5). Thus, although not all factor loadings are exactly delineated according to the initial item groups of the survey, the five dimensions derived from the factor analysis can be associated strongly with the groups of institutional factors which have already been raised in Section 2 of this paper, namely, in the order of the factors mentioned, with (1) external knowledge from other firms, (2) external knowledge from research institutions, (3) organization of technology transfer, (4) internal resources (namely R&D personnel), and (5) political, legal and administrative factors.

From the six items addressing technology acquisition performance, two underlying variables were derived (Table 6). The first of them can be interpreted as expressing the 'input and process performance' of technology acquisition since it loads on the low cost of input factors, efficiency, and speed. The second shows high loadings on the survey items addressing newness, market fit, and the transferability of new technologies and can therefore be associated with the 'output performance' of technology acquisition.[4]

The influence of institutional factors on input and process performance and on the output performance of technology acquisition was then measured separately by applying multiple linear regression models. In both groups of models, seven cases were eliminated from the sample because of the highly irregular values of the dependent variables which diverged more than two standard variations from the mean values. For the remaining 158 observations, the regression was conducted not only for the whole survey sample, but also for country- and industry-specific subsamples in order to assess the country- and industry-specific results. Additionally, in order to assess the impact of firm effects on the results, all the models were also extended with firm dummies for all 16 business units in the whole sample, or all business units present in the country- and industry-specific subsamples.

With reference to the input and process performance of technology acquisition (Table 7), the variable 'research institutions' clearly exerts the strongest positive influence among all the independent variables. It is significant in all the models except for the German subsample when not controlled for firm effects. The influence of 'R&D personnel' is notable as well. When controlled for firms, however, it is significant only for the subsamples for Germany and for the semiconductor industry. The impact of the remaining three inde-

[4] The input- and process- or output-related interpretation of some of the items is not totally clear-cut. For instance, speed might also be associated with the output and transferability with the process of technology acquisition. The nomination of the factors is based on the overall interpretation of the items they have been extracted from.

Table 5
Results of the factor analysis concerning the determining factors of technology acquisition performance ($n = 165$)

Factor loadings *situation concerning...*	Factors				
	Firms	Research institutions	External network	R&D personnel	R&D subsidies
Technological level of customer firms	0.833	−0.028	−0.015	−0.104	0.206
Business ties with customer firms	0.769	0.044	−0.060	0.054	0.219
Technological level of supplier firms	0.646	0.129	0.310	0.107	−0.031
Business ties with supplier firms	0.631	−0.167	0.297	0.125	0.102
Technological level of competitors and other firms	0.497	−0.102	0.273	0.277	−0.015
Freedom of the internal exchange of information	0.433	0.118	0.165	0.373	0.026
Conditions for R&D collaboration with university research institutions	0.067	0.766	0.085	0.064	0.018
Technological level of university research institutions	0.011	0.736	0.203	0.039	−0.029
Technological level of non-university research institutions	−0.144	0.705	0.118	0.057	0.064
Conditions for R&D collaboration with non-university research institutions	0.067	0.705	0.118	0.057	0.064
Recruitment potential through R&D collaboration with universities	0.302	0.582	−0.011	0.258	0.104
Potential for information exchange at external conferences	0.021	0.279	0.721	−0.026	0.174
Access to external technological databases and publications	0.093	0.191	0.685	−0.091	0.168
Strength of the external communication network	0.151	0.054	0.663	0.233	−0.036
Strength of the internal communication network	0.293	0.090	0.563	0.220	−0.048
Freedom of the external exchange of information	0.144	0.004	0.519	0.467	0.111
Business ties with competitors and other firms	0.305	−0.183	0.354	0.299	0.181
Professional skills of R&D personnel	0.072	0.266	0.140	0.737	0.006
Recruitment conditions for R&D personnel	0.219	0.118	−0.077	0.590	0.076
General education level of R&D personnel	−0.147	0.078	0.249	0.557	0.059
Networking of R&D personnel with research institutions	−0.137	0.212	0.220	0.429	0.287
Spatial mobility of R&D personnel	0.265	−0.057	0.157	0.373	0.077
Protection of intellectual property rights	0.152	0.303	0.219	0.347	0.099
Subsidies for collaborative R&D	0.121	0.095	0.209	0.036	0.836
General R&D subsidies	0.135	0.167	0.259	0.051	0.809
Spatial proximity to other firms	0.175	−0.076	−0.107	0.368	0.479
Spatial proximity to research institutions	0.207	0.113	−0.178	0.398	0.453
Eigenvalues	3.202	2.977	2.855	2.702	2.139
Explained part of total variance (%)	11.86	11.03	10.57	10.01	7.92
Cronbach's α	0.778	0.772	0.764	0.628	0.702

