INTERNATIONALIZATION OF TECHNOLOGY SOURCING: A REWARDING STRATEGY?

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ABSTRACT

The internationalization of the technology sourcing of firms is increasing globally. A review of the literature on this topic suggests that firms are facing a trade-off between gains in output performance (effectiveness) and losses in input performance (efficiency) when internationalizing their technology sourcing activities. A regression analysis of questionnaire data from 158 R&D managers of 16 leading pharmaceutical and semiconductor business units in Germany and Japan reveals that internationalization leads to an improvement in the output performance, whereas no significant adversary impact on input performance can be observed.

INTRODUCTION

This paper deals with the impact of internationalization on the performance of firms within the specific field of technology sourcing which is highly interrelated with R&D. The internationalization of industrial R&D has received increasing attention in the context of technology and innovation management in the last two decades [1], as business firms have gradually increased the weighting of international sources of technology in their R&D process [2].

In order to understand the underlying R&D internationalization strategies of firms, an analysis of their motivation is essential. Empirical surveys which reflect the situation in the 1980s revealed that at that time market-related issues like the necessity to adjust the development of new products to the needs of specific overseas markets or the support of overseas manufacturing activities were the most frequent motivation for the setting up of R&D sites in foreign countries [3,4]. More recent studies suggest, however, that technology-related issues, namely the access to cutting-edge technological knowledge in overseas locations, have gained in relative importance compared with those market-related motivations [5,6]. On the basis of this observation, the treatment in this paper is focused on the internationalization of *technology sourcing*, broadly defined as the sourcing of technological knowledge for developing new products and processes either from inside or outside a firm.

The increasing internationalization of R&D raises the issue of its effect on performance, particularly concerning the function of technology sourcing. In the literature on this topic, a considerable number of possible performance effects are raised [7]. Access to qualified R&D personnel at foreign locations, the lower cost of R&D personnel and improved access to external knowledge at scientific competence centers located abroad are mentioned as being potentially *positive* effects of the internationalization of R&D on technology sourcing. As *negative* effects, increased communication cost as a consequence of the international dispersion of R&D activities, the cost of maintaining secrecy, and increased cost because of minimum scale and scope requirements are all quoted.

These positive and negative effects apparently address different aspects of the technology sourcing performance. Some of the arguments listed above such as the improved access to cutting-edge knowledge at scientific centers of excellence located abroad are primarily concerned with the *output* of technology sourcing which may be incorporated into patents or into new processes or products, depending on the stage of the R&D activities considered. Other arguments concerning the impact of the internationalization of R&D on technology sourcing, however, relate to *input*-oriented performance yardsticks. From this viewpoint, the focus is to minimize the cost, the resources or the time needed to achieve a *given* output of technology sourcing. Therefore, when discussing the consequences of the internationalization of technology sourcing on its performance, it appears reasonable to distinguish between *input performance*, understood as the minimization of resources needed for a given output, and *output performance*, understood as the maximization of its output with a given input.

Despite the numerous contributions concerning the possible performance impact of the internationalization of technology sourcing, the literature on this topic is almost exclusively descriptive in its approach. For instance, R&D managers of firms have been frequently surveyed about their perception of the importance of different motivations for internationalizing R&D [8,9,10,11]. The actual performance outcome (either input- or output-related) of internationalization in the field of technology sourcing has not been directly assessed, however.

Aside from the general performance effects of the internationalization of technology sourcing, the issue of the access mode to foreign technology also deserves attention. There are two principal alternatives a firm may choose between when seeking access to technological knowledge in foreign countries. The first alternative is to establish their own R&D units abroad. In this case, firms are seeking access to foreign technology by hiring R&D staff at foreign locations and by collaborating with other firms and research institutions located abroad through their host country R&D units [5,6]. However, there is also the alternative of sourcing foreign technology by seeking direct access to foreign sources of technology without using the channel of host country R&D units.

Subsequently, a framework will be developed concerning the performance effects of the internationalization of technology sourcing. In addition to the main effects, moderating effects of different access modes to foreign technology will also be considered. The Hypotheses developed from this framework will be tested thereafter with survey data from leading high-tech manufacturing firms in Germany and Japan.

ANALYTICAL FRAMEWORK

Impact of internationalization on output performance

Access to external knowledge

The internationalization of technology sourcing can be regarded as a strategy for gaining access to technological knowledge that has hitherto been beyond the reach of a firm. Internationalization appears to be frequently motivated by access to cutting-edge knowledge at high-tech agglomerations and to market-related technological knowledge in large foreign countries, particularly the US. The importance of this aspect for high-tech firms is highlighted by the results of empirical research across various countries and industries [6,12,13,14].

