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International Transfer of Climate Technologies: Which Factors Influence the Firm's Choice of Transfer Channel?

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Abstract

Based on a survey among German climate technology companies, we analyse how characteristics of the technology and organization-specific resources influence the channel chosen for transferring climate technologies to other countries. We employ a multi-step method that combines factor analysis and hierarchical logistic regression. Our results suggest that organizations tend to choose hierarchical modes of transfer with increasing relevance of firm-internal capabilities. The most significant empirical link exists between the complexity of the relevant technology and the observed mode of transfer. A high degree of technological complexity tends to increase the likelihood of internal transfers, which is consistent with the assumption that the transfer of tacit knowledge requires a higher amount of personal communication between donor and recipient.

Keywords: International Technology Transfer; Climate Technology; Transfer Channel; Tacit Knowledge; Transaction Costs Economics;

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1 Introduction

Enhancing developing countries' access to climate technologies can provide a significant contribution to addressing climate change on a global scale. This fact was also acknowledged by the 2007 Conference of the Parties in Bali, where an Action Plan was adopted that led to the creation of the UNFCCC's Technology Mechanism in 2010. Cross-border technology transfer happens in many forms. Accordingly, there are numerous dimensions to classify the modes of technology transfer. One of the most basic distinctions is between internal and external modes of technology transfer, i.e. between hierarchical transfers within the boundaries of the organization and arm's-length market transactions. The choice of transfer channel has important implications, not only for the efficiency of international technology transfer and for the related costs of emission reductions, but also with regard to potential knowledge spill-overs to the receiving countries.

The literature on international technology transfer has developed from concepts that understood technology merely as scientific and engineering knowledge, to concepts that also incorporate capabilities and processes of organizations, where technological knowledge is embedded in the procedures and personnel that uses the technology (Brewer & Mani, 2008). In general, technological knowledge consists of tacit and explicit components. Depending on the degree of tacitness, technologies differ significantly regarding their ease of communication. Explicit knowledge components can be easily communicated and shared, for example via product specifications, scientific formulas or computer programs, while tacit knowledge components are harder to formalize and difficult to communicate to others. Accordingly, technology transfer is not supposed to be effortless and immediate and requires more than just giving access through the simple sharing of blueprints or recipes.

This basic intuition opens a novel perspective on technology transfer, which takes the specific kind of transferred knowledge and its transferability into consideration. In this study, we analyse the influence of technological characteristics and organization-specific resources on the choice of transfer channel. Our analysis relies on data gathered from a survey among German climate technology companies. The remainder is structured as follows: Section 2 introduces the theoretical concepts used in the study and generates hypotheses with regard to the influence of technology-specific and organization-specific factors on the choice of transfer channel. Section 3 starts by describing the data set generated by a survey conducted among German climate technology companies. After that, the hypotheses about the determinants of the international transfer channel for climate technologies are econometrically tested using the survey data. The final section summarizes and discusses the econometric results.

2 Theoretical Concepts

2.1 Types of Knowledge

Grant (1996) distinguishes knowledge according to its degree of transferability and the mechanisms for transfer. Whereas explicit knowledge – the knowing about facts and theories – is revealed by its communication; tacit knowledge – the knowing how – is revealed only through its application. Whereas explicit knowledge is formal and systematic, tacit knowledge is highly personal. According to Nonaka (2007), tacit knowledge is deeply rooted in action and in an individual's commitment to a specific context. Moreover, it has an important cognitive dimension. It consists of mental models, beliefs, and perspectives, which are so ingrained, that it is taken for granted, which makes it particularly difficult to communicate.

Grant (1996) further argues that the efficiency by which knowledge can be transferred depends on its capacity for aggregation. Knowledge absorption depends on the recipients' ability to add new to the existing knowledge at individual and at organizational level. Moreover, he addresses the appropriability of knowledge and states that "while most explicit knowledge and all tacit knowledge is stored within individuals, much of this knowledge is created within the firm and is firm specific" (Grant, 1996: 111).

