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Creating an Interactive-Recursive Model of Knowledge Transfer

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Abstract

This paper deals with the process of knowledge transfer related to generation, diffusion and absorption of external knowledge. Comprehensive models of knowledge transfer so far found little attention in the academic discussion. Decades of scientific work of different disciplines produced abundant literature on various aspects of knowledge and technology transfer from the perspective of different scientific interests. Although the lack of effectiveness or lack of success of knowledge transfer in various regions, countries, industries or forms of cooperation is noted and chosen in a variety of studies as a starting point, the question of the process of knowledge transfer so far has not been of central interest in economic research. This can be shown by a comprehensive analysis of publications on the subject of Technology Transfer of Gibson et al. (1990), which systematizes the amplitude of scientific papers on thematic priorities from 'accounting' to 'Yugoslavia'. The aim of this paper is to contribute towards closing this research gap by highlighting in a first step all those factors that are part of the knowledge transfer process and to develop a model of knowledge transfer by which in a second step possible barriers in the process of knowledge transfer can be identified and analyzed in their effect.

Jelcodes:O31,O32

Creating an Interactive-Recursive Model of Knowledge Transfer

1. Introduction

Knowledge as the basis for the economic development of modern economies has long been replaced capital and labor as key factors (Davenport and Prusak 1998). The still-growing role of knowledge-based technologies in the context of global competition due to rapid structural changes and the existence and emergence of new key technologies affecting almost all businesses regardless of size and sector (BMBF 2008, Schmoch et al. 2000). The generation, diffusion and absorption of knowledge are crucial factors in the Knowledge Society (Shapira et al. 2006). While companies concentrated a long time on developing new technologies and new knowledge internally, a change of this innovation strategy over the last decades can increasingly be identified: Many companies across all industries and industry sectors draw a significant percentage of new technologies from external sources. This combination between that from the perspective of the company, 'new' knowledge within the company and the existing 'old' knowledge is of crucial importance for the construction of knowledge (Tsai and Wu 2010:441). In contrast to the traditional internal or closed innovation strategies Henry Chesbrough developed his notion of 'open innovation' (Chesbrough 2003). This 'opening' of the innovation process was triggered by increasing competitive pressure, necessary due to globalization and an increased pressure to innovate due to shorter product life cycles (Galanakis 2006, Gassmann and Enkel 2006). The core of an open innovation strategy is the transfer of externally developed knowledge. The central importance of knowledge and technology transfer for the mastery of technological change and hence for the competitiveness of industry and services is already known since the early 1990s. The knowledge generated in universities and other public research institutions contributes in many ways to growth and technological change (Grimpe and Fier 2009:1):

> "Cooperative efforts among government, industry, and universities have grown in importance as strong contributors to the nation's technological and economic competitiveness in the global environment." (Geisler 2003:675)

However, especially in Europe seems to be a gap between outstanding scientific achievements on the one hand, and industry's competitiveness on the other side. This gap, as described in the literature as 'European paradox', is due mainly to a small or little effective knowledge transfer between science and industry (European Commission 1995:14). A survey of the European Community in 2000 showed that only a small fraction of innovative companies uses universities and other public research laboratories as an important source of information for their innovation process. Less than ten percent of innovative firms contracted to cooperative agreements with a university (Veugelers and Cassiman 2005:357).

For large enterprises (LE), just as well for small and medium enterprises (SME) the process of knowledge transfer is often not just about achieving entirely new innovations, but also to achieve solutions of current or even acute problems in process and production flows, to improve existing processes and products as well as adjustments to legal norms and standards.

Especially SME face growing research and development (R&D) costs they can only meet with limited own capacities (Eckl and Engel 2011, Walter 2003). In this context R&D collaborations, exchange of information with other companies and technology-oriented exchange relations with (technical) universities and other public and private research institutions are of central importance and have major impacts on the economic success of many companies (Lybaert 1998, Gemünden and Walter 1995).

2. Aim of the Paper

This paper deals with the process of knowledge transfer related to generation, diffusion and absorption of external knowledge. It is therefore part of the wide range of knowledge and technology transfer research, which in the last decades has gained continuously scientific and political importance and has now produced an immense number of studies. By Agrawal (2001) studies on knowledge transfer from research institutions to industry are concerned mainly with either (1) companies or (2) universities or (3) geographical reach or (4) different paths of the transfer.

Knowledge transfer is basically possible in two directions. The process of transferring externally generated knowledge to industry is called by Chesbrough and Crowther (2006:229) as "inbound open innovation". Unlike "outbound open innovation" refers to knowledge transfer in the opposite direction: the transfer of internally generated knowledge to other organizations or enterprises for commercializing purpose (cf. Lichtenthaler 2009:317f.; Spithoven et al 2010:130f.). Although many of the ideas and arguments developed in this paper are valid for the transfer of knowledge as such - regardless of its direction -, yet the transfer of externally generated knowledge to enterprises ('inbound open innovation') is the subject of this paper. This is caused by the research literature, which so far has almost exclusively dedicated to inbound open innovation '.

Comprehensive models of knowledge transfer so far found little attention in the academic discussion. Decades of scientific work of different disciplines produced abundant literature on various aspects of knowledge and technology transfer from the perspective of different scientific interests. Although the lack of effectiveness or lack of success of knowledge transfer in various regions, countries, industries or forms of cooperation is noted and chosen in a variety of studies as a starting point, the question of the process of knowledge transfer so far has not been of central interest in economic research. This can be shown by a comprehensive analysis of publications on the subject of Technology Transfer of Gibson et al. (1990), which systematizes the amplitude of scientific papers on thematic priorities from 'accounting' to 'Yugoslavia'.

The aim of this paper is to contribute towards closing this research gap by highlighting in a first step all those factors that are part of the knowledge transfer process and to develop a model of knowledge transfer by which in a second step possible barriers in the process of knowledge transfer can be identified and analyzed in their effect (see Eckl 2012).