Notes: Varimax-rotated factors, MSA-value: 0.730.

pendent variables on input performance is consistently weak and statistically insignificant in all the models. The only exception is the positive influence of 'firms' in the German subsample when not controlled for firm effects.

As regards the output performance of technology acquisition (Table 8), the strongest positive impact comes from 'R&D personnel'. This impact is significant in all the models and particularly strong in the subsamples for Germany. Among the other independent variables, 'firms' also exerts a considerable positive influence which is significant in three of the models. The positive contribution of 'research institutions' is also noticeable when not controlled for firm effects. In four of the five models with firm dummies, however, it even becomes slightly negative. The impact of 'R&D subsidies' is generally weak in the basic models, but becomes significant at the 0.1-level in the subsamples for Japan and for the semiconductor industry when controlled for firm effects. The effect of the 'external network' is generally weak and insignificant.

Table 6
Results of the factor analysis concerning the performance measures of technology acquisition ($n = 165$)

Factor loadings	Factors	
	Input and process performance	Output performance
Performance measure		
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
Cronbach's α	0.755	0.656

Notes: Varimax-rotated factors, MSA-value: 0.803.

In sum, the results indicate a considerable variation between the influence of different institutional factors on technology acquisition performance and therefore strongly support Hypothesis 1.

As regards international differences, the contribution of 'R&D personnel' to both performance dimensions is much stronger in Germany than in Japan, thereby lending support to Hypothesis 2. However, 'firms' and 'research institutions' are not contributing consistently more to input/process or output performance in Japan than in Germany. Thus, Hypothesis 3 is not supported. Hypothesis 4 is only partially supported since the contribution of 'R&D subsidies' to the success of technology acquisition is clearly more positive in Japan than in Germany only in the model with firm dummies concerning the output performance.

The inter-industrial comparison of the results shows that 'research institutions' are making a stronger contribution to the output performance in the pharmaceutical industry than in the semiconductor industry, whereas the reverse applies to 'firms'. Therefore, the regression data support Hypotheses 5 and 6 as regards output performance. The results on input and process performance do not support these two hypotheses, however. Finally, whereas the contribution of 'R&D subsidies' to the performance variables is generally weak in both industries, the results lend some support to Hypothesis 7, as there is a significant impact on

Table 7
Results of the linear regression analysis concerning the influence of institutional factors on the input and process performance of technology acquisition

Independent variables	Basic model					Model with firm dummies				
	Whole sample ($n = 158$)	Subsample Japan ($n = 109$)	Subsample Germany ($n = 49$)	Subsample pharmaceuticals ($n = 67$)	Subsample semiconductors ($n = 91$)	Whole sample ($n = 158$)	Subsample Japan ($n = 109$)	Subsample Germany ($n = 49$)	Subsample pharmaceuticals ($n = 67$)	Subsample semiconductors ($n = 91$)
Firms	0.088 (0.067)	−0.009 (0.081)	0.268* (0.114)	0.053 (0.118)	−0.023 (0.097)	0.053 (0.079)	−0.003 (0.094)	0.162 (0.105)	0.074 (0.115)	−0.001 (0.089)
Research institutions	0.287*** (0.066)	0.189* (0.085)	0.136 (0.121)	0.332*** (0.107)	0.377*** (0.096)	0.232** (0.078)	0.248** (0.095)	0.230* (0.103)	0.214* (0.107)	0.288*** (0.096)
External network	−0.026 (0.065)	0.001 (0.074)	0.026 (0.126)	−0.122 (0.091)	0.062 (0.097)	−0.049 (0.071)	−0.126 (0.079)	0.106 (0.114)	−0.137 (0.090)	0.026 (0.098)
R&D personnel	0.204** (0.068)	0.086 (0.082)	0.351** (0.130)	0.210* (0.090)	0.250** (0.100)	0.072 (0.071)	0.079 (0.082)	0.260** (0.112)	0.094 (0.097)	0.164* (0.092)
R&D subsidies	0.032 (0.066)	0.030 (0.092)	0.080 (0.092)	0.089 (0.099)	−0.053 (0.090)	0.063 (0.076)	0.078 (0.096)	0.038 (0.082)	0.058 (0.093)	0.009 (0.092)
R^2	0.137	0.041	0.179	0.151	0.183	0.409	0.181	0.552	0.367	0.434
Adjusted R^2	0.109	−0.006	0.083	0.079	0.136	0.303	0.069	0.418	0.236	0.341
F	4.845	0.870	1.869	2.105	3.895	3.856	1.612	4.140	2.799	4.658