Altogether, empirical research strongly indicates that one potential merit of the internalization of technology sourcing lies in the increase in the amount and quality of technological knowledge available to a firm due to better access to external technological knowledge located abroad. In other words: the output performance of technology sourcing may be improved because of the internationalization of the firm’s or business unit’s activities in this field.

Hypothesis 1. *The more internationalized the technology sourcing of a firm or business unit in a technological field, the better its output performance in this field.*

Moderating effect of access mode

In the literature on technology sourcing, there is frequent mention of the importance of spatial proximity. According to various empirical studies, the ability to tap into cutting-edge technology is greatly enhanced by involvement with regional clusters of firms, universities and research institutions [15,16,17]. This phenomenon can be explained by the existence of local R&D networks and the embeddedness of firms within these networks. The innovative output of firms is significantly enhanced by their participation in such regional clusters [18,19] which can also be conceptualized as innovation communities. According to embeddedness theory, this happens because individuals prefer to exchange proprietary information with other individuals they are well acquainted with personally [20]. Such strong personal connections between individuals belonging to different firms or organizations are supported by spatial proximity.

In the context of international technology sourcing, this implies that since direct access to external technology in foreign countries is difficult due to its local or regional embeddedness, host country R&D units can be regarded as being an effective channel for transferring such technology to the home country R&D of a firm [21]. Therefore, the positive effect of the internationalization of technology sourcing on output performance can be expected to be stronger when it is sought through host country R&D units than in the case of direct access from the home country to external sources of technology in foreign countries.

Hypothesis 2. *The positive effect of the internationalization of technology sourcing on output performance is stronger in the case of internal sourcing than in the case of the external sourcing of foreign technology.*

Impact of internationalization on input performance

Direct and indirect transaction cost of international technology sourcing

One potential demerit of international technology sourcing lies in higher transaction cost because of the geographical and institutional dispersion of a firm's activities. Such an increase in transaction cost has two aspects. First, the direct transaction cost, such as the cost of transportation and of using telecommunication equipment, can be expected to increase when a firm establishes overseas R&D units or cooperates in the field of technology sourcing with external organizations located abroad [22]. Additionally, the indirect transaction cost which are caused by behavioral uncertainty [23] may also increase as a consequence of the internationalization of technology sourcing. Whereas in the case of internationalization, the partners to be dealt with are not necessarily external in an institutional sense, they are located at foreign sites. On 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 the domestic sites of a firm may occur [24].

It can also be argued that the integration of international knowledge reduces the speed of R&D processes since such knowledge is harder to understand and to use than knowledge from domestic sources due to the different reference frames, standards, languages and codes in different organizations and countries. This loss of speed may further result in a cost increase of the overall R&D process [25].

Whereas it could be argued that firms may also lower the cost of the input factors of technology sourcing through internationalization and thereby *improve* their input performance in this field, surveys on the internationalization of the R&D of firms from home countries with high labor cost like Germany and Switzerland have consistently shown that the aspect of the international differences in labor cost is of relatively low importance in this field [9,10]. Therefore, it is assumed that the potential positive impact of internationalization on input performance because of labor cost savings is outweighed by the several negative aspects explicated above.

In total, the potential demerits of the internationalization of technology sourcing may result in higher cost, lower efficiency and a lower speed of technology sourcing activities. Such aspects primarily concern, in contrast to the expected merits of these strategies, the input performance of technology sourcing.

Hypothesis 3. *The more internationalized the technology sourcing of a firm or business unit in a technological field, the worse its input performance in this field.*

Moderating effect of access mode

In the literature on the effects of the internationalization of technology sourcing, cost increases and inefficiencies are frequently mentioned as disadvantages when setting up R&D units in host countries [7,16,26]. Such negative effects may derive from economies of scale, i.e. the insufficient divisibility of a firm's resources which has been identified as a potentially important hurdle for achieving efficient R&D operations [27].

In the case of the internationalization of R&D, additional sites have to be set up or acquired. Where the minimum scale of such an additional site is significant, its establishment may be limited 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 relatively high costs and a low efficiency of this site's operations.

