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## What Makes Foreign Knowledge Attractive to Domestic Innovation Managers?

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## **Non-technical summary**

The internationalization of innovation activities has largely been investigated for large multinational firms, often based on patent statistics. This approach typically implies that firms can only benefit from new globalization opportunities by investing and patenting in foreign subsidiaries. We choose a different perspective by focusing on a different channel through which the internationalization of markets and value chains alters innovation engagements. Our focus is on the early stages of the innovation process, which primarily involve identifying promising impulses and evaluating them. From our perspective, international impulses may not necessarily come in the form of international innovation investments. They may instead trigger domestic innovation activities. In that sense, we focus on a situation which may be more typical for firms that do not have the resources to spread innovation activities internationally.

At the early “initiation” or “sensing” stages information collection and evaluation are the most important tasks. Decisions on whether these impulses are turned into specific product or process innovations, used to alter existing designs or are simply used for defensive purposes follow in subsequent stages of the innovation process. In that sense our study differs from existing research which largely focuses on the complete innovation process typically embodied in patent data. We develop theoretical arguments based on transaction cost theory, which stresses a balancing act between low direct transaction costs and potential risks from neglect. These hypotheses are tested through a conjoint analysis among 158 heads of R&D departments of German high-tech firms. This allows us not only to identify significant effects but also to derive a preference ranking.

Our findings indicate that these sensing engagements are primarily driven by uncertainty avoidance motives. Ideas that are radically new and stem from a dynamic market are the most attractive. The potential downsides from overlooking these important developments outweigh the direct transaction costs associated with acquiring new knowledge (complementary to existing knowledge stocks) across language barriers. However, we can still identify significant effects for both of the latter. Interestingly, we find no distinction between technological or market impulses. These results indicate that an important part of sensing global innovation impulses is not strictly knowledge seeking but follows a strong uncertainty avoidance rationale. Not all of these impulses will be turned into innovations but they may alter existing trajectories. We develop management recommendations on how to develop sensing capabilities based on these insights.

# What Makes Foreign Knowledge Attractive to Domestic Innovation Managers?

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## Abstract

This study focuses on the early stages of international innovation activities, i.e. the organizational processes through which promising ideas from around the globe are collected and evaluated. We ask: What characteristics make foreign knowledge interesting to domestic R&D managers? We envision this process as a balancing act between direct transaction costs for communication and coordination and indirect transaction costs from overlooking or misinterpreting important global trends. These hypotheses are tested through a conjoint analysis among 158 heads of R&D departments of German high-tech firms. We find that uncertainty avoidance is the most important driver. Radically new ideas from dynamic markets are most attractive and must not be overlooked. Complementarities with existing knowledge stocks and low language barriers are also important but to a lesser degree. Interestingly, we find no distinction between market and technological impulses.

Keywords: Globalization, sensing, innovation impulses, conjoint analysis

JEL-Classification: F23, O31, O32

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# 1 Introduction

The internationalization of innovation activities has largely been investigated for large multinational firms, often based on patent statistics (see for example Almeida, 1996; Almeida and Phene, 2004; Frost, 2001; Singh, 2005). This approach typically implies that firms can only benefit from new globalization opportunities by investing and patenting in foreign subsidiaries. We choose a different perspective by focusing on a different channel through which the internationalization of markets and value chains alters innovation engagements. Our focus is on the early stages of the innovation process, which primarily involve identifying promising impulses and evaluating them. From our perspective, international impulses may not necessarily come in the form of international innovation investments. They may instead trigger domestic innovation activities. In that sense, we focus on a situation which may be more typical for firms that do not have the resources to spread innovation activities internationally.

Our theoretical arguments are based on transaction cost theory. We consider these sensing activities for international impulses as a balancing act between efficient communication and coordination costs (direct transaction costs) on the one hand and the risks from missing or misinterpreting important international developments (indirect transaction costs) on the other. For the empirical test of these hypotheses we conduct a survey among 158 heads of R&D management in German high-tech companies. Our goal is to estimate a preference ranking for the factors that make foreign innovation impulses attractive. To do so we rely on an experimental design and conduct a conjoint analysis.