3. Concepts and Definitions

Despite or perhaps because of the great abundance of articles on the topic ‘knowledge transfer' from different disciplines with different epistemological approaches and methods, explicitly defined or implicitly underlying concepts of knowledge and technology transfer as well as the in this context used key terms vary enormously. Without going into detail on the differences, it is therefore essential to discuss the following key features of the key terms and concepts associated with them briefly and to clarify its meaning in the context of the present work.[1]

Technology and Knowledge

Regarding knowledge transfer a discussion of the in the literature used concepts of 'technology' and 'knowledge' is firstly necessary. Walter (2003) defines technology as "any research and development results that can contribute to solve problems in form of procedures, methods and techniques" (Walter 2003:17). This primarily technically-oriented approach was used by Gibson and Smilor (1991) expanded by intellectual components. They understand technology as "knowledge and ideas as well as physical products" (Gibson and Smilor 1991:290). Accordingly Schmoch et al. (2000) note that in the literature on technology transfer no uniform understanding of 'technology' exists. While the term technology is more on application-oriented and relates to technological knowledge and material technology (machinery, materials, substances, etc.), the term 'knowledge' comprises also the application or implementation of knowledge and general or specific knowledge (know-how) (Schmoch et al. 2000:4).

Bozeman (2000) refers in its conceptual distinction between 'knowledge' and 'technology' on Sahale (1981) and stresses that in the process of knowledge transfer both concepts can not be thought of separately:

> “By Sahal’s concept the two are not separable – when a technological product is transferred or diffused, the knowledge upon which its composition is based is also diffused. Without the knowledge base the physical entity cannot be put to use. Thus, the knowledge base is inherent, not ancillary.” (Bozeman 2000:629)

Knowledge and technology are in this commonly accepted understanding not two different, complementary approaches, but knowledge is rather an integral part of technology. The knowledge associated with a technology is not a static concept, but the result of a permanent exchange:

> “First, successful technology transfer is an on-going, interactive process where individuals exchange ideas simultaneously and continuously. Feedback is so pervasive that the participants in the transfer process can be viewed as “transceivers”, exchanging ideas among the individuals involved.“ (Williams and Gibson 1990:15f.)

Spender uses a similar concept of knowledge, where knowledge is understood as "a process or a competent goal-oriented activity rather than as observable and transferable to resource" (Spender 1996b, quoted by Wahab et al. 2009:558).

In many, especially the more recent studies on the transfer of results from scientific research the term 'knowledge' instead of 'technology' is used. This knowledge combined with technology is a significant aspect for the analysis of transfer barriers. Therefore in this paper the concept of 'knowledge transfer' is used instead of the concepts 'technology transfer' or 'knowledge and technology transfer'. The concept of 'knowledge' is broadly defined and not merely seen as a component of the technology to be transferred, but as a generic term for all those aspects involved in the transfer of research findings. For example, the knowledge of a technology is a necessary precondition for technology transfer and the related knowledge. In addition to explicit, articulated knowledge also implicit knowledge is especially in relation to the applicability of research results an important aspect for the successful transfer of knowledge and thus also for an analysis of transfer barriers.

[1] Zhao and Reisman (1992) provide an overview of competing definitions and concepts related to knowledge and technology transfer in various disciplines till 1990. See also Bozeman (2000:628-630) for a brief discussion of more recently definitions and with further references.

Knowledge Transfer

The view on knowledge transfer by academic discipline depends on different issues and focuses on specific aspects or stages of the transfer process. Until the early 1980s, the focus of technology transfer research was on international transfers, especially from industrialized nations to LEs-industrialized countries (Croissant and Smith-Doerr 2007:691). With the end of the last century, the national research on knowledge transfer gained increasingly in importance. While early studies on business management often dealt with intra-sectoral knowledge transfers and the relationship between technology and business strategy, numerous recent economic studies focus on alliances of companies in the context of development and transfer of knowledge (Bozeman 2000:630).

Another concept that is often used in connection with the transfer of research results is ‘knowledge spillovers’. This type of knowledge-diffusion comprises external effects of private R&D (see Nelson 1959, Arrow 1962). Knowledge that is generated through in-house R&D activities can be *hired* by a third party without compensating the owner. Physical proximity and informal exchange between researchers play thereby an important role (e.g. Audretsch and Feldman 1996; Bond 1997; Breschi and Lissoni 2001; Muniagurria and Singh 1997).

While early models of technology and knowledge transfer are based on a uni-linear transfer concept, in which the knowledge-taker plays a mostly passive role (Wahab et al. 2009), recent knowledge-based business theories and models of organizational learning emphasize the importance of active participation of the knowledge-taker. For Tiemessen et al. (1997) knowledge transfer is "to accept the partner's knowledge, to integrate knowledge into one's own system or changing one's own resources to imitate knowledge" (Tiemessen et al. 1997, cited in Wahab 2009:560). In this paper the term ‘knowledge taker’ instead of the still pre-dominant ‘knowledge receiver' is chosen. In contrast to the rather passive term ‘receiver’, the concept of 'taker' emphasizes the active idea of the process and fits therefore more adequate to the current state of the understanding of knowledge transfer as an interactive process. A key component of knowledge transfer is the process of learning: "The process of knowledge transfer is not a static one, it is dynamic, and is part of a process of continuous learning" (Gilbert and Cordey-Hayes 1996:303). There is recent research in a broad consensus that the transfer of knowledge and its application to include: "[It] does not only require transmission of knowledge but also knowledge absorption and use" (Wahab et al 2009:556).

In this paper- analogous to the understanding of technology and knowledge - the definition of transfer is conceived widely for the detection of possible barriers. Understood as an interactive concept, it includes the generation, diffusion and absorption of knowledge, including the associated explicit and implicit basic and applied knowledge. For successful knowledge transfer, not the generation of theoretically sharable knowledge is sufficient, it also must be used.

The concept of ‘transfer’ is closely associated with obsolete uni-linear notions of knowledge. According to the interactive character of the process, the term ‘knowledge exchange’ instead of 'knowledge transfer' would be more adequate. However, since the entire research literature on the subject until now used the term ‘transfer’ it will be retained in the present paper.