The numbers without parentheses are beta coefficients, the numbers in parentheses are standard deviations. The beta coefficients and standard deviations for the firm dummies are not included.

* $P < 0.1$.

** $P < 0.05$.

*** $P < 0.01$.

Table 8
Results of the linear regression analysis concerning the influence of institutional factors on the output performance of technology acquisition

Independent variables	Basic model					Model with firm dummies				
	Whole sample ($n = 158$)	Subsample Japan ($n = 109$)	Subsample Germany ($n = 49$)	Subsample pharmaceuticals ($n = 67$)	Subsample semiconductors ($n = 91$)	Whole sample ($n = 158$)	Subsample Japan ($n = 109$)	Subsample Germany ($n = 49$)	Subsample pharmaceuticals ($n = 67$)	Subsample semiconductors ($n = 91$)
Firms	0.150** (0.070)	0.091 (0.091)	0.321** (0.102)	0.007 (0.124)	0.156 (0.104)	0.088 (0.083)	0.130 (0.098)	0.160 (0.113)	−0.004 (0.118)	0.163* (0.094)
Research institutions	0.137* (0.069)	0.007 (0.090)	0.021 (0.118)	0.239** (0.115)	0.080 (0.102)	−0.052 (0.082)	−0.054 (0.096)	−0.040 (0.121)	0.141 (0.109)	−0.164 (0.104)
External network	0.081 (0.069)	0.141 (0.082)	0.015 (0.116)	0.109 (0.102)	0.027 (0.101)	0.049 (0.074)	0.025 (0.084)	0.067 (0.119)	−0.030 (0.097)	0.045 (0.101)
R&D personnel	0.307*** (0.069)	0.164* (0.085)	0.449*** (0.124)	0.352*** (0.094)	0.258** (0.102)	0.279*** (0.073)	0.180* (0.082)	0.501*** (0.129)	0.322*** (0.099)	0.207** (0.094)
R&D subsidies	−0.011 (0.068)	0.122 (0.100)	−0.148 (0.086)	−0.069 (0.107)	0.043 (0.094)	0.032 (0.081)	0.163* (0.100)	−0.130 (0.092)	−0.120 (0.096)	0.181* (0.096)
R^2	0.144	0.077	0.284	0.239	0.108	0.380	0.270	0.451	0.466	0.385
Adjusted R^2	0.116	0.032	0.201	0.177	0.056	0.269	0.170	0.288	0.359	0.281
F	5.125	1.712	3.414	3.835	2.061	3.412	2.701	2.761	4.364	3.706

The numbers without parentheses are beta coefficients, the numbers in parentheses are standard deviations. The beta coefficients and standard deviations for the firm dummies are not included.
* $P < 0.1$.
** $P < 0.05$.
*** $P < 0.01$.

output performance in the semiconductor industry, but not in the pharmaceutical industry.

The explanatory power of the regression models increases substantially when firm dummies are included, indicating that firm-specific strengths and weaknesses also exert a considerable effect on technology acquisition performance. Most of the results for the impact of the variables addressing institutional factors on the performance indicators do not change to a large extent, however.

A notable result is the comparatively weak performance of the regression models in the subsamples for Japan which also remains when controlled for firm effects. This means that for this subsample most of the variance of the performance indicators can be explained neither by institutional effects nor by firm-specific circumstances, and this raises the question of the validity of the self-assessments by the R&D managers for this subsample.