The analysis is structured as follows: The section subsequent to this introduction provides a brief review of the literature on the internationalization of innovation impulses. We develop hypotheses based on transaction cost theory in the next section. Section 4 presents the empirical study and section 5 shows its results. Section 6 provides a discussion of these results while the final section outlines the limitations of this study and opportunities for further research.

## **2 A brief review on the internationalization of innovation impulses**

The global distribution of new technology development is heavily skewed. The seven most industrialized countries (G7) performed 80% of global R&D in 2005 (OECD, 2007) which is only slightly below the 84% in 1995 (Keller, 2004). This implies that the productivity growth of most countries relies to a large extent on foreign technology sources. A limited number of countries, such as South Korea, have been catching up in recent years (Furman and Hayes, 2004; Mahmood and Singh, 2003). Global growth depends therefore heavily on international knowledge spillovers (Romer, 1990). Important research in the field has focused on the role of multinational companies (MNCs) in this process. Research in international economics has focused on their potential to transfer knowledge to the host country (see for example Aitken and Harrison, 1999; Haskel et al., 2002; Keller, 2002) while international business literature has chosen a different perspective by emphasizing the role of subsidiaries for accessing knowledge from host countries (see for example Almeida, 1996; Frost, 2001).

Both streams of research indicate that the transfer of knowledge across physical and psychological distance is challenging. Knowledge flows have been found to be geographically localized and largely an intra-national phenomenon (Branstetter, 2001). Jaffe et al. (1993) find that not only national but also state borders are important barriers to the diffusion of knowledge. These obstacles remain even when controlling for the geographic concentration of production (Audretsch and Feldman, 1996). Keller (2002) estimates that roughly half of the original knowledge is lost after it has been transferred 1,200 kilometers. His results go beyond spatial distance by confirming the negative effect of difference in languages. The latter are an important dimension of cultural differences (West and Graham, 2004).

These border effects occur because knowledge cannot be totally separated from the commitments and belief patterns of its holders (Nonaka, 1994). This implies that it cannot be comprehensively articulated, codified and transferred. Crucial elements remain tacit, i.e., they are acquired through action (Polanyi, 1967) or understood in practical experience under changing conditions. Nelson and Winter (1982) define the latter as skills. Interpersonal networks and social context are required to minimize the frictional losses from cross border knowledge transfers (Kogut and Zander, 1993). This function of multinational firms and their international network of subsidiaries has been investigated with mixed results for knowledge flows towards host countries (for a review see Keller, 2004) and those out of host countries (see for example Almeida, 1996; Frost, 2001).

The success of international knowledge sourcing depends heavily on generating access to local knowledge flows through interfirm and interpersonal linkages (Almeida and Phene, 2004). Becoming fully embedded in these local networks is difficult as they are determined by cultural and social rules that are rarely codified and causally ambiguous because they are acquired through long-lasting market exposure, experience and interaction (Jensen and Szulanski, 2004). These barriers are typically summarized as liability of foreignness (Zaheer, 1995), a sociological concept with structural, relational and legitimacy dimensions (Zaheer,

2002). It materializes in the form of more frequent errors, unnecessary risks and delays in cross border interactions (Lord and Ranft, 2000). It is therefore not surprising that foreign subsidiaries have been found to learn more frequently from other subsidiaries than from the host country environment (Feinberg and Majumdar, 2001). These barriers can be overcome through the social capital of individual employees. Such social capital facilitates knowledge flows through “goodwill”: sympathy, trust and forgiveness (Adler and Kwon, 2002). These linkages may arise from the mobility of host country engineers (Almeida and Kogut, 1999) or previously established education or career networks (Agrawal et al., 2006; Singh, 2005). Kalnins and Chung (2006) even point towards the effects of co-ethnicity.

