Knowledge Spillover Effects in German Knowledge-Intensive Industries

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ABSTRACT

It is widely assumed that firms collaborating in Research and Development (R&D) activities benefit from knowledge spillovers. However, there has been little discussion about the synergistic effects of knowledge spillovers and R&D collaboration. This paper examines the role of three types of knowledge spillovers, namely internal, market and institutional. R&D collaboration mediates the knowledge spillovers effects in the proposed structural equation models. This study demonstrates that German knowledge-intensive firms prefer internal knowledge transfer and market R&D collaboration, respectively. The empirical evidence shows that these tools promote innovation performance. The highest effects are obtained for the combination of market knowledge spillovers (.043***) and market R&D collaboration (.066***). This research thus provides justification for this strategy. It also shows that public financial support represents an effective measure for establishing R&D collaboration based on knowledge spillovers generated in the communication within the firm, in the market and with public institutions. The support of market and institutional R&D collaboration seems to be particularly important.

Keywords: Knowledge spillover, knowledge-intensive industries, innovation, collaboration, Germany

I INTRODUCTION

The great advance in new technologies in the last years has become the driver of the world economy in all industrial sectors (Chesbrough, 2006). Many theoretical and empirical studies have analysed the relationship between innovation capacity and technology-orientation of the firm (Hakala & Kohtamäki, 2011). They confirmed that the use of high-technologies has a positive effect on firm's product and process innovation success. The globalisation leads to higher dynamics of the use of high-technologies. This is associated with the price reduction of the available technologies, increasing scope of their use in "common practice". The rapid tempo of new knowledge application paradoxically requires a high initial investment in science and research (Carpenter & Petersen, 2002).

The firms and organizations that do not have investment necessary for a continuous stream of new technologies, must find new ways to provide them. More intensive cooperation in innovation processes seems to be a solution; the firms have to cooperate with the specific type of partners (customers, suppliers, competitors, etc.) on innovation processes. The cooperation with a large number of partners forms a cooperative network where every subject involved contributes with specific assets (from common production factors to patents, technology, knowledge or know-how) (Tsai, 2001; Matatkova & Stejskal, 2013; Hajek et al., 2014). These assets form the comparative competitive advantage of the firm. However, the firms have to be willing to share these sources of the advantage in the knowledge network (Meihami & Meihami, 2014).

It should be noted that companies build up and maintain only those relationships which are particularly valuable for them. As companies differ in respect of their needs for networking, it is plausible to assume that companies also differ in respect of the types of external partners they collaborate with (Gemünden, Ritter & Heydebreck, 1996).

The cooperating subjects are forming the networks, which are sometimes based solely on co-operation ties, but the networks based on knowledge usually achieve a greater efficiency. Some authors agree that the network configuration is shaped by both the importance of cooperation (perceived by the members of the network) and the intensity of cooperation. In knowledge networks, the synergistic and knowledge spillover effects occur. These effects significantly increase the efficiency of knowledge and innovation processes (Alegre, Sengupta & Lapiedra, 2013; Puškárová & Piribauer, 2016; Wang et al., 2016).

So far, however, there has been little discussion about the synergistic effects of knowledge spillovers and Research and Development (R&D) collaboration. This paper aims to shed some new light on the role of various types of knowledge spillovers on R&D collaboration and innovation performance, respectively. Specifically, it is hypothesized that firm innovation performance is significantly affected by the synergistic effects of knowledge spillovers and R&D collaboration.

The remainder of this paper is structured as follows. In the next section, a theoretical background is presented on knowledge spillover effects. Section 3 provides the research methodology and the characteristics of the data. Section 4 provides the empirical results. In Section 5, the paper is concluded, some political

implications are discussed and future research directions are suggested.

II THEORETICAL BACKGROUND

As mentioned above, knowledge, ability to learn and creativity are precisely those production factors which constitute a source of competitive advantage of different economic actors across the world. The transfer and acquisition of knowledge are realized in networks. Knowledge as a production factor is both easily transferable (codified explicit knowledge) and hardly transferable (un-codified tacit knowledge). Cooperation-based network simplifies the transfer of tacit knowledge. During the cooperation, knowledge articulation and subsequent knowledge transfer is realized. In parallel, knowledge spillover effect occurs too. Generally, the more knowledge is codified, the less possibility of control the owner has. He cannot exercise the ownership rights; there is no control of who receives the tacit knowledge, because its transfer can be influenced by other employees and the transfer also influences others.

However, this does not mean that un-codified knowledge cannot lead to a spillover. Note that this phenomenon is not so common and easy. Tacit knowledge is largely dependent on the absorption ability of firms (and their employees). Mueller (2006) describes the absorption capacity of firms such as the ability to produce, identify and utilize knowledge. This ability depends on the existing knowledge stocks and the absorption capacity of subjects (employees in firms or researchers at universities or research institutions).