In order to address this issue, the performance assessments have been validated with patent data from the business units surveyed. For this purpose, the number and the development of patents granted by the US Patent and Trademark Office to the firms which the business units surveyed belong to in the relevant technological fields were analyzed by using the online patent database of the Office. In order to preclude a bias in favor of diversified firms, only those patent classes which can be clearly attributed to either semiconductor or to pharmaceutical technology, and therefore to the corresponding business units, were included.[5] On the basis of the patent data, two performance indicators were created:

(1) Patent productivity, measured as the number of patents which were applied for by a firm in 1998 and which had been granted by October 2003, divided by a business unit's R&D expenditures in 1998.
(2) The relative growth of patent output, measured as the absolute growth of the number of patents granted to a firm (the number of patents between 1998 and 2002 divided by the number of patents between 1993 and 1997), divided by the overall

[5] The analysis covered the IPC class A61K (preparations for medical, dental, or toiletry purposes) in the pharmaceutical industry and the IPC class H01L (semiconductor devices; electric solid state devices not otherwise provided for) in the semiconductor industry.

Table 9
Correlation between technology performance assessments by R&D managers and patent-related performance indicators of the business units surveyed

	Business unit patent productivity (semiconductors) $n = 82$	Business unit patent productivity (pharmaceuticals) $n = 50$	Relative growth of business unit patent output $n = 132$
Input and process performance	0.043	−0.009	0.188**
Output performance	−0.163	0.257*	0.239***

* $P < 0.1$.
** $P < 0.05$.
*** $P < 0.01$.

growth of patents granted by the US Patent and Trademark Office in the respective patent classes of the pharmaceutical or semiconductor industry in the same reference periods.

Since reliable patent data were available for only 12 out of the 16 business units surveyed, the remaining four business units were excluded from this part of the analysis due to measurement problems related to firm mergers or to the fact that only a very small total number of patents was granted.

Table 9 shows the correlation between the performance indicators derived from the performance assessments by the business units' R&D managers and the two patent-based performance indicators. For the business units' patent productivity, the results are reported separately for semiconductors and pharmaceuticals since the level of patent output differs very much between the two industries. For the relative patent growth, the correlation for the total sample is shown, however, since the patent growth of the business units is already normalized by the total growth in their respective industries.

The results indicate that the assessments by the R&D managers of both the input and process performance and the output performance of technology acquisition are not strongly related to patent productivity. Only the productivity in the pharmaceutical industry is positively related to the output performance at the 0.1-level. There is a highly significant correlation, however, between both the performance indicators derived from the survey data and the growth of patent output. This suggests that the R&D managers' assessments reflect the development of the technological capabilities of a business unit over time rather than the absolute level of technology acquisition performance at a given point in time.

3.5. Discussion

The analysis of the survey data has revealed strong differences in the influence of institutional factors on the technology acquisition performance of the business units, as was proposed in Section 2. In general, R&D personnel and external knowledge appear to be of primary importance, whereas the relevance of political, legal and administrative factors and of the organization of knowledge transfer seems to be lower.

The results of the regression analysis indicate that the input and process performance of technology acquisition is significantly determined by strong links with technologically outstanding research institutions. Output performance is influenced particularly by access to highly qualified R&D personnel and the efficient internal use of these resources. Therefore, most factors which were rated as being highly important by the R&D managers and department heads were also found to contribute significantly to their performance assessments.

However, the findings concerning the institutional factors which were found to be *not* significantly linked with technology acquisition performance are noteworthy as well. On its own, the external networking of the R&D personnel of business units does not appear to be a factor which significantly influences their performance. The same applies to R&D subsidies and to the spatial proximity to external sources of knowledge.

As concerns the lack of relevance of R&D subsidies and of spatial proximity, the subsamples for Japan and for the semiconductor industry, when controlled for firms, represent two remarkable exceptions. Does this finding indicate that in Japan the government is still in effect enhancing the performance of large high-tech firms through R&D subsidies? The recent literature on this topic does not lend support to this interpretation of the findings. First, at least in quantitative terms, governmental R&D subsidies have been much less important in Japan than in Western countries in recent years (Odagiri and Goto, 1993; Watanabe and Hemmert, 1998). Second, to the extent that the Japanese government *has been* giving R&D subsidies to firms, it has been guided by a 'picking winners' policy which restricts access to government funds to those few firms perceived as being the industry leaders (Callon, 1995). This suggests a interpretation contrary to the survey results: Rather than government subsidies leading to a better technology acquisition performance, the superior performance of firms may have caused comparatively higher R&D subsidies to be granted to them.