Hence, there are indications that access to international knowledge flows is challenging but can be optimized through organizational practices. This study therefore chooses a process perspective and focuses on the early stages that trigger innovation activities. Szulanski (1996) distinguishes between four stages of knowledge transfer: Initiation, implementation, ramp-up and integration. We focus on the initiation stage, which is characterized by information collection and evaluation. It starts with the discovery of internal needs or external superior options. Subsequently, solutions have to be identified, their fit assessed and the feasibility for transfer evaluated (Szulanski, 1996). It culminates in the implementation stage of the knowledge transfer. Similarly, Doz et al. (2001) introduce a multi-stage concept for international innovation activities. Its earliest phase is “sensing” for new competencies, innovative technologies and lead market knowledge. This constitutes the basic layer of internationalizing innovation activities. It lays the foundation for the subsequent mobilization of resources and operational implementation of successful innovation projects. Sensing is therefore close to the conceptualization of an initiation stage by Szulanski (1996). Relatively little is known about these early stages of international knowledge sourcing, at which the knowledge flow is just an impulse or idea.

A majority of important studies in the field rely on patent statistics to capture knowledge flows (e.g., Almeida, 1996; Almeida and Phene, 2004; Frost, 2001; Singh, 2005). However, patents represent only a certain section and hence type of knowledge flow. Most importantly, “not all inventions are patentable, not all inventions are patented” (Griliches, 1990; p.1669). Besides, they are more the output or end of an innovation process. This neglects the role of international knowledge spillovers as an impulse for triggering innovation activities. What is more, the distribution of patenting firms is heavily skewed. Bloom and Van Reenen (2002) illustrate such a case - 72 per cent of their sample of almost 60,000 patents by UK firms stem from just 12 companies. Patenting implies the disclosure and codification of knowledge in exchange for protection (Gallini, 2002). The greatest potential for generating competitive advantage, though, can be achieved if companies have the competencies and capabilities to identify, combine and develop market and technology opportunities that are unarticulated, overlooked or underestimated (Von Zedtwitz and Gassmann, 2002).

Our goal is to extend the existing literature by investigating the organizational mechanisms behind sensing activities. More precisely, we ask: What characteristics make foreign innovation impulses attractive to domestic firms?

### 3 Hypotheses development

We ground our argumentation in a transaction cost economics perspective (Williamson, 1975) assuming that firms organize their sensing activities to minimize total costs. These comprise both direct transaction costs for communication and governance and indirect transaction costs arising from behavioural uncertainty about external factors (Pisano, 1990). Both are interconnected. Galbraith (1977) defines uncertainty as the gap between the knowledge a company already holds and the knowledge it is about to acquire. Other definitions have highlighted the inability to predict a future event accurately because of a lack of sufficient information or reliable data (Milliken, 1987) or the inability to assign probabilities to the likelihood of future outcomes (Duncan, 1972). As uncertainty increases ex-ante planning becomes less reliable which increases the probability of increased communication and governance costs (Hoetker, 2005). Dealing with uncertainty across borders holds special challenges. Harvey and Novicevic (2000) introduce the concept of global organizational ignorance to cross border interactions. The concept entails unawareness of relevant information and of how to interpret it correctly. Faced with contextual ambiguity abroad, managers rely on past experiences (Dow, 2006). This follows general decision making theory. Deciders tend to rely on knowledge from their home market even when it is not fitting for the host country context. This is due to the fact that it is more readily available, can be related back to a class of previous experiences and provides consistency with previous convictions (Harvey and Novicevic, 2000). Hence, relying on practices that reduce direct transaction costs increases the indirect transaction costs incurred by missing or misinterpreting important international technology and market trends (Rugman and Verbeke, 2004).

We argue that firms will balance the two challenges by relying on signals from prospective impulses. Drawing on Ndofor and Levitas (2004) we define signals as observable attributes that convey information about unobservable attributes to other individuals in the market. This implies signals for low direct transaction costs as well as low risks from blind spots. We argue that these will occur at two levels: the source of the impulse and its content.

#### **Attributes that signal low direct transaction costs**

The effectiveness and efficiency of communication depends heavily on the congruence of partners (Rogers, 1995). Similarity between “teacher” and “student” firms has been found to facilitate learning and the transfer of knowledge (Lane and Lubatkin, 1998). Cultural differences lead to liabilities of foreignness (Zaheer, 1995), resulting in deficits in effectiveness and efficiency (Mezias, 2002). We hypothesize that cultural differences are a major driver of direct transaction costs as they increase cognitive uncertainty, i.e. they diminish the ability to identify and explain behaviour (Harvey and Novicevic, 2000). Language barriers and the way people communicate have been identified as a major, visible component of these obstacles (West and Graham, 2004). We propose:

Hypothesis I: If linguistic barriers are low, innovation impulses are more attractive.