In sum, there are additional input-related disadvantages to international technology sourcing apart from the increased transaction cost. These disadvantages, however, apply to foreign R&D, but not to the direct sourcing of international technology from external organizations. In the latter case, no significant R&D resources have to be deployed in the host countries. Therefore, the negative effect of the internationalization of technology sourcing can be expected to be stronger when a firm is seeking access to international technology through internal sources than in the case of direct sourcing from external organizations.

Hypothesis 4. *The negative effect of the internationalization of technology sourcing on input performance is stronger in the case of internal sourcing than in the case of the external sourcing of foreign technology.*

RESEARCH METHODOLOGY

Data collection

In the following, the results of an empirical survey of the technology sourcing of high-tech firms from two countries (Japan and Germany) and two industries (pharmaceuticals and semiconductors) are reported. The selection of countries and industries has been guided by two aspects: their global importance in the field of technology sourcing and the marked structural differences between them.

Japan and Germany incorporate the second- and third-largest economies in the world. Therefore, firms from these two countries can be expected to play an important role in the global process of the internationalization of technology sourcing. However, the internationalization of German firms is much higher in this field than that of Japanese firms [28]. Furthermore, the innovation systems of the two countries are also perceived as being largely different. Germany has a reputation for a strong science base and for weaknesses in the knowledge transfer between research institutions and firms [29]. In contrast, Japanese firms are renowned for their successful commercial application of upstream knowledge [30], but the country's basic research system is considered to be relatively weak [31].

Like Germany and Japan on the country level, semiconductors and pharmaceuticals can be regarded as two industries which play a central role in the internationalization of technology sourcing since they are two very important high-tech industries on a global scale. However, the degree of internationalization of R&D activities is much higher in the pharmaceutical industry than in the semiconductor industry [28]. Moreover, the organization of knowledge generation and knowledge transfer appears to be very different in the two industries. The R&D process in the pharmaceutical industry is regarded largely as a sequential one [32]. In the semiconductor industry, there appears to be much more overlap between the different stages of R&D, and the role of tacit knowledge is more important [33].

The empirical survey was conducted during the second half of 1999. Because of scale requirements, a substantial part of the R&D activities in both industries is concentrated in a few large firms. Therefore, it was decided to focus the research on a detailed analysis of the technology sourcing of these leading firms instead of conducting a survey among a large number of firms. Out of a total number of the largest 26 firms in the two countries and industries contacted, 16 firms eventually participated in the survey.

In the empirical study, personal assessments concerning internationalization and the performance of technology sourcing activities were requested in a questionnaire addressed to the high-tech business unit's R&D managers in each firm. Due to the high degree of diversity of technology sourcing activities in large high-tech firms, numerous questionnaires were sent to each business unit in order to gain a precise picture of the technology sourcing within the business units. Each questionnaire was to be answered by a different R&D manager within the business unit who was responsible for a different field of technology. 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%. Seven cases were eliminated from the sample, however, due to insufficient response rates. This resulted in a sample of 158 responses which were used for the subsequent analysis.

Since each questionnaire was answered by a R&D manager representing one technological field within the firms surveyed, each case in the subsequent statistical analysis represents not a whole firm or business unit, but one technological field within these business units. The level of each single technological field within the business units surveyed therefore constitutes the main unit of analysis in the subsequent discussion.

Sample

The 16 business units are quite evenly distributed among the countries and industries (5 in the Japanese semiconductor industry, 4 in the Japanese pharmaceutical industry, 4 in the German semiconductor industry, 3 in the German pharmaceutical industry). The average size of the business units in all countries and industries is in the range of 2.5 to 5.5 billion US-$ of annual sales, indicating a structural similarity of most of the business units surveyed. Only two semiconductor business units from Germany are relatively smaller with annual sales of less than 1 billion US-$. The average R&D intensity of the business units surveyed is well above 10% in all the countries and industries.

The distribution of questionnaire responses on the field level by countries, industries, and categories of technological fields is shown in Table 1.

Distribution of responses	Number of responses
Responses by country:	
Germany	50
Japan	108
Responses by industry and technological field:	
pharmaceutical; among which	64
= general R&D management (not field-specific)	(6)
= research	(25)
= pre-clinical development	(15)
= clinical development	(15)
= others (no field specified)	(3)
semiconductors; among which	94
= general R&D management (not field-specific)	(9)
= research	(12)
= process development	(26)
= product development	(47)
Total number of responses	158

Table 1
Distribution of questionnaire responses by country, industry, and technological field

Measurement of variables

Internationalization

The internationalization of technology sourcing was measured by indicating 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. This list of items reflects the very diverse sources of knowledge which firms may seek access to in the course of their technology sourcing activities. Since technology sourcing was surveyed within a *given* structure of internal and external sources on the level of each technological field, however, mergers and acquisitions have not been included as a source of technology in the survey items.