The low importance assigned to the spatial proximity to external sources of knowledge is remarkable in view of the literature which stresses this very factor as being a crucial one for the technology acquisition of firms. This literature refers mostly to small and medium-sized firms from smaller European countries (OECD, 2001a; OECD, 2001b). Saxenian's (1994) study of high-tech agglomerations in the United States, however, also stresses the aspect of regional technological interaction for large firms. The different findings of these studies and of the survey discussed in this paper suggest that firm size is an important moderator for the importance of the spatial proximity to external sources of knowledge. Moreover, the outcome may also differ depending on the country observed. This suggests that the empirical findings from certain countries are not easily transferable to others.

The country- and industry-specific differences proposed in Section 2 were supported by the analysis of the data surveyed to a varying degree. On the country level, the data lend some support to the notions that R&D personnel is more important in Germany, whereas external knowledge is more important in Japan. As regards the second aspect, technological interaction between suppliers and users appear to be of particularly high importance. This finding is consistent with the results of earlier studies on Japan (Nishiguchi and Ikeda, 1996; Lee, 1998). However, the study does not lend strong support to the notion that political, legal and administrative factors are generally more important in Japan than in Germany. One possible explanation is that the difference between the two countries concerning these aspects is no longer as strong as it appeared to be in previous decades due to the ongoing structural reform in the Japanese innovation system (Hemmert and Oberländer, 1998).

From an industry-specific perspective, the findings of the study support the notions that external knowledge from research institutions is more important in the pharmaceutical industry and that external knowledge from other firms is more important in the semiconductor industry. As regards the influence on performance, however, the expected inter-industrial differences could be observed only as regards output performance, but not as regards input and process performance. The assumed higher relevance of political, legal and administrative factors in the pharmaceutical industry as opposed to the semiconductor industry could be observed only for two survey items: the 'impediments to R&D by administrative/legal barriers' and the 'protection of intellectual property rights'. This suggests that the impact of political, legal and administrative factors on technology acquisition should be discussed on the level of specific issues rather than on a general level.

The findings of the different parts of the survey are mostly consistent with each other. Taken together, they lead to the following two conclusions: First, whereas all of the institutional factors mentioned in the literature as being important for the technology acquisition of firms were found to be somewhat relevant, their *relative* importance varies to a large extent. Some of them appear to be extremely important, whereas the role of others may be only a secondary or even a tertiary one. Second, whereas many of the findings apply to both countries and industries, some significant country- and industry-specific differences were observed concerning the importance of certain institutional factors for technology acquisition. This applies particularly to the field of R&D personnel on the country level and to external sources of knowledge on the industry level.

3.6. Limitations

First of all, 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. Moreover, since the survey focused on large firms, the results cannot easily be applied to small and medium-sized firms. This applies particularly to size-specific issues such as the low relevance of the availability of capital to large firms' R&D managers, resulting in the exclusion of this aspect from the survey, or to items such as the spatial proximity to external sources of technology.

Moreover, only a moderate part of the total variance of the performance indicators could be explained in the regression analysis by the factors generated from the survey data. Therefore, additional research on the institutional factors which influence the technology acquisition of business firms is necessary.

Another limitation of the study stems from its data source, that is, the assessments given by R&D managers. This emphasis in the data collection derives from the assumption that technology acquisition activities are conducted mainly within R&D departments of firms. As a result, however, the views of general managers which might differ significantly from those of their R&D colleagues are not reflected in the results. An additional issue derives from the assumption that the R&D managers who responded to the questionnaire within each business unit surveyed are responsible for separate fields of technology acquisition. In reality, the responsibilities for such fields cannot always be expected to be delineated in such a clear-cut fashion. Therefore, the possibility cannot be excluded that in some cases the respondents were at least partially referring to the same technological fields.

Furthermore, since the assessments concerning the institutional factors and the performance of technology acquisition were supplied by the same questionnaire respondents, there is the possibility of a common informant bias which may have affected the results of the regression analysis. It was however possible to partially validate the performance-related assessments by using patent data. In a dynamic context, a highly significant correlation between both groups of observations was measured. This suggests that, despite the probable existence of a common informant bias, the questionnaire data reflect the true situation to a high degree.