Extending this idea to the content of the innovation impulse, learning is most effective if new knowledge components are related to existing stocks (Lane et al., 2006). Firms develop absorptive capacities to identify, assimilate and exploit external knowledge as a by-product while performing R&D themselves (Cohen and Levinthal, 1989; 1990). Sensing capabilities can be considered a more closely defined type of absorptive capacity as they are also directed at predicting the nature of technological advances more accurately (Cohen and Levinthal, 1994), albeit with a clear international focus on idea generation. Given the accumulative nature of the concept (Zahra and George, 2002) we argue that global sensing activities are most efficient in detecting complementary knowledge to existing stocks since the process of identification and assimilation is more efficient.

Hypothesis II: Impulses that complement existing expertise are more attractive than substituting ones.

Besides, potential sources may be built around technological expertise or market experience (Almeida and Phene, 2004). The effectiveness of knowledge transfers depends on the how effectively it can be articulated, captured and codified (Zander and Kogut, 1995). This is especially difficult when dealing with the demand side. Customer impulses have been found to be frequently narrow, myopic or simply wrong (Frosch, 1996). Technological expertise, though, can be traced through R&D outputs and inputs like patents or R&D investments. The latter have been found to be an important signal for the innovation engagements of foreign firms (Almeida and Phene, 2004). We conclude:

Hypothesis III: Technological leadership is a more attractive trait of foreign impulse sources than market dominance.

### **Attributes that signal high risks of neglect**

While sensing knowledge from familiar and reliable sources may keep direct transaction costs low it limits exposure to versatile ideas (Rogers, 1995). Sensing follows a forward looking logic. International knowledge sources should prevent firms from missing or misinterpreting important technological and market trends (Rugman and Verbeke, 2004). Hence, a major rationale for sensing activities lies not only in enriching but also critically evaluating the existing resource portfolio (Sirmon et al., 2007). We conclude that global sensing activities are best directed at possible disruptions from radically new technologies and competencies. We hypothesize:

Hypothesis IV: Radical innovation impulses are more attractive than incremental ones.

Finally, we argue that sensing is not a fully rational process based on the assessment of individual knowledge sources. We draw from the literature of country-of-origin effects of product evaluation which finds that customers use the country of origin as a clue for expected product quality, e.g. “Made in Germany” (see for example Bilkey and Nes, 1982; Gurhan-Canli and Maheswaran, 2000; Samiee et al., 2005). This behaviour can be linked to categorization theory. Hence, we suggest that the country of origin influences its attractiveness for global sensing, e.g., an impulse of similar quality from China or India would be treated differently than one from Switzerland.

Hypothesis V: There exists a positive country of origin effect for foreign innovation sources.

## **4 Empirical study**

### **4.1 Methodology**

We develop an empirical evaluation scheme for testing the previously outlined hypotheses through a conjoint measurement experiment. While this approach is widely used in marketing (see for example Carroll and Green, 1995; Green and Srinivasan, 1978; 1990) it has also made inroads into technology and innovation management (see for example Teichert, 1993). Our experimental approach implies primarily that observations are not random. Interviewees are systematically confronted with scenarios on potential innovation impulses and asked to rank these hypothetical impulses according to their overall attractiveness. Preference functions can subsequently be estimated based on this information. The relative importance of individual effects as well as their interactions can be decomposed. This feature makes it especially fitting for our research question.

The holistic approach of ranking complete impulse scenarios reflects real life decision making. Judging the prospective value of external ideas for innovation abroad is challenging. Its features are both highly uncertain and intertwined. Strict decision routines are difficult to establish and codify. Hence, decision makers rate the value of ideas based on what the complete “package” looks like and not strictly based on individual items. Especially favorable parameter values may outweigh deficits in other areas. The conjoint analysis allows us to estimate not only the main variable effects but also their interactions. Trade-offs become visible and quantifiable. In conclusion, the goal of this exercise is not only to identify important signals. It also allows us to provide a ranking of relative importance.