Many studies show that knowledge spillovers are an important determinant of the innovative effects (Hajek & Stejskal, 2015). They were defined as unintended, unplanned (and often unwanted) effects, which cause the transfer of knowledge between the different actors. It is a kind of externality, i.e. the transfer does not require any direct costs, and they are incurred outside the market, and have a direct impact on the firms' production function. If there is a knowledge transfer between the originator and the recipient, we call it direct spillover effect. A knowledge transfer realized with the assistance of a third side is then called indirect.

Theoretical approaches define several types of individual spillover effects. Some authors distinguish borrowed knowledge from those obtained by spillover (Lee, 2006), further scholars divide the effects into monetary and non-monetary (Fischer et al., 2009). Monetary spillover effects is embodied in the tradable capital, whereas non-monetary are generated by activity that is financed from the public sector (such new knowledge have the character of a pure collective good). The problem of non-monetary spillover effects is that their transfer cannot be reduced, controlled, and therefore they do not become a source of competitive advantage. Another way how to divide the spill-over effects is into vertical and horizontal (De Faria et al., 2010). Vertical spillover is associated with the interaction among the suppliers, competitors and customers, and it has a significant impact on research and development activities of the firms. The horizontal spillover occurs when firms are interacting with universities and research institutes, in particular.

There is one important categorization of knowledge spillover effects – according to the subjects that are the source of the effects. We distinguish the *internal knowledge spillovers* that arise in a closed unit (firm) and the effects occur among staff during the work tasks or implementation of research tasks in the firm (Henderson & Cockburn, 1996; Pallotta, Tubaro & Lomi, 2015). There are some advantages attributed to these effects: easy protection of the created knowledge, no spillover outside the firm, and a high level of efficiency (this follows from the very nature of entrepreneurial behavior). On the other hand, internal knowledge spillovers have several disadvantages: the absence of further knowledge expansion and high cost. The second type is *institutional knowledge spillovers* (Audretsch, Hulsbeck & Lehmann, 2012; Casper, 2013). These arise during the implementation of joint projects (often R&D-oriented) between firms and universities (or research institutes). The advantages are as follows: a broad knowledge base, sufficient quantity of skilled science workers from universities, and low cost. The disadvantages include a threat of both free spillover and inflexible university approach (this follows from the behavior of public research subjects). The third type of knowledge spillover effects arises when firms collaborate with any public sector organization - *governmental knowledge spillover* effects (Lichtenberg, 1987; Hayashi, 2003). These are mainly advisory and support public agencies, regional development agencies, associations and professional chambers. This collaboration mode can be beneficial mainly due to the broad involvement of similarly oriented firms, whereas a high inefficiency of the public sector seems to be the disadvantage.

The last type of knowledge spillover is the effects arising from the market knowledge acquisition - *market knowledge spillovers* (where the knowledge acquisition or transfer are taking place in the market and under market conditions; Becker & Dietz, 2004). The advantages of this spillover mode are mentioned as follows: a high speed, technological innovations are found as a "turnkey" solution according to the demand assignment. A high cost and risk of insufficient supply from the market (and semi-market) entities are the disadvantages of market knowledge spillovers.

III DATA AND RESEARCH METHODOLOGY

Our research methodology is based on the conceptual model in Fig. 1, illustrating both the direct and indirect effects of knowledge spillovers on firm innovation performance. Previous literature has shown that knowledge spillovers positively affect firm collaboration and innovation activity (Montoro-Sanchez et al., 2011). As discussed above, collaboration is also regarded as a strong determinant of innovation performance. Therefore, we examined the effects of knowledge spillovers and collaboration in three modes, namely internal, market and institutional. Here, the collaboration (internal, market and institutional) mediates the effects of knowledge spillovers. In addition, the strengths of the effects can be further influenced by R&D expenditure and public financial support (Abramovsky et al., 2009). Therefore, we also included the moderating effects of internal R&D expenditure and public innovation support (local, regional, government and EU).

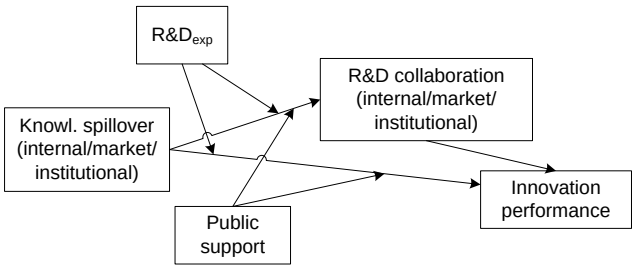

Figure 1. Conceptual Model.

Following previous empirical studies in knowledge spillovers analysis (Hashi and Stojcic, 2013; Stejskal and Hajek, 2015), we used the data collected within the Community Innovation Survey (CIS) carried out Germany for the period 2010-2012. The CIS combines stratified random sampling and exhaustive surveys are thus considered a reliable source of innovation statistics in the EU. The CIS is based on the harmonised questionnaire of EU Member States. The data set contained 6,328 German firms with at least 10 employees. We filtered only the firms in knowledge-intensive industries (NACE rev. 2 activities with more than 33% tertiary educated persons employed). As a result, we obtained data for 2,263 firms. In the data pre-processing step, we used linear regression for the imputation of missing values, where all input variables except the missing one were used to estimate the missing value.