Finally, since the survey referred only to a specific point in time and was not based on longitudinal data, the possibility cannot be excluded that some of the importance assessments concerning institutional factors may have been influenced by short- and medium-term developments which may not hold in the long-term. For instance, the high importance assigned to the 'recruitment conditions for R&D personnel' by the German R&D managers appears to have been influenced by the shortage of skilled labor in the German high-tech sector in the late 1990s. This had eased considerably by the turn of the millennium.

4. Implications for science and technology policy

As has been previously mentioned, the survey results indicate that not all aspects of the institutional setting which surrounds business firms in the field of technology acquisition are of the same importance for their performance in this field.

Among the factors which were assessed by R&D managers as being particularly important, the primary one was the education and the skill level of R&D personnel. This education and skill level can be improved by a country's or region's government providing good conditions for high-level education, particularly in technical disciplines. Moreover, the technological level of research institutions and their interaction with firms can be enhanced by a country's science and technology policy through the supply of sufficient funding for public research institutions and universities as well as through the creation of good institutional conditions for interaction between research institutions and firms.

At the same time, some other factors which are frequently discussed in the context of science and technology policy, namely the spatial proximity of firms to external sources of knowledge and R&D subsidies, appear to have only a weak influence on performance. At least in the case of large high-tech firms, this questions the effectiveness of governmental policies directed towards the spatial concentration of firms such as the establishment of science parks or the direct support of the firms' R&D efforts through R&D subsidies.

Therefore, the findings suggest that with respect to large high-tech firms, science and technology policy can support their R&D and technology acquisition efforts to a much greater extent by indirect measures such as maintaining excellence in high-level education or in public research institutions and universities rather than by direct measures such as subsidizing the firms' R&D. This indicates that, at least in highly developed industrial countries, those science and technology policies which are meant to support such firms should be concentrated on indirect support by securing good overall conditions for R&D rather than on the direct support of R&D activities by subsidies.

Another finding of the study is that even among large high-tech firms from leading industrialized countries there are considerable country- and industry-specific differences concerning the importance of institutional factors for technology acquisition, namely, the fact that in Germany R&D personnel appears to be particularly important, whereas the role of external knowledge is relatively larger in Japan. This suggests that science and technology policy in Germany should give high priority to the education and skill formation of R&D personnel, whereas in Japan particular attention should be paid to investments into research institutions in order to increase the quantity and quality of external knowledge that can be made available to firms. Moreover, whereas research institutions play a particularly large role in the technology acquisition of pharmaceutical firms, the relative importance of other firms as sources of technology is higher in the semiconductor industry. These sectoral differences should also be taken into account when policy measures are developed and implemented.

Acknowledgements

Funding for this research was provided by IBRE Research Grant, Korea University Business School. The author thanks Klaus Ruth, Franz Waldenberger and two anonymous reviewers for their helpful comments on earlier versions of this paper.

References

Barker, B., 1998. Internationalizing Japanese science. In: Hemmert, M. Oberländer, C. (Eds.), Technology and Innovation in Japan. Policy and Management for the Twenty-first Century. Routledge, London and New York, pp. 70–86.

Beise, M., Stahl, H., 1998. Public Research and Industrial Innovations in Germany. ZEW Discussion Paper No. 98-37. Centre for European Economic Research (ZEW), Mannheim.

Braczyk, H.-J., Cooke, P., Heidenreich, M. (Eds.), 1998. Regional Innovation Systems. The role of governances in a globalized world. UCL Press, London and Bristol.

Breschi, S., Malerba, F., 1997. Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries. In: Edquist, C. (Ed.), Systems of Innovation. Technologies, Institutions and Organizations. Pinter, London, Washington, pp. 131–156.

Brockhoff, K., 1998. Internationalization of Research and Development. Springer, Berlin.

Callon, S., 1995. Divided Sun: MITI and the Breakdown of Japanese High-Tech Industrial Policy, 1975–1993. Stanford University Press, Stanford.

Caluori, M., Schips, B., 1991. Internationalisierung der Forschungs- und Entwicklungsaktivitäten schweizerischer Unternehmen: Empirische Befunde und volkswirtschaftliche Konsequenzen. Rüegger, Chur, Zürich.