The concepts of 'technology' and 'transfer' can be described with the words of Gibson und Rogers (1994):

> “The concepts of technology and of transfer are defined by both theoreticians and practitioners in many different ways. There is usually agreement, however, that (1) technology is not just a ‘thing’, and (2) transfer is a profoundly human endeavor. Essentially, ‘technology’ is information that is put to use in order to accomplish some task, the knowledge of how to do something. ‘Transfer’ is the movement of technology via some channel from one individual or organization to another. So technology transfer involves the application of knowledge, putting a tool in use.” (Gibson und Rogers 1994: 333; similar Steele 1989:158)

For analytical considerations the process of knowledge transfer can be divided in three basic dimensions of *generation, diffusion* and *absorption*. Knowledge-generation is defined in this study not only by the actual execution of research projects, but also by the process of topic selection and the procedure for the selection and approval of research projects. In the process of knowledge generation are not only the researchers themselves involved, but also those persons and institutions that accompany the whole process of knowledge generation through coordination and / or control.

The concept of 'diffusion', especially in communication-based approaches, is such broadly defined that it is largely synonymous with the concept of transfer. Scott-Kemmis et al. (1988) for example define diffusion as follows: „Diffusion is not a process which occurs after innovation but an integral phase of the process of technological development“(Scott-Kemmis et al 1988:3). In this paper, the term ‘transfer’ is used for the entire process from knowledge generation through diffusion to its absorption. In contrast to this, the notion of 'diffusion' - similar to its use by Lundvall (1992, 1994, 1998) and others with regard to innovation systems – is reserved for all those activities and processes aimed at bridging between knowledge generation and knowledge absorption.[2] Diffusion thereby explicitly includes the processing of knowledge. The concept of ‘absorption’ refers to evaluation, assimilation and application of external knowledge in industrial organizations. Following Cohen and Levinthal (1994:227) absorption is described in this paper as the process, during which the value of external knowledge is evaluated, adopted in corporate production methods and procedures and applied.

Systems of Innovation and Research Collaborations

A large part of the relevant, mainly economic, but also sociological literature on knowledge transfer is part of the field of innovation research. It is therefore appropriate to consider the relationship of the two concepts, knowledge transfer 'and' innovation '. A broad and widely accepted definition of innovation offers Fischer (2006):

> “Innovation is generally defined as the activities of developing and commercialising new products and processes. These innovation activities are of two major types: fundamental, which involves the creation and utilisation of a piece of new scientific, technological or organisational knowledge; and incremental, which concerns product or process improvements based on existing knowledge.” (Fischer 2006:119, with reference to Hall 1986 and Freeman 1986).

Commonly accepted is also the systemic view of innovation processes. The concept of 'innovation system' was decisively shaped by Lundvall (1992): „A system of innovation is constituted by elements and relationships which interact in the production, diffusion, and the use of new, and economically useful, knowledge“ (p.2). A similar concept is represented by Edquist (1997), innovation systems must therefore include "all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations" (p.14). Or, in more universal terms: „[A] system approach accepts that in principle ‘everything interacts with everything’ but recognizes that in practice, some interactions matter more than others“ (Padmore et al. 1998, p.606).

If systems can be defined as „entities based on common standards of communication and information, a common set of interpretations, and a shared view of values and meaning“ (Kaufmann und Tödtling 2001:794), than three different systems are involved in the knowledge transfer process: economics, science and politics.

Knowledge transfer is an important component of innovation processes. Schmidt (1994) describes the relationship between the knowledge transfer and innovation as follows: "The goal of publicly funded technology transfer is to increase innovations and investments of the firms" (p.232). Staudt and Krause (1999) argue in line: "The objective of transfer efforts is to support and encourage small and medium-sized enterprises in their innovation activities" (p.57). The concept of knowledge transfer, as it is used in this work, is related not only on new products and production processes, but also well to internal processes and organizational structures. Knowledge transfer often takes place within the framework of joint research of enterprises and research institutes. The list of possible research or other kinds of cooperative relationships is long, and multiple terms are used, such as 'research cooperation', 'research partnership', 'community research' or 'collaborative research'. Stewart and Gibson (1990:124-129), for example, list 72 different types of university-industry relations. In this paper the terms are used interchangeably in reference to Geisler's comprehensive definition: “Broadly, cooperation in R&D technology may be defined as any arrangement, formal or informal among two or more parties in which resources are utilised by the parties for a scientific and/or technical activity shared by at least

[2] Diffusion corresponds therefore to the ‘interface' as a central element in communication-based models of knowledge transfer, see e.g. the description of "Boundary spanning in technology transfer at the researcher / commercial user interface" by Irwin and More (1991:278).

two of the parties“ (Geisler 2003:677). A preferably open definition of cooperation is useful to include a broad spectrum of possible relationships between research institutes and companies in the analysis.

4. Modeling the Process of Knowledge Transfer

Subject of this paper is the derivation and analysis of potential barriers in the process of knowledge transfer. To identify and analyze those transfer barriers in this section a model of knowledge transfer is developed using past models of technology and knowledge transfer.

4.1. Two Existing Models of Knowledge Transfer

Models help to reduce complex issues and relationships into particular components and to make clear the relationships between them. Thus, they are not only useful for the description and understanding of complex structures, but also serve as a starting point for the analysis of correlations. So far, a model of knowledge transfer barriers, as they are the subject of this work, has not yet been developed.

The past scientific debate on the issue of knowledge transfers has produced a number of models.[3] Two model types can be used as basic concepts for developing an own model of knowledge transfer for the analysis of transfer barriers: The first one are stage models developed by Gibson and co-authors (Gibson and Smilor, 1991, Gibson and Rogers 1994, Sung and Gibson 2000), the second one is an interaction model from Bozeman (2000) designed to describe the effectiveness of technology transfer. Both models and model types will be outlined briefly below to subsequently develop an own model through criticism, merging, and modification of the two types.

The Stage Model of Gibson et al.

The stage model developed by Gibson and co-authors differentiates the process of knowledge transfer in different stages by different criteria for success, taking into account the role and function of the actors. As a stage model it allows also insights into the procedural nature of knowledge transfer. It therefore represents an important basis for understanding the process of transfer of knowledge both with regard to the interaction of the actors as well as to its temporary dimension.

The model „Technology transfer at three levels of involvement“ (see Figure 1) was developed by Gibson and Smilor (1991) in the context of an empirical analysis of the U.S. Research Consortium "Microelectronics and Computer Technology Corporation" (MCC) [4]. In its first version, there are three levels of involvement in the process of knowledge transfer.