Since the distribution of values for the fourteen items was highly inter-correlated, in order to reduce the complexity of the data and to identify the underlying dimensions in the internationalization of technological sources, factor analysis was applied to both categories of items mentioned above. In the factor analysis, an orthogonal factor rotation was conducted.

The five items measuring the internationalization of internal technology sourcing commonly loaded on two factors (Table 2), and from the nine items expressing the internationalization of external technology sourcing four underlying dimensions were identified (Table 3).

Items *Internationalization of technology sourcing from…*	**Factor loadings**	
	‘internationalization of firm-internal technology sourcing’	‘internationalization of technology sourcing from group firms’
internal R&D	0.836	0.095
internal databases	0.776	-0.010
internal seminars	0.753	0.311
other internal departments	0.630	0.134
group firms and subsidiaries	0.125	0.979
Eigenvalues	2.281	1.082
Explained part of total variance (%)	45.63	21.63
Cronbach’s α	0.7566	—

Table 2
Factor analysis concerning the internationalization of internal technology sourcing (MSA-value: 0.760. Rotated factors with the varimax method)

Items *Internationalization of technology sourcing from…*	**Factor loadings**			
	‘internatio-nalization of TS from open sources’	‘internatio-nalization of TS from research institutions’	‘internatio-nalization of TS from supplier firms’	‘internatio-nalization of TS from customer firms’
external publications	0.811	0.081	0.208	-0.011
patents	0.811	0.261	-0.063	-0.092
internet and external databases	0.644	0.241	0.322	0.172
competitors and other firms	0.639	0.103	0.092	0.491
non-university research institutions	0.120	0.869	0.091	0.041
university research institutions	0.284	0.766	0.109	0.146
supplier firms	0.048	0.051	0.919	0.146
external conferences	0.446	0.213	0.582	-0.012
customer firms	0.005	0.114	0.099	0.929
Eigenvalues	2.435	1.547	1.389	1.154
Explained part of total variance (%)	26.46	17.39	15.10	12.42
Cronbach’s α	0.7869	0.6718	—	—

Table 3
Factor analysis concerning the internationalization of external technology sourcing (MSA-value: 0.729. Rotated factors with the varimax method)

Performance

Technology sourcing performance was measured on a five-point scale in which the questionnaire respondents rated the performance in their respective fields concerning six specific performance criteria relative to their competitors. Some of these criteria such as the ‘low cost of input factors’, the ‘efficiency of technology sourcing’, and the ‘speed of technology sourcing’ primarily address the input performance of technology sourcing, while others such as the ‘newness of technologies’, the ‘market fit of technologies’, and the ‘transferability of technologies’ were provided as indicators of output performance. The highest rating was assigned to a much better, the lowest to a much worse performance when compared with competing firms. These data were also treated as interval data.

In order to explore the significance of the distinction between the input performance and output performance of technology sourcing, all six items were included in one factor analysis. The results clearly confirm the existence of two underlying dimensions which can be described as the 'input performance' and the 'output performance' of technology sourcing in accordance with the conceptual framework developed above (Table 4).

Items	**Factor loadings**	
Performance measure	'input performance of technology sourcing'	'output performance of technology sourcing'
Low cost of input factors	0.826	0.032
Efficiency of technology sourcing	0.743	0.337
Speed of technology sourcing	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	0.772	0.662

Table 4
Factor analysis concerning performance of technology sourcing
(MSA-value: 0.803. Rotated factors with the varimax method)

Control variables

Various dummy and control variables were also included in the regression models to measure the influence of other potential determinants on technology sourcing performance. 'Country' is a dummy variable with a value of 1 for the German respondents and a value of 0 for the Japanese respondents. Similarly, 'Industry' is a dummy variable with a value of 1 for the respondents from the semiconductor industry and a value of 0 for the respondents from the pharmaceutical industry. The 'Market proximity' of the managerial fields of the respondents was measured by assigning the highest value to R&D activities closest to the market (product development and clinical development respectively), an intermediate value to process development and pre-clinical development respectively, and the lowest value to research.