2.2 Modes of Technology Transfer

Trade is often regarded as transmission of technological information (Maskus, 2004). Analyzing trade flows and patent applications, Bascavusoglu (2006) showed empirically that trade implies the transfer of technology across countries and sectors. This is related to the assumption that "embodied in a product or process, technology resembles a blueprint, or kind of information, that is easily available to the producer and consumer" (Radosevic, 1999: 14). But, “if a significant part of a technology is tacit and embodied in people and organizational routines, the efficient transfer of technology means the transfer not only of technological information, but also of the capability to master that technology.“ (Radosevic, 1999: 18). In such a situation, trade may not an adequate channel to transfer technology effectively. Technology licensing is regarded as the most direct channel of technology diffusion (Dechezleprêtre et al., 2011). It typically involves the purchase of production or distribution rights as well as the related technical information and know-how (Maskus, 2004). A firm may license its technology to a company abroad that uses it to upgrade its own production. It can be distinguished between market-mediated and intra-firm licensing, whereas intra-firm licensing guarantees proprietary control of intellectual property and knowhow to the transferring organization (Maskus, 2004).

In comparison, technology transfer evoked by FDI (Foreign Direct Investments) or within joint ventures is always internal. Joint ventures are defined as contractual agreements between two or more firms, in which each provides some advantage to common operations (Maskus, 2004). FDI is conducted by multinational companies outside their home country but inside the investing company. The control over the use of the transferred resources herein remains with the investing company (Maskus, 2004; Radosevic, 1999). Multinational organizations – including joint ventures – are able to transfer technology internationally as well by cross-border movement of skilled personnel, such as engineers or technicians. This is advantageous if a transfer requires complementary on-site service and know how.

Teece defines technology transfer as “process of transferring from one production entity to another the know-how required to successfully utilize a particular technology” (Teece, 1976: 17). Based on that, he distinguishes between internal and external, i.e. arms-length, market-mediated transfers. Whereas in internal transfers, the transfer interface is contained within recipient and donor, in market-mediated transfers an intermediary, generally an engineering contractor, is located at the interface (Teece, 1976: 24). According to Radosevic (1999), market transfer encompasses licensing and trade, whereas the term network transfer refers to cases of cooperative alliance, subcontracting, ‘transfer by people’, or development assistance.

The variety of channels of international technology transfer is much broader than outlined here and existing mechanisms could as well be distinguished in more detail.

2.3 Transaction Costs Theory

According to Teece (2003), the cost of transferring an innovation to other firms is much lower than the investment needed for developing a completely new product or production process that is economically feasible. Technology transfer therefore promises economic benefit to the companies involved. But, it would be inappropriate to regard existing technology as something that can be easily made available to all at zero cost. The resources necessary to transfer technology internationally are considerably. Consequently, if and how a company participates in mechanisms of international technology transfer is assumed to be a decision driven by many different factors.

Our theoretical framework for explaining the choice of transfer mode is rooted in Transaction Cost Theory (Williamson, 1975) and in the more general theory of the firm (Coase, 1937), according to which intra-firm transactions are used when markets fail or perform less efficiently. It is based on the assumption that "intra-firm and market exchange exhibit potentially different levels of efficiencies in executing different types of transactions." (Davidson and McFetridge, 1985: 5).

According to Williamson (1981), uncertainty, the frequency of interaction, and, most importantly, the asset specificity of the required investments critically affect the optimal make-or-buy decision, and thus implicitly define the efficient boundaries of the organization.

Davidson and McFetridge (1984, 1985) identified several factors that influence the choice of transfer mode. Compared to market transactions, hierarchical relations within an organization are supposed to weaken the direct link between an individual's productivity and its income. Employees are therefore supposed to be monitored to avoid shirking behavior. On the other hand, employees have less incentive to engage in activities designed to redistribute gains from trade than they would have in a market relation. Accordingly, “Intrafirm exchange will be less costly than market exchange whenever the value of resources saved by redistributive activity exceeds the sum of the values of output lost due shirking (given optimal monitoring) and the resources devoted to monitoring” (Davidson and McFetridge, 1984: 254).

In order to move toward identifying sets of factors that are likely to influence the international transfer and application of technology, Teece (2003) shows that, for example, the number of previous transfers of a technology has considerable influence on the level of transfer costs. Furthermore, the transfers of internationally more experienced companies turn out to be more successful.