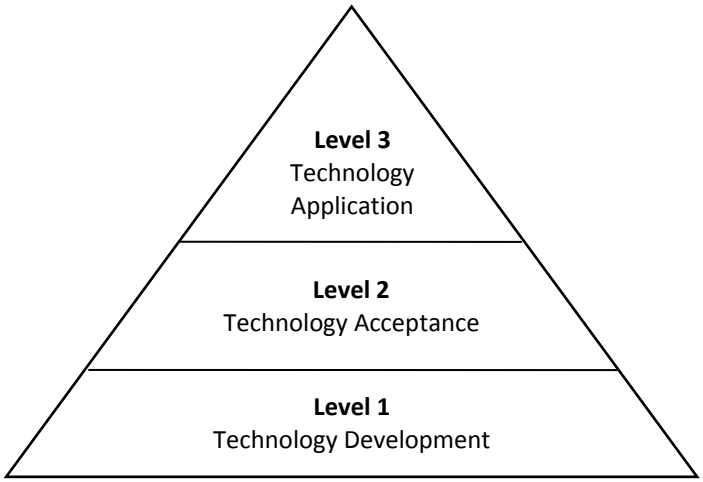
Each of the three stages of the model integrates dominant concepts of knowledge transfer during the second half of the 20th Century. Level 1 is the "Appropriability Model" or "Automatic Model" prevailing from 1945 to the 1950s that emphasizes R&D and market competition as a starting point for technology transfer. Level 2 corresponds to the "Dissemination Model" of the 1960s and 1970s, which focus on the dissemination of knowledge as a key element of knowledge transfer. Level 3 is in

[3] A discussion of various models of technology transfer in their respective epistemological and scientific-historical context offer Rothwell (1992) and Wahab et al. (2009) and - almost identical - Sazali et al. (2009). See also the comprehensive discussion of Forrest (1991) and Schmoch et al. (2000:3-13), both with a stronger focus on innovation processes. Murphy (1985), Raz and Assa (1988), McFall and McKelvey (1989) and Kassicieh and Radosevich (1991) are examples of older models for technology transfer. Geisler (1993) notes critically in relation to these models: „Yet, due to the different disciplinary orientations and methodologies, there is little convergence. Further, it has generated only marginal contributions to the design of the domain. This is mainly because the models identified actors and activities, rather than intensely describing and explaining the technology-transfer phenomenon” (Geisler 1993:89).

[4] The MCC was founded in 1982 by the U.S. industry to improve their competitiveness against Japan. The fully industry-funded MCC was a pioneer for more than 350 industrial research consortia that are pursuing joint research by universities and other publicly and privately funded research institutes and industry (Gibson and Rogers 1994: xv).

accordance with the "Knowledge Utilization Model" developed at the end of the 1980s (cf. Devine et al. 1987; Gibson und Niwa 1991:504; Sazali et al. 2009:80f.).

Figure 1: Technology transfer at three levels of involvement

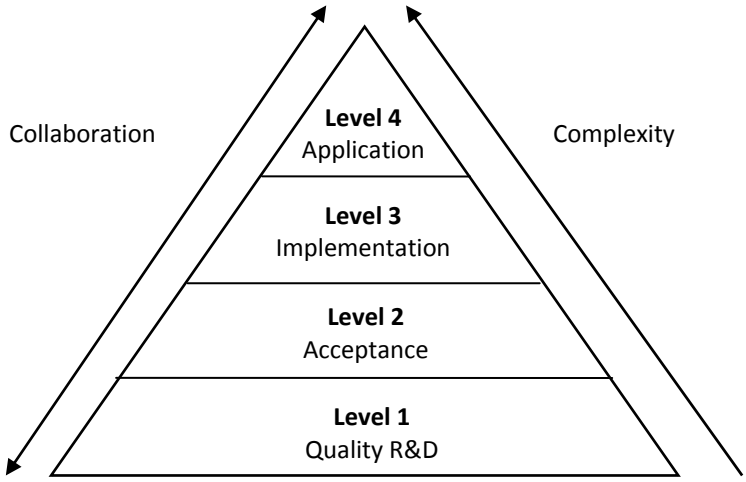


Notes: Gibson and Smilor (1991:290)

First, knowledge transfer at level 1 happens largely passive by research reports or publications. The second level of knowledge transfer includes the receptor in such an extent that the knowledge is accessible for him and can be understood by him. Finally, the third level also comprises the application of new knowledge in market products or company internal processes (Gibson and Smilor. 1991: 289f).

Based on this three-stage model Gibson and Rogers (1994) develop a model of technology transfer with "four levels of collaborative activity and four correspondingly different definitions of technology transfer success“ (Gibson and Rogers 1994:334; see Figure 2). The model describes not primarily the process of knowledge transfer, but divides it on the basis of four different success criteria. The focus of the first stage is to carry out R&D. The dissemination of the results occurs, for example through publications, lectures and exhibitions. According to Gibson and Rogers (1994:336) the criterion for success at this level of knowledge transfer can be measured by quantity and quality of research reports and publications. It is not the diffusion efforts and processes of knowledge transfer that are important, but only the quality of research, because this is decisive for successful knowledge transfer, which is thought in the first stage as a passive process that requires very little interaction with the knowledge receiver. The assumption is that interested firms contact the developers of the technology to acquire new knowledge. The reason for this is found in the argument that good ideas sell themselves: "If a technology is superior, it will be used" (Gibson and Rogers 1994:336). If no transfer takes place at this level of knowledge, the reason for this is seen in the technology that has not found a market.

Figure 2: Technology transfer at four levels of involvement



Notes: Gibson und Rogers (1994:335)

This kind of direct transfer as described in step 1 will remain the exception (Irwin and More 1991:275). At the second stage, the acceptance of external knowledge, therefore the common and shared responsibility between donors and recipients of knowledge is emphasized. Knowledge transfer takes place on the second stage when technological knowledge is passed from experts over personal, functional and organizational boundaries to the knowledge recipient and is there accepted and understood. Basic assumption of stage 2 is the notion that successful technology transfer happens through the dissemination of information to the right audience at the right time. In contrast to stage 1 the role and function of the actors in the knowledge transfer process is taken into account. However, knowledge transfer is here also understood as a uni-linear process in which the interaction of involved actors is not considered (Rogers and Shoemaker 1971, Rogers 1983). Even if new technologies provide significant productivity and quality advantages, they are used often very much slower than expected. At level 3 the 'implementation of knowledge' the knowledge should therefore promptly and efficiently integrated by the recipient. Technology implementation can take place in processing or even in product development such as the creation of prototypes. In this stage an increased value of the implemented technology can be achieved by the knowledge recipient. Characteristic for knowledge transfer in this stage is the consideration of the mutual and reciprocal relations between the actors and the economic and technical components of the diffusion process (Scott-Kemmis et al. In 1988, Irwin and More 1991:276). Finally, step 4, the application of knowledge builds cumulatively on the previous levels of technology transfer and on the economic value of technological knowledge. At this stage of knowledge transfer not only the successful implementation of knowledge, but an existing market for the new technology is necessary. This long-term success in step 4 can be measured in terms of corporate profits or market share (Gibson und Rogers 1994:336f.).