Clark, K.B., Fujimoto, T., 1991. Product Development Performance: Strategy, Organization, and Management in the World Auto Industry. Harvard Business School Press, Boston.

Cockburn, I.M., Henderson, R.M., 1998. Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery. Journal of Industrial Economics 46, 157–182.

Corey, E.R., 1997. Technology Fountainheads: The Management Challenge of R&D Consortia. Harvard Business School Press, Boston.

Ebling, G., Gottschalk, S., Janz, N., Niggemann, H., 2000. Zukunftsperspektiven der deutschen Wirtschaft: Innovationsaktivitäten im Verarbeitenden Gewerbe. Ergebnisse der Erhebung 1999. Centre for European Economic Research (ZEW), Mannheim.

Ernst, A., Wiesner, G., 1994. Japans technische Intelligenz. Personalstrukturen und Personalmanagement in Forschung und Entwicklung. ifo Studien zur Japanforschung 7, ifo Institut für Wirtschaftsforschung, Munich.

Furman, J.L., Porter, M.E., Stern, S., 2002. The determinants of national innovative capacity. Research Policy 31, 899–933.

Gambardella, A., 1995. Science and Innovation: The US Pharmaceutical Industry During the 1980s. Cambridge University Press, Cambridge.

Gerybadze, A., Reger, R., 1999. Globalization of R&D: recent changes in the management of innovation in transnational corporations. Research Policy 28, 251–274.

Granstrand, O., Håkanson, L., Sjölander, S., 1992. Technology Management and International Business: Internationalization of R&D and Technology. Wiley, Chichester.

Guerrieri, P., Tylecote, A., 1997. Interindustry Differences in Technical Change and National Patterns of Technological Accumulation. In: Edquist, C. (Ed.), Systems of Innovation. Technologies, Institutions and Organizations. Pinter, London and Washington, pp. 107–129.

Hagedoorn, J., 1995. Strategic technology partnering during the 1980s: trends, networks and corporate patterns in non-core technologies. Research Policy 24, 207–231.

Hagedoorn, J., 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. Research Policy 31, 477–492.

Hatzichronoglou, T., 1997. Revision of the High-Technology Sector and Product Classification. STI Working Papers 1997/2. OECD, Paris.

Helms, R.B., 1996. Competitive Strategies in the Pharmaceutical Industry. AEI Press, Washington, DC.

Hemmert, M., Oberländer, C., 1998. The Japanese system of technology and innovation: preparing for the twenty-first century. In: Hemmert, M. Oberländer, C. (Eds.), Technology and