### **4.2 Variables**

We translate the previously outlined hypotheses into variables by focusing both on contextual congruence and their feasibility for conjoint analysis (Weisenfeld, 1989). We introduce two layers of quality assurance: Variables are discussed, tested and refined with a group of scholars in innovation management and a group of practitioners. The final set of variables has been found to be independent as well as theoretically and empirically relevant. The presentation of the scenarios reflects the intended constructs.

We choose dichotomous levels for all variables. This approach is widely used and keeps the extent of the study at a manageable level while allowing robust estimation results (Teichert, 1993; Weisenfeld, 1989). Nevertheless, it has to be acknowledged that it prevents us from modeling non-linear relationships. Table 1 provides an overview of the resulting variable set. The first three variables reflect attributes of impulse sources, the last two attributes of impulse contents.

**Table 1: Variables**

<i>Hyp.</i>	<i>Variable</i>	<i>Value L (+1)</i>	<i>Value K (-1)</i>
III	Source status	Technological leadership	Market dominance
I	Source language	Official company language	No official company language
V	Country of origin	Upcoming and dynamic	Established and saturated
IV	Impulse novelty	Radically new	Incremental development of existing technology
II	Impulse fit	Complement existing competencies	Substitute existing competencies

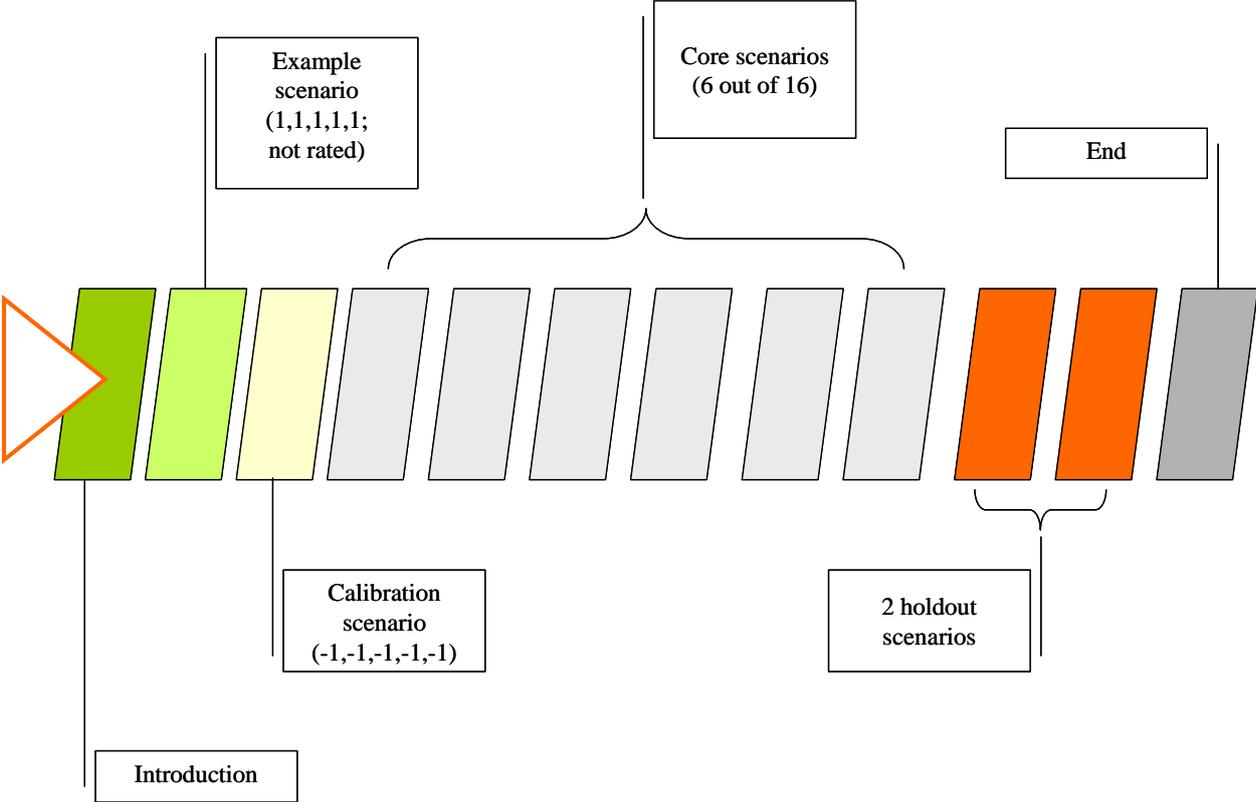
### 4.3 Survey design

Conjoint analysis relies on the systematic variation of variables. A set of five variables with two levels each produces 32 possible combinations ( $2^5$ ). While this so-called full factorial design is desirable, it places a heavy burden on interviewees. They would have to rate 32 different impulse combinations which vary only mildly, raising questions of participation, motivation and response accuracy. Hence, we refine the design at two levels to achieve a compromise between response quantity and quality.

First, we reduce the number of scenarios systematically and retain only a pure orthogonal design of 16 scenarios (Weisenfeld, 1989). Put simply, this assumes that for example the answer to scenario (1,1,1,-1,-1) can be derived from its orthogonal counterpart (-1,-1,-1,1,1). To facilitate a subsequent internal validity test of this assumption two so-called holdout scenarios from the orthogonal group remain in the set. These are presented to interviewees and evaluated but do not enter the final estimation procedure. Instead, they can be used to test how well the latter predicts these actually observed valuations. As a result 18 scenarios remain in the set. However, the study targets leading R&D and innovation managers. Pretests reveal that the number of 18 scenarios is still too high. Several pretest partners indicated that “below ten” would be a feasible option.