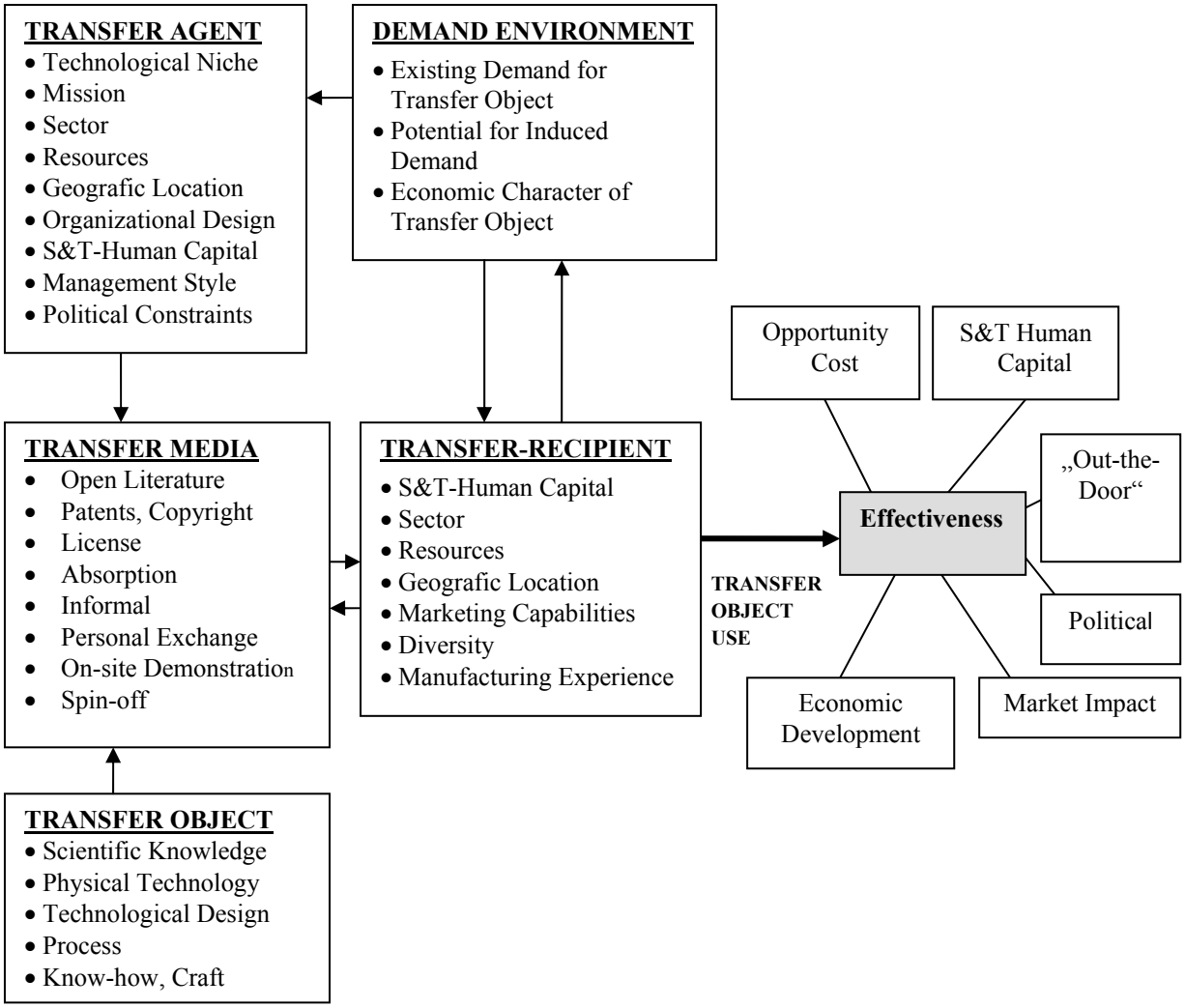
The stage model represents no linear process of knowledge transfer, which takes place gradually from level one to four. Each step in itself represents a kind of knowledge transfer, which differs from one another by its success criteria. The complexity of transfer increases with each step. A collaboration of knowledge-giver and knowledge-recipient is needed mainly in the second and third stages 'acceptance' and 'implementation' of research results, while in stage one and four the 'generation' and 'application' of research results each actor is responsible on his own.

The Contingent Effectiveness Model of Technology Transfer of Bozeman

A second model of knowledge transfers that can be used as a basis for developing an own model of knowledge transfer is the "Contingent Effectiveness Model of Technology Transfer" by Bozeman (2000, see Figure 3). Bozeman (2000) developed his model of technology transfer based on an analysis of numerous recent publications in the field of technology transfer research from universities and other public research institutions. The model is thus the result of a systematic mapping of scientific contributions and recognized as such, a wide range of issues that are dealt with in the

literature. Bozeman's effectiveness model is therefore suitable as a starting point for developing an own model of knowledge transfer to analyze the effectiveness of transfer barriers.

Figure 3: The Contingent Effectiveness Model



Notes: Bozeman (2000:636), S&T = Scientific and Technical

According to Bozeman (2000) knowledge or technology transfer between the public and private sector is a complex process that depends on the involved actors, (1) the transfer agent, the research institution that generates and disseminates the research results, and (2) the transfer recipient, the company that tries to incorporate the research results in their own products and production processes, their characteristics as well as their interactions. Furthermore the constitution of the transfer object, e.g. the knowledge to be transferred, the transfer channel through which the results are disseminated and the economic environment in which the transfer takes place are important features of Bozeman's technology transfer model.