Additionally, four control variables were included which reflect some structural features of the firms and business units of the respondents. The variable 'Diversification' is the relation between the annual sales of the firms surveyed and the annual sales of the high-tech business units which are part of these firms. 'R&D size' is the amount of annual R&D expenditure of the respective business units of the respondents. Furthermore, the impact of 'R&D intensity' on technology sourcing performance, measured as the relation between the R&D expenditure and the sales of the respective business unit, was analyzed. Finally, 'R&D externalization' was measured as the percentage of total R&D expenditure spent externally by the business units.

Regression analysis

In the next step, linear regression analysis was applied with output and input performance as dependent variables and the variables addressing the internationalization of technology sourcing and the control variables as independent variables. Seven outlier cases were eliminated from each of the regression samples since, for these cases, the values of the independent variables deviated more than two standard deviations from the mean values.

All variables were included in the regression model since none of them has a particularly variance inflation factor, indicating that the potential for multicollinearity appears to be limited.

The main effects (Hypotheses 1 and 3) were tested by an assessment of the standardized beta coefficients of the variables which express the effect of the internationalization of technology sourcing on the independent variables. The moderating effects of the access mode of internationalization (Hypotheses 2 and 4) were assessed by a comparison between the coefficients for the two variables related to the internal sources of technology and for the four variables related to the external sources of technology.

Moreover, firm effects were tested in an extended regression model by introducing firm dummies for all 16 business units. Because of the high number of variables, most of the other control variables had to be eliminated in this model variation.

Finally, the results were tested for country-, industry- and field-specific subsamples in order to assess the robustness of the results. The field-specific subsamples were defined by assigning all observations from downstream respondents (product development and clinical development respectively) to one group designated 'downstream R&D', and all the remaining observations, except for those which could not be assigned to a specific field in the R&D process, to the other, which was labeled 'upstream R&D'. All variables were measured on standardized scales with a mean of 0 and a standard deviation of 1.

RESULTS

The results of the regression analysis are summarized in Tables 5 and 6. The two indicators of the internationalization of internal technology make significant positive contributions to output performance. This positive impact remains largely stable for the model with the firm dummies and for the subsample regressions. Thus Hypothesis 1 is supported so far. The impact of the indicators for the internationalization of external technology sourcing is close to zero, however. Therefore, Hypothesis 1 is not supported as regards the internationalization of external technology sourcing since no clear effect on output performance can be observed.

At the same time, these findings lend support to Hypothesis 2 since the positive effect of internationalization on output performance is much stronger for internal than for external technology sourcing.

A look at the group-specific results shows that in the subsample for Japan, the positive impact of the two indicators of the internationalization of internal technology sourcing on output performance is significant, whereas it is insignificant for the German subsample. Furthermore, this positive impact is also much stronger in the pharmaceutical industry than in the semiconductor industry. Between the subsamples for upstream and downstream R&D, however, no clear-cut difference concerning the impact of internationalization on output performance can be observed.