3 Empirical Analysis

3.1 Data

The data for the empirical analysis was collected between September and December 2013 in an online survey conducted among German climate technology companies that operate internationally in the field of climate technologies. The invitation to participate in the survey was sent out to organizations that had registered with an international activity regarding climate technologies in the public database 'Environmental Technology Atlas for Germany' of the German Federal Ministry of the Environment. In total, 53 organizations answered the questionnaire, of which about one third were developers/engineering companies (18), another third belonged to the manufacturing industry (16) and about one fifth were service providers (11). Only a few respondents worked for either scientific (3) or administrative/ governmental institutions (1).

The questionnaire asked respondents to provide information on the organization and the climate technologies it dealt with, as well as the technology-specific activities in the international market. In order to capture the organization-specific resource profile, the survey asked respondents to rate the relevance of different kinds of assets for their organizations:[1]

- MATERIAL RESOURCES: “How relevant are material resources (land and buildings, technical facilities, factory and office equipment) for your organization? (Please indicate the degree of relevance on a scale from 1 = very low to 5 = very high)”
- ORGANIZATIONAL ROUTINES: “How relevant are organizational-based routines (operational procedures, internal processes, corporate culture) for your organization? (Please indicate the degree of relevance on a scale from 1 = very low to 5 = very high)”

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[1] The following questions have been translated from the German original.

- RELATIONAL CAPITAL: “How important is the relational capital (relations to customers, suppliers and other partners) for your organization? (Please indicate the degree of relevance on a scale from 1 = very low to 5 = very high)”

- IMMATERIAL ASSETS: “How relevant are immaterial assets (patents, trademarks, designs, reputation, goodwill, etc.) for your organization? (Please indicate the degree of relevance on a scale from 1 = very low to 5 = very high)”

Respondents were asked to select from a predefined list of 50 climate technologies up to three technologies, which are of the highest relevance to their business activities. Of the 133 chosen technologies about half (69) were related to the field of energy supply, of which about two thirds (43) fall in the category of renewable energies. Other important technological fields were energy efficiency (30) and water technologies (15).

Respondents were then asked to provide information about the technologies important to their organization. For each of the selected technologies respondents should answer four questions:

- MARKET AVAILABILITY: “For how long are, according to your knowledge, similar technologies already available on the market? (more than 10 years, 5 to 10 years, 2 to 5 years, less than 2 years)”

- TIME OF COMMERCIALIZATION: “For how long does your organization (or your business partners) commercialize this technology? (more than 10 years, 5 to 10 years, 2 to 5 years, less than 2 years)”

- PRE-COMMERCIAL DEVELOPMENT: “How many years did it take your organization to bring this technology to marketability? (less than 1 year, 1 to 2 years, 2 to 3 years, 3 to 4 years, more than 4 years)”

- COOPERATION REQUIREMENT: “How important was the collaboration with external partners (e.g. universities, research institutes, suppliers, customers) for the development of this technology? (1 = very low, 5 = very high)”

Finally, respondents were asked to indicate whether their organization has employed ‘export’, ‘licensing’, ‘Joint Ventures’ and/or ‘FDI’ to transfer the selected technology internationally by checking all the options that applied. As expected, 50 percent of the technologies being exported, trade is by far the most commonly used mode of transfer. Technology licensing and international Joint Ventures, each accounting for 16 percent, as well as FDI with a share of 14 percent are considerably less frequently chosen Based on the answers to this question , a binary variable (*mod*) is constructed, which takes on a value of 1 whenever the respective technology is being used in either Joint Ventures or FDI activities and a value of zero otherwise, identifying the selection of a hierarchical transfer mode. It turns out that in about one third (32 out of 97) of the cases, one or another kind of hierarchical transfer mode is being used. In the logistic regression analysis (see Section 3.3), this binary indicator will be used as dependent variable and the characteristics of the technology and the organization serve as independent variables to explain the probability of observing a hierarchical transfer mode.

3.2 Factor Analysis

In a first step, the dimension of the set of the explanatory variables is reduced. This treatment not only serves to identify the underlying characteristics at the technological and organizational level that have influenced the survey responses but also has the important advantage of avoiding problems of multi-collinearity in the subsequent econometric analysis.

Based on the assumption that the obtained survey responses are various imprecise measures of the same underlying drivers, we use Principal Axis Factor Analysis (PFA) and oblique rotation methods to obtain indicators of the latent determining factors at the level of technology and of the organization. The resulting factor loadings, as reported in Table 1, provide the basis for the factor interpretation with regard to the tacitness of knowledge, as well as physical, organizational and human resources.