The broad definition of knowledge transfer effectiveness opens up the view on a wide range of potential barriers by which the effectiveness of the transfer can be adversely affected. The model distinguishes six criteria by which the effectiveness or success of technology transfer are determined. A simple criterion is the criterion of "out-the-door" that Bozeman and Coker (1992: 243) in an earlier publication described as follows: "The 'out-the-door' model assumes that transfer itself equates with success. Once the technical good has been adopted by another organization, then an instance of successful technology transfer has been accomplished." The 'out-the-door' criterion is closest to this work underlying criterion for knowledge transfer: the unspecified use of knowledge by companies.

The cornerstones of this model are - according to the characteristics of each of the five areas - different aims of the involved actors in connection with different criteria for determining the effectiveness of the transfer: "The Contingent Effectiveness Model draws its name from its assumption that parties to technology transfer have multiple goals and effectiveness criteria" (Bozeman 2000:637).

4.2. **An Interactive-Recursive Model of Knowledge Transfer**

The presented models offer possible approaches for developing an interactive-recursive model of knowledge transfer which is suitable for the analysis of barriers.

First of all it is necessary to realize the shortcomings of the models of Gibson and Rogers (1994) and Bozeman (2000). The real deficit with view to the possible transfer barriers in the stage model of Gibson and Rogers is the lack of interaction specification of the knowledge transfer actors involved. In addition, the importance of tacit knowledge in particular in connection with the transfer of knowledge from external non-corporate sources remains not considered. Gibson and Rogers do recognize the interaction of the actors as an important element of the transfer process: "[W]e can think of technology transfer as in interactive process with a great deal of back-and-forth exchange among individuals over an extended period of time" (Rogers and Gibson 1994:33) while Gibson and Smilor (1991) stressed that the scope of the transfer actors must be taken into account (Gibson and Smilor 1991:290 f.). In the level model this two aspects ‘interaction’ and ‘scope of action’ are only striven and pushed into the background in favor of a focus on the process of the - mainly company-internal - transfer process.

Furthermore, the model of Bozeman has shortcomings related to the interactivity of the process involved in knowledge transfer. Schmoch et al. (2000) indicate that it is essential for a scientific research institute as knowledge generator to be informed about ongoing developments in relevant technology companies as knowledge-recipients. It adds that the knowledge-taker may have high impact on the transfer object e.g. within research collaborations and contract research. Based on these arguments Schmoch et al. (2000) complement the model of Bozeman by a direct relationship between transfer-recipient and transfer-agent (Schmoch et al. 2000:9, 13).

The extension of Schmoch et al. (2000) draws attention to the actual deficits of the model. In contrast to the stage model it does provide a comprehensive overview of the system of knowledge and technology transfer, emphasizing the interactions of diverse actors. However, questions about the impact of different factors, the *how?* and *how much?* and their interaction over time do not come apparent. In addition, the model lacks a systematic consideration of components that are beyond the direct observation: specific interests and dependencies, as well as the involvement of cognitive and cultural characteristics of the actors.

This paper does not aim at describing the complex process of knowledge transfer as a whole, which is – as Bozeman (2000:627) stresses – practically impossible even in outline. It aims to explore potential barriers in the process of knowledge transfer. Significant here are the possibilities and limits of the interactions of the actors involved in the light of relevant interests.

In contrast to the connected components in the technology transfer model of Bozeman (2000), Gibson et al. depict a clear sequence of seemingly self-contained units. However, in the context of research collaborations those isolated levels of knowledge transfer are to a significant extent dependent on each other. The expectations of the firms with regard to the adoption and implementation of research findings will have an important influence on the acceptability of research and participation in the knowledge generation process. This in turn affects the diffusion of the results.

A comprehensive model of knowledge transfer, which also includes the transfer of pre-competitive knowledge, requires - compared to the models discussed - adjustments and modifications.

First, the four levels of the step model have to be reduced to the original underlying three levels. Level°3 ("Application") and Level 4 ("Implementation") differ in terms of the success criterion, but not essential in view of the procedural nature of transfer. Second, it is necessary to differentiate Bozeman's five dimensions or determinants of effectiveness in actors and determinants of knowledge transfer and supplement with respect to their function within the knowledge transfer and adaptation process. The particular modifications are explained with reference to the gradual development of a

knowledge transfer model. Three elements are characteristic for its structure: The fundamental dimensions of knowledge transfer, the respective actors and the determinants of the transfer process.

Fundamental dimensions of knowledge transfer

The identification and analysis of barriers in the process of knowledge transfer requires a comprehensive concept of knowledge transfer to not obstruct the view of potential transfer barriers a priori. Knowledge transfer is understood here as a complex interactive, non-linear and possible recursive process, which - according to the stage model of Gibson - has three basic dimensions:

- *knowledge generation* (defined by the process of topic selection, project selection and project implementation),
- *knowledge diffusion* (defined by the process of preparation and dissemination of knowledge) and
- *knowledge absorption* (defined by the process of assessment, assimilation and application of knowledge).

The concept of knowledge transfer is therefore not regarded merely as a link between existing knowledge and its application, but encloses constitutively the generation of knowledge and its absorption by the knowledge-taker. The notion dimension is used here in reference to its use in mathematics, where it essentially indicates the degrees of freedom of movement in a particular area. Each of the three dimensions is understood as an integral part of the knowledge transfer process (motion), within the scope of possible design (degree of freedom) by the actors in relation to certain determinants of knowledge transfer (space) is determined.