Therefore, we introduce a second layer of design modification. We do no longer insist on having all interviewees rate the 18 scenarios set, but draw six scenarios randomly and ensure that each scenario is covered with equal frequency. This modification is made possible through an online platform. To ensure that respondents possess equal information before their rating we further adjust the sequence of scenarios. Each participant is presented with both extreme scenarios (1,1,1,1,1 as an example) and (-1,-1,-1,-1,-1 for rating) before evaluating randomly drawn scenarios. Hence, their answers can be considered calibrated. As a result, interviewees rate 9 scenarios as illustrated in Figure 1.

**Figure 1: Scenario sequence**



**4.4 Experiment implementation**

We construct a sample of interviewees from participants of the German Innovation Survey 2006 conducted by the Centre for European Economic Research (ZEW) in Mannheim, Germany. All potential interviewees are heads of R&D departments or innovation management and can therefore be considered relevant experts for the topic. Important patent based studies in the field have been conducted for high-tech industries like semiconductors (Almeida, 1996; Almeida and Phene, 2004). We ensure consistency by focusing on firms that are part of medium high-tech (e.g., automotives) or high-tech manufacturing (e.g., medical instruments) as well as knowledge-intensive (e.g., consulting) or technological services (e.g., ICT services). Industry classification is based on the product that produces the majority of sales. A detailed industry breakdown is provided in Appendix A.

We retain a sample of 539 potential interviewees. All of them were directly contacted via telephone and asked to participate in the study. Once they had agreed they immediately received an email with a personalized hyperlink directing them to the online survey. 158 provided full information and rated seven scenarios each (plus two holdout scenarios) thereby generating 1,106 observations.

Data from the German Innovation Survey 2006 are used to obtain information on key firm characteristics. The average firm in our sample has 396 employees, exports roughly a third of its sales and spends about 10 per cent of sales on R&D which confirms the coverage of high-tech firms. 23 per cent operate in manufacturing medical, precision and optical instruments, followed by the manufacture of machinery and equipment (17 per cent), chemicals (16 per

cent), ICT services (15 per cent), technical services (13 per cent), manufacture of electrical machinery (10 per cent), automotives and financial services with 3 per cent each. 33 per cent of firms are located in East Germany which corresponds with the sampling of the German Innovation Survey.

Our survey instrument was administered in German. Scenario texts were refined to reflect intended constructs through pre-testing. Interviewees were informed through an introduction page that they would receive a hypothetical email from their sales department informing them about a new idea put forward by a foreign customer. The idea would have the potential to translate into a new product and be characterized by five attributes. They were asked to judge its attractiveness on a ten point likert scale. Attractiveness was operationalized as the intensity with which they would promote the idea. Figure 2 shows an example scenario translated into English.