Independent variables	Basic model n=151	Model with firm dummies n=151	Subsample Japan n=104	Subsample Germany n=47	Subsample pharma-ceuticals n=62	Subsample semi-conductors n=89	Subsample upstream R&D n=72	Subsample downstream R&D n=61
Internationalization of firm-internal TS	0.331*** (0.100)	0.292*** (0.101)	0.327*** (0.124)	0.008 (0.197)	0.469*** (0.144)	0.272* (0.154)	0.446** (0.156)	0.176 (0.172)
Internationalization of TS from group firms	0.153* (0.074)	0.170** (0.071)	0.206* (0.082)	0.084 (0.172)	0.216* (0.113)	0.119 (0.103)	0.103 (0.119)	0.215* (0.107)
Internationalization of TS from open sources	0.009 (0.071)	-0.029 (0.068)	-0.017 (0.071)	0.274 (0.668)	-0.069 (0.104)	-0.008 (0.102)	0.025 (0.098)	-0.025 (0.125)
Internationalization of TS from research institutions	-0.011 (0.075)	-0.061 (0.071)	-0.049 (0.085)	-0.010 (0.200)	-0.201 (0.137)	0.050 (0.096)	-0.022 (0.107)	-0.059 (0.132)
Internationalization of TS from supplier firms	-0.103 (0.070)	-0.139* (0.067)	-0.146 (0.072)	-0.414*** (0.350)	-0.108 (0.138)	-0.102 (0.087)	-0.137 (0.132)	-0.085 (0.089)
Internationalization of TS from customer firms	-0.004 (0.072)	0.000 (0.070)	-0.077 (0.076)	0.339** (0.235)	-0.040 (0.126)	0.055 (0.092)	-0.012 (0.100)	0.113 (0.126)
Country	0.165 (0.098)	—	—	—	-0.230 (0.184)	0.336** (0.148)	-0.019 (0.144)	0.435*** (0.169)
Industry	0.287** (0.131)	—	-0.084 (0.282)	0.000 (0.488)	—	—	0.226 (0.196)	0.271 (0.221)
Market proximity	-0.072 (0.080)	-0.065 (0.078)	-0.182* (0.093)	0.360** (0.155)	-0.168 (0.122)	-0.011 (0.110)	—	—
Diversification	-0.054 (0.085)	—	0.298 (0.688)	-0.099 (0.080)	-0.023 (14.036)	-0.044 (0.099)	-0.071 (0.142)	-0.102 (0.133)
R&D size	0.035 (0.097)	—	0.302 (0.295)	0.427 (0.208)	0.089 (0.166)	0.064 (0.191)	0.002 (0.141)	-0.004 (0.183)
R&D intensity	-0.123 (0.080)	—	-0.143 (0.084)	-0.308 (0.359)	-0.341* (0.147)	0.035 (0.216)	-0.041 (0.108)	-0.158 (0.152)
R&D externalization	0.112 (0.125)	—	0.260** (0.170)	-0.009 (0.292)	0.369 (0.207)	0.141 (0.762)	-0.048 (0.193)	0.226 (0.214)
15 firm dummies	—	not reported	—	—	—	—	—	—
R^2	0.260	0.395	0.189	0.482	0.368	0.310	0.194	0.446
Adjusted R^2	0.190	0.291	0.082	0.300	0.213	0.201	0.030	0.308
F	3.698***	3.794***	1.769*	2.640**	2.373**	2.840***	1.182	3.227***

Table 5. Results of the linear regression analysis concerning the output performance of technology sourcing
Note. *: $p < 0.1$; **: $p < 0.05$; ***: $p < 0.01$. The numbers in parentheses are standard deviations.

Independent variables	Basic model n=151	Model with firm dummies n=151	Subsample Japan n=104	Subsample Germany n=47	Subsample pharma-ceuticals n=60	Subsample semi-conductors n=91	Subsample upstream R&D n=71	Subsample downstream R&D n=62
Internationalization of firm-internal TS	-0.141 (0.091)	-0.139 (0.092)	-0.056 (0.109)	-0.502** (0.194)	-0.069 (0.110)	-0.279* (0.147)	-0.077 (0.131)	-0.222 (0.160)
Internationalization of TS from group firms	-0.025 (0.068)	-0.051 (0.066)	-0.030 (0.073)	-0.036 (0.178)	-0.150 (0.086)	0.021 (0.098)	-0.232** (0.104)	0.065 (0.100)
Internationalization of TS from open sources	-0.086 (0.065)	-0.103 (0.063)	-0.142 (0.063)	0.022 (0.742)	-0.281** (0.084)	0.010 (0.093)	-0.333*** (0.089)	0.143 (0.117)
Internationalization of TS from research institutions	-0.006 (0.070)	-0.015 (0.067)	-0.023 (0.077)	-0.100 (0.192)	-0.192 (0.112)	-0.007 (0.090)	0.014 (0.096)	-0.052 (0.123)
Internationalization of TS from supplier firms	0.152** (0.067)	0.162** (0.064)	0.220** (0.065)	0.037 (0.826)	0.219* (0.111)	0.159* (0.087)	0.321*** (0.121)	0.128 (0.084)
Internationalization of TS from customer firms	-0.062 (0.068)	-0.053 (0.066)	-0.111 (0.069)	0.139 (0.353)	-0.205* (0.112)	0.007 (0.088)	-0.237** (0.094)	-0.054 (0.117)
Country	0.322*** (0.090)	—	—	—	-0.258 (0.144)	0.658*** (0.144)	0.209 (0.127)	0.463*** (0.154)
Industry	-0.083 (0.121)	—	0.252 (0.251)	-0.287 (0.485)	—	—	-0.006 (0.169)	-0.200 (0.209)
Market proximity	-0.023 (0.074)	-0.005 (0.074)	-0.028 (0.084)	0.063 (0.152)	0.015 (0.097)	-0.047 (0.106)	—	—
Diversification	0.280*** (0.078)	—	-0.338 (0.620)	0.401** (0.079)	-0.242 (11.419)	0.367*** (0.094)	0.300** (0.123)	0.310** (0.125)
R&D size	0.263** (0.091)	—	0.182 (0.264)	1.098*** (0.204)	0.333 (0.132)	0.388** (0.176)	0.174 (0.126)	0.328* (0.171)
R&D intensity	-0.023 (0.074)	—	-0.024 (0.075)	-0.851** (0.347)	-0.178 (0.116)	-0.241* (0.198)	0.022 (0.095)	-0.039 (0.142)
R&D externalization	0.027 (0.116)	—	0.244** (0.154)	-0.069 (0.289)	0.588** (0.164)	0.331** (0.707)	0.097 (0.167)	0.077 (0.203)
15 firm dummies	—	not reported	—	—	—	—	—	—
R^2	0.291	0.415	0.206	0.466	0.486	0.360	0.404	0.417
Adjusted R^2	0.224	0.315	0.102	0.278	0.355	0.261	0.281	0.275
F	4.323***	4.136***	1.973**	2.474**	3.703***	3.650***	3.276***	2.925***