The establishment of three fundamental dimensions of knowledge transfer expresses the process-related character of knowledge transfer. This should not be thought of as a unidirectional sequence, but must be understood non-linear and potential recursively, because he has neither a real beginning nor real ending. It does not begin with the generation of knowledge and does not end with its usage – this would be equivalent to a linear notion, as it was prevalent for a long time (Wahab et al 2009). Knowledge transfer is rather understood as a continuous, never-ending process, in which a new spiral of knowledge transfer can be set in motion at any point, and in which the direction of the process can be turned the other way around at any point.[5]

In the course of project works it may be necessary, for example because of partial results, to reconsider the project issues and either adapt ongoing research recursively, or initiate a new project and thus a new spiral of knowledge transfer. The model fulfills therefore the requirements of a non-linear concept of knowledge transfer:

> "The concept of non-linearity implies that innovation is stimulated and influenced by many actors and sources of information, both inside and outside the firm. It is not only determined by scientists and engineers working in R&D or the top-management. In addition, there are interactions feeding back the experience of production, marketing, and of customers into earlier phases of the innovation process." (Kaufmann und Tödtling 2001:804; vgl. Cohen et al. 2002:3)

The establishment of three fundamental dimensions has the advantage in that it combines the benefits of now obsolete linear models with the epistemological requirements of recursive models by describing the processes of knowledge transfer in the time without necessarily thinking of it as a (uni-) linear. Schmoch et al. note in relation to recursive models of the innovation process, that "the insight that linear models are obsolete is generally accepted. However, there are no ideas how alternative processes could look like" (Schmoch et al. 2000:6).[6]

[5] This view of the knowledge transfer process as a never-ending, spirally developing process corresponds to the process of knowledge generation, particularly outlined by Nonaka and co-authors.

[6] Etzkowitz and Goktepe (2005) who argue in relation to the U.S. Technology Transfer Offices for an "assisted linear model of innovation" notice in this context: „The linear model, often declared 'dead' in the innovation

Players of knowledge transfer

The motives and resulting actions of the players are of crucial importance for the analysis of knowledge transfer processes and potential barriers within each of the three basic dimensions. Extensive literature studies have shown that empirical and theoretical work on knowledge transfer usually differentiates only knowledge-donor and knowledge-recipient at the subject level. This differentiation is for an analysis of the barriers of the knowledge transfer process misleading in two respects. First, it gives the impression that there were two groups of actors in the process of knowledge transfer, either interactively operating, but nevertheLEs clearly distinguishable: the group of those who 'gives' and the group of those who 'receives'. A distinction between the two groups is under functional aspects useful, but must not obscure the fact that in practice it may well be intersections of stakeholder groups in research collaborations, such as companies, both as a knowledge-donors, as well as knowledge-takers. Second, it suggests that the consideration of two groups of players would be sufficient for an analysis of the transfer process. In view of possible barriers an adequate analysis of the role and function of the actors in the knowledge transfer process requires the establishment of three player groups:

- *knowledge-creators*: those who are actively involved in the creation of knowledge. In the model it represents the group of actors in the dimension of knowledge creation.
- *knowledge-disseminators*: those who are actively involved in the dissemination process of knowledge. In the model it represents the group of actors in the dimension of knowledge dissemination.
- *knowledge-takers*: those who accept and absorb the generated and disseminated knowledge. In the model it represents the group of actors in the dimension of knowledge absorption.

This three-fold differentiation of the player groups corresponds to their role and function in all three dimensions. The significant advantage of this tripartite division is also the fact that the pre-competitive knowledge transfer is taken into account, as knowledge-takers do not necessarily have to be involved in the process of knowledge creation and diffusion, but it can be. In this way the model is suitable to describe manifold forms of knowledge transfer.

For the success or failure of knowledge transfer the key stakeholder groups within each dimension are of crucial importance. The fundamental factors of knowledge transfer are determined by the interaction of knowledge-creator, knowledge-disseminator and knowledge-taker. The output or the results of their actions in each of the dimensions produce the determinants of knowledge transfer, which are in the center of attention within the analysis of transfer processes.

Determinants of Knowledge-Transfer

The nature of knowledge transfer determinants is of vital importance for the analysis of knowledge transfer processes and potential barriers. Since formed within each of the three basic dimensions, a differentiation of the knowledge transfer process in three dimensions is due primarily analytical considerations. Determinants of knowledge transfer are defined as:

- *transfer-object* in the context of the dimension of knowledge creation,
- *transfer-media* in the context of the dimension of knowledge dissemination, and
- *absorptive ability* of the knowledge-taker in the context of the dimension of knowledge absorption.

Object, media and absorptive ability are called determinants because its characteristics are decisive for the success of knowledge transfer. The model of Bozeman (2000) includes besides the actors (agent

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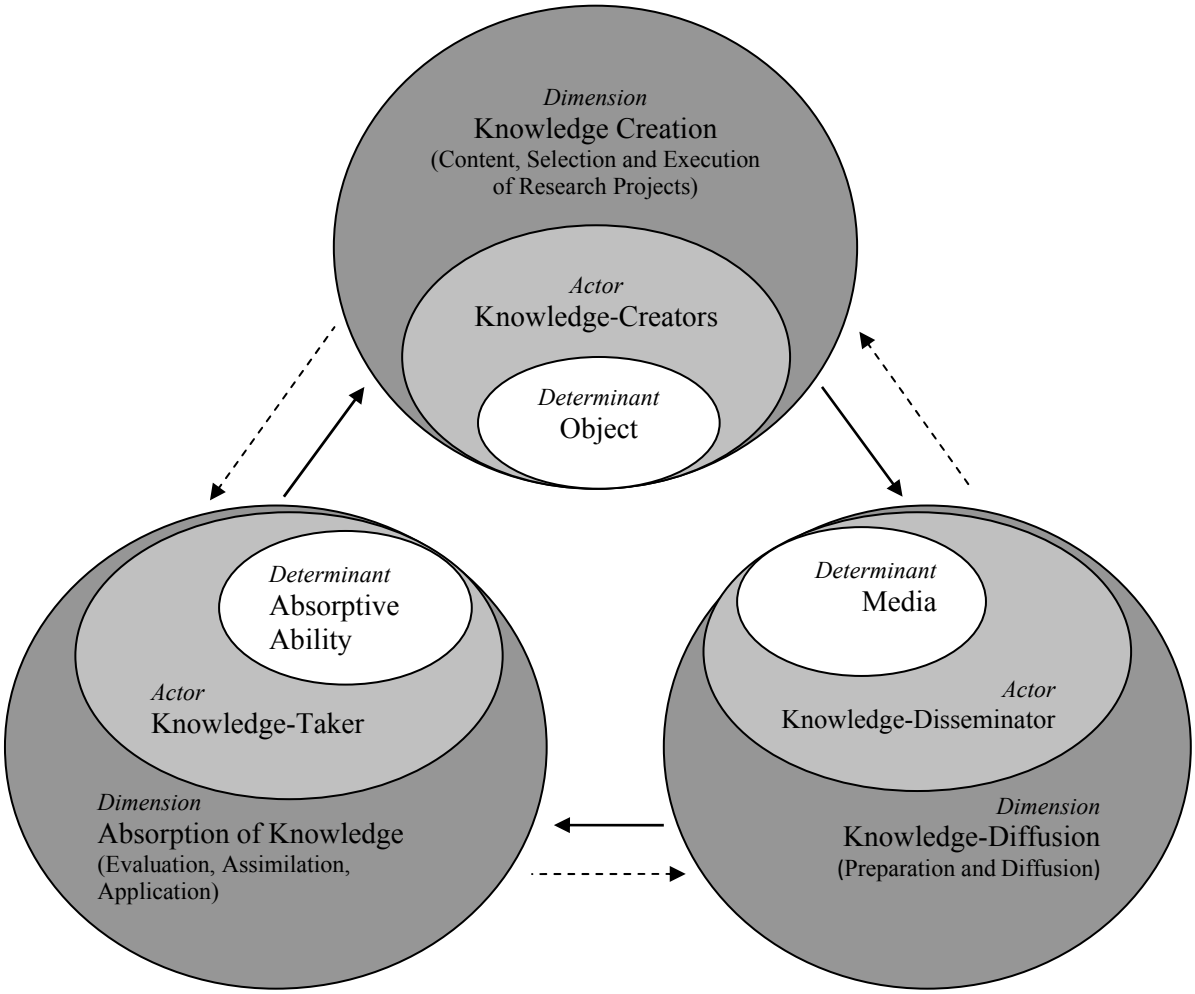
literature is like the mythical hydra whose head reappears doubled when it is cut off" (Etzkowitz und Goktepe 2005:1).