Table 1: Loadings on rotated factors (PFA and oblique rotation)

	Technology-level factors	
Technology characteristics	NOVELTY (*nov*)	COMPLEXITY (*com*)
MARKET AVAILABILITY	.922	.007
TIME OF COMMERCIALIZATION	.647	-.006
COOPERATION REQUIREMENTS	.110	.629
PRE-COMMERCIAL DEVELOPMENT	-.122	.618
	Organization-level factors	
Organization characteristics	INTERNAL CAPABILITIES (*int*)	EXTERNAL RELATIONS (*ext*)
MATERIAL RESOURCES	-.604	-.067
ORGANIZATIONAL ROUTINES	.270	-.043
RELATIONAL CAPITAL	.369	.543
IMMATERIAL ASSETS	-.099	.533

The survey responses on four questions regarding the technology characteristics entered the first principal factor analysis. According to the Kaiser criterion, it is reasonable to extract two factors, which are interpreted as follows:

- NOVELTY (*nov*): This factor loads highly on TIME OF COMMERCIALIZATION and MARKET AVAILABILITY. It is supposed to reflect the degree of novelty of the respective technology, because both items give information on the time since the emergence of the technology. MARKET AVAILABILITY measures the existence outside, TIME OF COMMERCIALIZATION the existence inside the organization. The higher the factor scores for NOVELTY, the more recent is the technology. Because cutting-edge technology is still subject to frequent changes, the associated knowledge is difficult to codify. Thus, we posit that the newer the technology, the higher is the amount of tacit knowledge involved.

- COMPLEXITY (*com*): This factor loads highly on the technology attributes PRE-COMMERCIAL DEVELOPMENT and COOPERATION REQUIREMENT, which both measure the intensity of the development process. The time, which has been necessary to bring the technology to market and the importance of cooperating with external partners in the development process both hint at a high complexity of the relevant knowledge. The higher the factor scores for COMPLEXITY, the more complex is the technology. A high degree of technological complexity will make it difficult to codify the underlying knowledge, even for mature technologies. Based on these theoretical considerations, we expect that, more complex technologies, the higher the relevance of tacit knowledge.

In the second factor analysis, the survey responses on four organizational characteristics were included. Again, two factors are extracted according to the Kaiser criterion, with the following interpretations:

- INTERNAL CAPABILITIES (*int*): This factor loads strongly negative on the item MATERIAL RESOURCES. However, it positively correlates with RELATIONAL CAPITAL and ORGANIZATIONAL ROUTINES. Thus, the core competences of organizations that score high on this factor are not build upon tangible and easily tradable assets, but rather on soft, hard to communicate, highly context-specific capabilities within the organization. Based on these considerations, INTERNAL CAPABILITIES are supposed to rely on knowledge of a more tacit character.

  EXTERNAL RELATIONS (*ext*): This factor loads highly on the RELATIONAL CAPITAL (for instance, good relations to customers, suppliers and other partners), and IMMATERIAL ASSETS (such as reputation, intellectual property rights, etc.) held by the organization. Both items represent highly company-specific resources that help in dealing with agents outside the company, e.g. a good reputation will make it easier to build trustful relationships with external partners.

3.3 Regression Analysis

As result of the previous analysis, we retained four factors at two different levels of analysis that are supposed to influence the selection of the mode of transfer for climate technologies: the NOVELTY and the COMPLEXITY of the respective technology, as well as the INTERNAL CAPABILITIES and the EXTERNAL RELATIONS of the respective organization. These factors serve as independent variables to explain why an internal transfer mode has been selected. The regression shall examine the following hypotheses:

- As the importance of tacit knowledge is expected to increase with the NOVELTY and COMPLEXITY of the technology, we expect technologies that score high on these factors to have a higher probability of being transferred within the organization.
- As the importance of tacit knowledge is expected to increase with the relative importance of soft and non-marketable assets in the organizational resource base, we expect to find a positive relationship between INTERNAL CAPABILITIES and the probability of hierarchical transfer.
- When external collaborations and immaterial assets are of particular importance to the organization, we expect to find a positive relationship between EXTERNAL RELATIONS and the probability of hierarchical transfers, because companies that are experienced in building trustful relationships with external partners will be more likely to form a joint venture or to conduct FDI.