Table 6. Results of the linear regression analysis concerning the input performance of technology sourcing
Note. *: $p < 0.1$; **: $p < 0.05$; ***: $p < 0.01$. The numbers in parentheses are standard deviations.

The results concerning the impact of the various control variables on the output performance of technology sourcing show a considerable volatility for the different subsamples. None of these variables has a consistently strong positive or negative impact.

The effect of internationalization on the input performance of technology sourcing is slightly negative for all indicators with the exception of the 'internationalization of technology sourcing from supplier firms' which has a significant *positive* impact in all models except for the German subsample. Apart from this indicator, Hypothesis 3 is therefore moderately supported, although the negative impact of the internationalization variables on input performance is weak and not significant in most cases.

However, this negative impact is not consistently stronger for internal than for external technology sourcing. Thus, the results do not lend support to Hypothesis 4.

As with output performance, the results differ quite strongly between the country-specific groups. The 'internationalization of firm-internal technology sourcing' has a strong negative impact on input performance only for the German, but not for the Japanese subsample. As regards the external sources of technology, however, the results are less clear-cut. Between the two industry- and field-specific samples, no consistent difference concerning the impact of internationalization on input performance is observable.

Among the control variables, the R&D size of the business unit and the country dummy exert a strong positive effect on input performance in most of the models, indicating that the R&D managers from Germany and from the larger business units assess input performance more highly than their colleagues from Japan and from the smaller business units. In the basic model and some of the subsample models, there is also a significant positive effect of firm diversification on input performance. Moreover, in some subsamples, R&D externalization has a positive effect whereas R&D intensity has a negative effect on input performance.

The R^2 and F values are, for most of the subsamples, similar to the values for the models which refer to the full sample. An exception, however, is the subsample for Japan. Concerning both output and input performance, the models for this subsample have a relatively weak explanatory power. Moreover, the model of the subsample for upstream R&D concerning output performance is statistically insignificant. The latter observation may be rooted in the general difficulty of assessing the output performance in upstream R&D, even for the managers working in this field.

DISCUSSION

When summarizing the results of the survey with regard to the analytical framework, the findings suggest that

(1) the hypothesized trade-off between gains in output performance and losses in input performance when internationalizing technology sourcing is supported by the empirical data, but as concerns internal technology sourcing, the positive effect on output performance is much stronger than the negative effect on input performance,

(2) the positive effect of the internationalization of technology sourcing on output performance is stronger for internal than for external technology sourcing, whereas the negative effect of internationalization on input performance is generally weak,

(3) the positive effect of the internationalization of internal technology sourcing on output performance is particularly strong in Japan and in the pharmaceutical industry, whereas the negative effect on input performance is strongest in Germany.

The results of the research altogether indicate that large, technology-intensive firms may improve the output performance of their technology sourcing activities by internationalizing their R&D, whereas the negative effect of internationalization on input performance is comparatively small. In contrast, direct access to external sources of technology in foreign countries appears in itself to be a less promising approach for improving a firm's technology sourcing performance. Rather, direct technology sourcing from foreign research institutions may increase *as a consequence* of the internationalization of internal technology sourcing.

Moreover, the results suggest that the performance outcome of the internationalization of technology sourcing is moderated considerably by country effects. The relative gains in terms of output performance appear to be smaller and the relative losses in terms of input performance appear to be larger for the highly internationalized firms from Germany than for less internationalized firms from Japan. This indicates that with an increasing degree of internationalization, its returns might be diminishing and its costs might increase.