**Figure 2: Example scenario**

The **foreign** customer from which the innovation idea originated is characterized by the following attributes:

You know the customer primarily because of	its high market share in its home market.
The customer speaks	not your official company language.
The home country of the customer is known as	established and saturated.

The innovation idea of the foreign customer is characterized by the following attributes:

The innovation idea is	radically new.
The technology on which the innovation idea is based	substitutes existing competencies in your company.

With which level of intensity would you further pursue this idea?

1 (reject as not interesting) 10 (immediate, intensive)

**4.5 Estimation strategy**

We estimate ordered probit models to assess the additive effects of each impulse attribute. The dependent variable is ordinal in nature (between 1 and 10) and the ordered probit is therefore superior to ordinary least squares estimation. Attribute variables are coded as +1 when the hypothesis suggests a positive effect and -1 otherwise (Table 1). Hence, positive and significant coefficients indicate support for a hypothesis. We adjust standard errors for intragroup correlation because each interviewee produced 7 observations and variance originates between these groups. Finally, we use nonparametric bootstrap methodology because normal distribution cannot be assumed.

We estimate three different models. Model I tests the main effects. Model II includes control variables for firm characteristics (location in East Germany, size, exports as a share of sales, R&D expenditure as a share of sales and a dummy variable for manufacturing firms). Model III concludes with the inclusion of interaction terms between attributes to test for non-linear relationships.

## 5 Results

The results of the ordered probit estimation are summarized in Table 2. We find all main effects and hence hypotheses supported across model specifications with the exception of differentiation between technological and market competence. Apparently, respondents do not distinguish between the nature of competence (market or technology) when it comes to impulse attractiveness. Control variables for company specifics have no significant impact. This provides some indication that the sample is indeed homogeneous across firms and a feasible representation of the preference structure of individual R&D managers is achieved.

**Table 2: Results of ordered probit estimation**

<i>Variables</i>	<i>Model I</i>	<i>Model II</i>	<i>Model III</i>
Technological vs. market competence	0.01 (0.03)	0.01 (0.03)	0.01 (0.03)
Low/high language barriers	0.10*** (0.04)	0.10*** (0.04)	0.11*** (0.03)
Dynamic/static country of origin	0.18*** (0.03)	0.18*** (0.03)	0.19*** (0.03)
Radical/incremental novelty of idea	0.20*** (0.04)	0.20*** (0.03)	0.20*** (0.03)
Complementary/substituting knowledge	0.14*** (0.03)	0.15*** (0.04)	0.15*** (0.04)
Company located in East Germany (dummy)		-0.08 (0.16)	-0.09 (0.15)
No of employees (logs)		0.01 (0.04)	0.01 (0.05)
Exports as a percentage of sales (%)		0.00 (0.00)	0.00 (0.00)
R&D expenditures as a percentage of sales (%)		0.00 (0.00)	0.00 (0.01)
Company is in manufacturing (dummy)		0.25 (0.15)	0.25 (0.18)
Interaction: competence & language			-0.05* (0.03)
Interaction: competence & country of origin			0.02 (0.03)
Interaction: competence & novelty of idea			0.00 (0.03)
Interaction: competence & complementarity			-0.01 (0.03)
Interaction: language & country of origin			0.02 (0.03)
Interaction: language & novelty of idea			0.02 (0.03)

<i>Variables</i>	<i>Model I</i>	<i>Model II</i>	<i>Model III</i>
Interaction: language & complementarity			-0.03 (0.03)
Interaction: country of origin & novelty of idea			-0.04 (0.04)
Interaction: country of origin & complementarity			0.05* (0.03)
Interaction: novelty of idea & complementarity			0.04 (0.03)
Constant	1.89*** (0.17)	1.76*** (0.27)	1.77*** (0.37)
Number of Observations		1106	
Number of Clusters		158	
Replications		50	
Wald $\chi^2$	82.02	191.70	196.05
Prob> $\chi^2$	0.00	0.00	0.00
Aldrich Nelson Pseudo $R^2$	0.13	0.15	0.15

\* significant at 90%, \*\* significant at 95%, \*\*\* significant at 99%  
bootstrapped standard errors in parentheses