The econometric model accounts for the fact that there are multiple observations from the same organization, such that organization-related characteristics are not independent at the level of technology. We use a random-intercept logistic regression model, which extends ordinary logistic estimation by the aspect of a hierarchical data structure. For this type of model, the assumption of conditional independence of responses is relaxed, by including a cluster-specific random intercept in the linear predictor of the logistic regression model.[2]

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2 For the hierarchical logistic regression, the Stata program GLLAMM is used, which estimates Generalized Linear Latent And Mixed Models. Information, documentation, syntax, and exemplary data are available at the GLLAMM website (www.gllamm.org).

Table 2: Results of the hierarchical logistic regression estimation

	Estimated coefficient	Odds Ratio	Significance
NOVELTY (*nov*)	-1.671	.1881088	0.138
COMPLEXITY (*com*)	3.922	50.48461	0.020
INTERNAL CAPABILITIES (*int*)	3.168	23.75071	0.026
EXTERNAL RELATIONS (*ext*)	-1.289	.2754507	0.318
Constant	-2.661	.0698813	0.013

The regression results are reported in Table 2. The estimated coefficients for COMPLEXITY and INTERNAL CAPABILITIES are positive at a statistical significance level of 0.05, and negative for NOVELTY and EXTERNAL RELATIONS. An increase in the factor scores for COMPLEXITY or INTERNAL CAPABILITIES therefore leads to an increase of the probability of hierarchical transfer. The effects of NOVELTY and EXTERNAL RELATIONS are not statistically significant at conventional levels. The estimation results thus corroborate the assumption that both technology-specific and organization-specific factors have an influence on the selection of the mode of transfer for climate technologies. Disregarding one or the other can lead to significant misconceptions of transfer mechanisms for climate technologies.

At each level of influence, one determining factor clearly stands out. At the technology level, the COMPLEXITY of the technological knowledge, indicated by a time-consuming and cooperation-intensive development process, significantly increases the likelihood of observing an internal mode of technology transfer. At the organizational level, the relative importance of INTERNAL CAPABILITIES, like specific organizational routines, personal relations and experiences, that usually are extremely context-specific and deeply entrenched in the corporate culture, similarly make the use of hierarchical modes of transfer within the boundaries of the organization more likely.

Overall, the empirical results can be interpreted as a confirmation of the initial assumption that highly tacit technologies, i.e. technological knowledge that is to a significant part dependent on hard to communicate know-how and usually embodied in people rather than material artefacts, need to be transferred rather within organizational boundaries than over arm-length market transactions.

4 Conclusions

There is some evidence that both the characteristics of the transferred knowledge as well as the specific resources held by the transferring organization determine the optimal choice of transfer mode. The results of the survey among German climate technology companies shows that the preferred mode of their international activity can be explained by specific organizational assets and capabilities as well as certain properties of the relevant technological knowledge. The econometric analysis reveals that respondents tend to use internal transfer mechanisms the more complex is the relevant technology and the more important are internal capabilities for their organizations.

This implies that organizations tend to choose hierarchical modes of transfer with increasing relevance of organization-based routines, but if material resources are considered to be of high relevance to the organization, strategies of internal transfer are less likely to be observed. The most significant empirical link exists between the factor that measures the complexity of the relevant technology and the observed mode of transfer. A high degree of complexity of the concerned climate technology tends to increase the likelihood of internal market transfers, which is consistent with the assumption that the transfer of tacit knowledge requires a higher amount of direct communication between donor and receiver.

From a transaction cost perspective, the transfer of tacit knowledge requires more direct communication and interaction than transferring explicit knowledge, which can easily be codified and articulated. Accordingly, a high degree of tacitness hampers the transfer of technological knowledge based on arm's-length market transactions and is better accomplished via hierarchical modes of knowledge transfer. Joint ventures or foreign direct investments provide channels that are better adapted to the requirements of tacit knowledge transfer. The empirical results corroborate this fundamental assumption, which thus also applies to the international transfer of climate technologies

The concept of tacit knowledge has turned out to be meaningful for explaining why certain technologies or technological knowledge components are rather transferred internally than externally. The tacit nature of the relevant knowledge base helps to better understand the international diffusion of climate technologies and will certainly contribute to the explanation of observed patterns and dynamics in the emergence of global production networks in related industries.

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