Innovation in Japan. Policy and Management for the Twenty-first Century. Routledge, London and New York, pp. 3–19.
Irwin, D.A., Klenow, P.J., 1994. High Tech R&D Subsidies: Estimating the Effects of Sematech. NBER Working Paper 4974. National Bureau of Economic Research, Cambridge.
Janz, N., Licht, G. (Eds.), 1999. Innovationsaktivitäten in der deutschen Wirtschaft. Schriftenreihe des ZEW, Band 41. Nomos, Baden-Baden.
Kim, L., 1997. Imitation to Innovation. The Dynamics of Korea's Technological Learning. Harvard Business School Press, Oxford.
Kimura, Y., 1997. Technological innovation and competition in the Japanese semiconductor industry. In: Goto, A. Odagiri, H. (Eds.), Innovation in Japan. Oxford University Press, Oxford, pp. 121–158.
Kuemmerle, W., 1999. The drivers of foreign direct investment into research and development: an empirical investigation. Journal of International Business Studies 30, 1–24.
Kumar, N., 2001. Determinants of location of overseas R&D activity of multinational enterprises: the case of US and Japanese corporations. Research Policy 30, 159–174.
Le Bas, C., Sierra, C., 2002. 'Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies. Research Policy 31, 589–609.
Lee, K.R., 1998. The Sources of Capital Goods Innovation: The Role of User Firms in Japan and Korea. Harwood, Amsterdam.
Lundvall, B.-Å. (Ed.), 1992. National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning. Pinter, London and New York.
Lundvall, B.-Å., Johnson, B., Andersen, E.S., Dalum, B., 2002. National systems of production, innovation and competence building. Research Policy 31, 213–231.
McMillan, G.S., Narin, F., Deeds, D.L., 2000. An analysis of the critical role of public science in innovation: the case of biotechnology. Research Policy 29, 1–8.
Mowery, D.C., Oxley, J.E., Silverman, B.S., 1996. Strategic alliances and interfirm knowledge transfer. Strategic Management Journal 17, 77–91.
Nelson, R.R. (Ed.), 1993. National Innovation Systems. A Comparative Analysis. Oxford University Press, New York, Oxford.
Nishiguchi, T., Ikeda, M., 1996. Suppliers' process innovation: understated aspects of japanese industrial sourcing. In: Nichiguchi, T. (Ed.), Managing Product Development. Oxford University Press, New York, Oxford, pp. 206–230.
Niosi, J., 1999. Introduction: the internationalization of industrial R&D, from technology transfer to the learning organization. Research Policy 28, 107–117.
Nonaka, I., Takeuchi, H., 1995. The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation. Oxford University Press, New York, Oxford.
Odagiri, H., Goto, A., 1993. The Japanese system of innovation: past, present, and future. In: Nelson, R.R. (Ed.), National Innovation Systems: A Comparative Analysis. Oxford University Press, New York and Oxford, pp. 76–114.
OECD—Organisation for Economic Co-operation and Development, 1999a. Globalisation of Industrial R&D: Policy Issues. OECD, Paris.
OECD—Organisation for Economic Co-operation and Development, 1999b. Managing National Innovation Systems. OECD, Paris.
OECD—Organisation for Economic Co-operation and Development, 2001a. Innovative Clusters. Drivers of National Innovation Systems. OECD, Paris.
OECD—Organisation for Economic Co-operation and Development, 2001b. Innovative Networks. Co-operation in National Innovation Systems. OECD, Paris.
Patel, P., 1996. Are large firms internationalizing the generation of technology? Some new evidence. IEEE Transactions on Engineering Management 43, 41–47.
Pavitt, K., 1984. Patterns of technical change: towards a taxonomy and a theory. Research Policy 13, 343–373.
Pisano, G.P., 1997. The Development Factory: Unlocking the Potential of Process Innovation. Harvard Business School Press, Boston.
Porter, M.E., Stern, S., 2001. Innovation: Location Matters. Sloan Management Review 42, Summer, 28–36.
Reger, G., Beise, M., Belitz, H., 1999. Innovationsstandorte multinationaler Unternehmen: Internationalisierung technologischer Kompetenzen in der Pharmazeutik, Halbleiter- und Telekommunikationstechnik. Physica, Heidelberg.
Sakakibara, K., 1995. Nihon kigyō no kenkyū kaihatsu manejimento. Soshikinai dōkeika to sono chōfuku [The R&D Management of Japanese Firms. Organizational Isomorphism and its Overcoming]. Tokyo: Chikura Shobō.
Saxenian, A., 1994. Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Harvard University Press, Cambridge, London.
Semiconductor World, 1999. 1999-nenpan nihon handōtai nenkan [Japan Semiconductor Handbook, 1999 Edition]. Puresujānaru, Tokyo.
Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strategic Management Journal 15, 387–394.
Sōmuchō Tōkeikyoku, 2000. *Heisei 11-nen kagaku gijutsu kenkyū chōsa hōkoku* [Report on the Survey of Research and Development 1999]. Nihon Tōkei Kyōkai, Tokyo.
Tapon, F., Thong, M., 1999. Research collaborations by multinational research oriented pharmaceutical firms: 1988–1997. R&D Management 29, 219–231.
Teichert, T.A., 1997. Success potential of international R&D cooperations. International Journal of Technology Management 14, 804–821.
von Boehmer, A., 1995. Internationalisierung industrieller Forschung und Entwicklung. Deutscher Universitätsverlag, Wiesbaden.
von Hippel, E., 1988. The Sources of Innovation. Oxford University Press, Oxford, New York.
Watanabe, C., Hemmert, M., 1998. The interaction between technology and economy: has the 'virtuous cycle' of Japan's technological innovation system collapsed? In: Hemmert, M., Oberländer, C. (Eds.), Technology and Innovation in Japan: Policy and Management for the Twenty-first Century. Routledge, London, New York, pp. 37–57.