The ranking of individual signals may be more important than significance tests. Radical innovation impulses are the most attractive signal followed by a dynamic country of origin. Complementarities in knowledge and language follow. This provides some interesting insights. First, high risks of neglect may be the dominant driver behind sensing activities. Radically new impulses coming from dynamic markets must not be overlooked. However, this effect is additive in nature as the interaction term of both (Model III) has no significant impact. Complementarity with existing knowledge inside the firm has the third highest impact. It has a reinforcing effect with the country of origin as illustrated by the interaction term. Language barriers have the lowest significant effect. Interestingly, these language barriers have a significant negative effect if they coincide with technological competence of the knowledge source. One may assume that English is the dominant language among high-tech firms and if a source cannot effectively communicate in this de-facto standard language the effects are especially problematic. All other interaction effects have no significant impact.

## 6 Discussion

We focus in this study on the early stages of international innovation activities that could be called “initiation” (Szulanski, 1996) or “sensing” (Doz et al., 2001). At these early stages information collection and evaluation are the most important tasks. Decisions on whether these impulses are turned into specific product or process innovations, used to alter existing designs or are simply used for defensive purposes follow in subsequent stages of the innovation process. In that sense our study differs from existing research which largely focuses on the complete innovation process typically embodied in patent data. We develop theoretical arguments based on transaction cost theory, which stresses a balancing act between low direct transaction costs and potential risks from neglect. These hypotheses are empirically tested through an experimental study among German high tech companies. This allows us not only to identify significant effects but also to derive a preference ranking.

Our findings indicate that these sensing engagements are primarily driven by uncertainty avoidance motives. Ideas that are radically new and stem from a dynamic market are the most attractive. The potential downsides from overlooking these important developments outweigh the direct transaction costs associated with acquiring new knowledge (complementary to existing knowledge stocks) across language barriers. However, we can still identify significant effects for both of the latter. Interestingly, we find no distinction between technological or market impulses. These results indicate that an important part of sensing global innovation impulses is not strictly knowledge seeking but follows a strong uncertainty avoidance rationale. Not all of these impulses will be turned into innovations but they may alter existing trajectories.

Based on these findings management recommendations can be derived for firms that want to develop or refine international sensing activities. They should not think in the narrow terms of market or technology seeking. Analyses based on patent statistics imply that external knowledge is only valuable if it directly translates into innovation output (i.e. new patents). However, our study indicates that management of uncertainty is an equally important part of international knowledge sourcing. The scope of sensing activities should therefore be broad and not narrowly confined. Firms should focus on organizational practices that favor frequent, multiple interactions and experimentation instead of efficient routines. The latter have their merits at later stages of the learning process when operational efficiency can be increased by standardization and formalization for narrowing down the pool of prospective ideas (Jansen et al., 2005; Zahra and George, 2002). Interestingly, complementarity with existing knowledge stocks and linguistic proficiency are also important factors but not the dominant ones. This should be reflected in a firm’s staffing decisions for sensing activities. Language skills and in-house experience should not outweigh open-mindedness for new customers and technologies.

## **7 Limitations and future research**

Our study has been confined by certain limitations that may provide promising paths for future research. First, our empirical tests are limited to Germany's high-tech industry. Being one of the largest economies and a leading exporting country in the world makes it an especially relevant study object. However, our findings may not be readily generalized. They would benefit from comparative studies with other established economies but also emerging countries which may have very different needs and opportunities. Secondly, low-technology industries have received little attention so far with regards to the globalization of their innovation activities. The relative stability in their technological processes and opportunities should be reflected in their search behavior for external knowledge.

## 8 Appendix

### Appendix A: Industry breakdown

<b>Industry</b>	<b>NACE Code</b>	<b>Industry Group</b>
Chemicals / petroleum	23 – 24	Medium high-tech manufacturing
Manufacture of machinery and equipment	29	Medium high-tech manufacturing
Manufacture of electrical machinery	30 – 32	High-tech manufacturing
Medical, precision and optical instruments	33	High-tech manufacturing
Manufacture of motor vehicles	34 – 35	Medium high-tech manufacturing
Financial intermediation	65 – 67	Knowledge-intensive services
ICT services	72, 64.2	Technological services
Technical services	73, 74.2, 74.3	Technological services
Consulting	74.1, 74.4	Knowledge-intensive services

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