and receiver), the determinants of the transfer-object, the transfer-media and the demand environment. The concept of the object is retained and adopted for the recursive-inter-active model of knowledge transfer. It describes knowledge as a result of the process of knowledge creation in its entirety. Also, the term transfer-media can be assumed unchanged and incorporated in our model with the same meaning. The concept of media, understood as a communication medium of any kind, includes all forms and actions which by their nature are liable to disseminate the results of knowledge treatment and processing. Though, Bozeman's term "demand environment" requires a modification in this context. In the interactive-recursive model the determinant in terms of knowledge absorption is formed by characteristics of the knowledge-taker in relation to its absorptive ability. The choice of the term absorptive 'ability' emphasizes that absorption is not only determined by objective factors as they are described for instance within the concept of absorption capacity of Cohen and Levinthal (1989,1990). In addition subjective and cognitive factors are of crucial importance. Decisive for the absorption of knowledge is not merely the fact that the potential recipient has the necessary capacity and is therefore able to absorb external knowledge, he must also intend to. The concept of absorption ability, as used in this study includes all those properties, ranging from human and material resources to profound cognitive attitudes and expectations, which determine the opportunity of the knowledge-taker to apply externally generated knowledge.

The relationship between object, media and absorption capacity of the knowledge-taker is reflected in the procedural character of the three dimensions. The transfer characteristics of the object are undoubtedly of great significance for the combination of the most suitable transfer media. Both object and media are not to be seen in isolation from the absorptive ability of the knowledge-taker. In contrast to the effectiveness model of Bozeman (2000) the determinants of the interactive-recursive model are understood not individually but related to each other. In respect to the dimensions of the transfer process, the relationship between object, media and knowledge absorption ability of the knowledge-taker is to interpret neither linear nor unidirectional. While object and media may be influenced and designed in the process of knowledge transfer, this applies to the absorptive ability only to a limited extent. The absorptive ability of the knowledge-taker is much more important for the design of object and media than the opposite direction.

Figure 4: An interactive-recursive model of knowledge transfer



Notes: Own illustration

Specifics of the model

The interactive-recursive model of knowledge transfer depicted above (see Figure 4) is a comprehensive model insofar as it integrates different forms of knowledge transfer outlined in the literature. This is made possible through the establishment of three basic dimensions and the connection of each dimension with a group of actors that represent the variables of the model. The particular group of actors is defined by their participation in the respective dimension. The composition of the major players involved in each dimension can vary depending on the type of knowledge transfer from case to case. Basically, all actors treated in the literature can be taken into account. The aspect of interaction in the process of knowledge transfer is here – in contrast to previous models, in which interactive relations are usually indicated with the help of arrows – integrated in the form of groups of actors. Motives and resulting actions of the players are crucial for the analysis of knowledge transfer processes within each dimension for the configuration of the determinants. Individual groups of actors such as private or public institutions and organizations, research institutes and companies are therefore not analyzed separately, but always in conjunction with all other stakeholders of significant importance within the same dimension.

The basic dimensions of the model - depending on interest in knowledge and, ultimately, from the data available for empirical verifiability - can be further differentiated without violating the overall design of the model. Another dimension requires just the addition of a new group of relevant actors; the mapping of the determinants remains unaffected. Thus it is conceivable to differentiate the dimension of knowledge creation in e.g. topic selection and project implementation. The analysis of the knowledge transfer process then refers to the act of issue discovery and actors involved in project implementation. The differentiability of the model makes it possible to integrate other models of knowledge transfer perhaps from the field of organizational learning. The dimension of knowledge absorption, for example, could be differentiated according to the five stages of organizational learning within the model by Gilbert and Cordey-Hayes (1996:309): acquisition, communication, application, acceptance and assimilation.

5. Implications

The interactive-recursive model of knowledge transfer can serve as a basis for the identification and analysis of potential transfer barriers. Based on the assumptions that (1) research projects lead to positive results respectively solutions are found for previously defined problems, and that (2) the existence of these solutions are known to a circle of potential knowledge-takers, barriers of knowledge transfer - including the perspective of SME – may happen basically in two ways: Either (1) the potential for knowledge is not or not sufficiently relevant to the knowledge-taker or (2) it is indeed relevant, but the knowledge-takers are not able to absorb the knowledge. The latter may be caused by the fact that (a) the results are not available or only available in inadequate manner, or that (b) the abilities of the potential knowledge-taker are not sufficient to evaluate, assimilate and apply the external knowledge.

The question about the possible transfer barriers associated with relevance, applicability and utilization of externally generated knowledge are in the focus of a subsequent work in progress.

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