From an industry-specific perspective, a clear difference could be observed only as concerns the output performance, but not as concerns the input performance of technology sourcing. A possible explanation for this difference lies in the observation that international knowledge transfer is probably easier to conduct in the pharmaceutical industry than in the semiconductor industry due to the greater importance of tacit knowledge in the latter when compared with the former industry.

Finally, the comparison between upstream and downstream R&D revealed no clear difference in terms of the impact of internationalization on technology sourcing performance. Therefore, the survey data give no indication of whether the internationalization of either upstream or downstream technology sourcing activities is more advantageous in terms of its performance outcome.

The positive impact of the country dummy on both the output and input performance of technology sourcing shows that the German R&D managers evaluated their performance in this field much more highly than their Japanese colleagues did. This suggests the existence of a cultural bias concerning self-evaluation. Follow-up interviews with 44 R&D managers from the firms surveyed revealed, however, that this difference in self-evaluation was not simply due to a different response behavior in the questionnaire survey. The German managers really perceived their technology sourcing performances to be much better than the Japanese managers did. This particularly applied to the semiconductor industry, as the regression data also indicate.

The strong country-specific difference concerning technology sourcing performance assessment can be explained by the more favorable conditions for technology sourcing in the German innovation system than in the Japanese one. Recent surveys indicate that public research institutions and small and medium technology firms appear to support large high-tech firms in Germany [34,35] much more strongly than in Japan [31,36].

The results of the regression analysis further indicate that diversification and R&D size may also exert a positive impact on the input performance of technology sourcing. These findings are plausible if one recalls the economies of scale issue in R&D discussed above in the context of the potential demerits of internationalization. Diversified firms and large firms may have better capabilities than smaller and less diversified firms for setting up efficient operations by better fulfilling scale requirements and by sharing R&D facilities with other internal business units.

When compared with the input performance, the output performance of technology sourcing is influenced by the control variables to a much smaller degree. This suggests that the firm's management has more influence on output performance than on input performance in this field by exerting strategies like the internationalization of R&D since other factors are less important.

A specific finding which was not predicted by the theoretical framework is the positive impact of the internationalization of technology sourcing from supplier firms on input performance. A possible explanation is that the cost savings and efficiency gains which are a focus of global sourcing strategies in the field of manufacturing [37,38] may also be achieved in the field of technology sourcing.

LIMITATIONS

First of all, despite its comparatively wide scope, the survey covers only two countries and industries. Therefore, notwithstanding the high importance of the countries and industries surveyed, the applicability of its results to firms from other countries and industries cannot be automatically assumed.

Moreover, the scope of technology sourcing is only partially covered. In particular, the acquisition of firms for technological purposes was not considered from the outset due to the field-specific nature of the questionnaire survey.

Another point lies in the assumption that the R&D managers who responded to the questionnaire within each business unit surveyed cover separate fields of technology sourcing. In reality, the responsibilities for such fields cannot be expected to always be delineated in such a clear-cut fashion. Therefore, the possibility cannot be excluded that in some cases the respondents to the survey were at least partially referring to the same technological fields.

Finally, since the assessments of the internationalization and of the performance of technology sourcing are supplied by the same questionnaire respondents, there is the possibility of a common informant bias which may have affected the results.

MANAGERIAL IMPLICATIONS

From the viewpoint of the R&D management of large firms, the findings suggest that whereas a trade-off between output and input performance exists when internationalizing technology sourcing, the improvement in output performance appears to outweigh the deterioration in input performance by far when the internationalization is conducted via internal technology sourcing from host country units. Therefore, the internationalization of technology sourcing through firm-internal activities appears to be a useful strategy for improving the output performance of technology sourcing, whereas direct sourcing from external sources of technology in foreign countries seems to be less promising.

The country-specific results also indicate, however, that the success of the internationalization of internal technology sourcing may depend to a large extent on how far the internationalization of a firm or business unit has already progressed. For firms which are already internationalized to a high degree, the positive impact of a further internationalization on output performance may become smaller and the negative impact on input performance may become stronger. In other words, the internationalization of internal technology sourcing may be particularly promising for firms which have not hitherto internationalized their activities in this field to a high degree. These firms should seek internationalization through the establishment of own R&D activities in host countries in order to realize its advantages in full instead of relying on external sources of technology located abroad.

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