In conformity with prior research (Montoro-Sanchez et al., 2011), we estimated the level of knowledge spillovers from the average degrees of importance of communication sources for innovation activities (measured on a scale from 0 – not used, to 3 – highly important). Thus, internal knowledge spillovers refer to the importance of communication sources within enterprise or enterprise group. Market spillovers come from suppliers, clients or customers (private and public), competitors and consultants. Finally, institutional spillovers include universities or other higher education institutions and government or public research institutes. The basic characteristics of the data show that firms mostly used internal and private customers' knowledge (Table 1). The same categorization was used for collaboration activities (dummy variable 0 for no and 1 for yes). Table 1 indicates that market collaboration was preferred.

Table 1. Descriptive statistics of knowledge spillovers and collaborative activities.

knowledge spillover	source	average
internal	SENTG	1.67
market	SSUP	0.72
	SCLPR	1.28
	SCLPU	0.65
	SCOM	1.05
	SINS	0.54
institutional	SUNI	0.84
	SGMT	0.21
collaboration		
internal		0.03
market		0.21
institutional		0.05

Legend: SENTG – information within company, SSUP – information from suppliers, SCLPR – information from private customers, SCLPU – information from public customers, SCOM – information from competitors, SINS – information from consultants, SUNI – information from universities, SGMT – information from government institutes.

The internal R&D expenditure included in-house R&D (80% firms), purchase of external R&D (14%), and acquisition of equipment and external knowledge (6%). Furthermore, 12% received local or regional public financial support for innovation activities, 28% government and 12% EU support.

The innovation performance of the industries was estimated by calculating the percentage of total turnover coming from new or significantly improved products introduced during the three years 2010 to 2012. On average, this share was 10% for the knowledge-intensive firms.

To examine the above-mentioned directs and indirect effects, we used structural equation models. In the models, internal/market/institutional knowledge spillovers were used as causal predictors of innovation performance, internal/market/institutional R&D collaboration was a mediator variable, and internal R&D expenditure and public financial support represented the moderators of the causal effect. Thus, we could estimate both the mediation and moderation effects. The modelling was performed using the structural equation models in the Process tool for SPSS (Hayes, 2013).

IV EMPIRICAL RESULTS

To extract uncorrelated input variables for structural equation models, it was necessary to perform a confirmatory factor analysis. We used maximum likelihood estimates to obtain factors. Specifically, we applied this procedure for market and institutional knowledge spillovers because there were more than one source for these input variables. As a result, we obtained one factor for each spillover. Table 2 shows the factor loadings for these new variables. Similarly, we performed the confirmatory factor analysis for internal R&D expenditure and public financial support (Table 3). Using Cronbach's alpha, we confirmed the internal consistency of the factors (all values at least > .60).

Table 2. Confirmatory factor analysis on knowledge spillovers.

market	factor loading	institutional	factor loading
suppliers	.669	universities	.808
customers - private	.706	R&D institutes	.808
customers - public	.540		
competitors	.782		
consultants	.523		

Table 3. Confirmatory factor analysis on internal R&D expenditure and public financial support.

internal R&D exp.	factor loading	public fin. support	factor loading
in-house R&D	.447	local/regional	.575
purchase of external R&D	.985	government	.669
acquisition of equip.	.942	EU	.604

Figure 2 shows the results of the structural equation model for internal knowledge spillovers. In this model, internal knowledge spillovers significantly promote both internal R&D collaboration and innovation performance. However, the effect of the internal R&D collaboration on the innovation performance is not significant. This suggests that the use of internal knowledge spillovers directly leads to innovation. Additionally, public financial support plays an important role in promoting innovation performance based on internal knowledge spillovers.

Figure 3 presents the model of market knowledge spillovers. In contrast to the previous model, market R&D collaboration represents a strong mediator of market knowledge spillovers. The indirect effect on innovation performance seems to be even stronger than the direct one. Market R&D collaboration can be significantly increased through public financial support rather than via internal R&D expenditure. On the other hand, internal R&D expenditure promotes innovation performance directly from market knowledge spillovers.

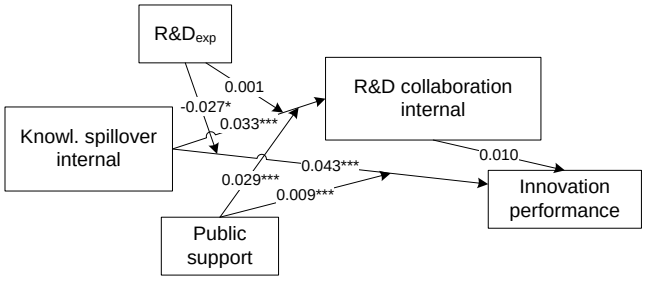

Figure 2. Effects of internal knowledge spillovers.

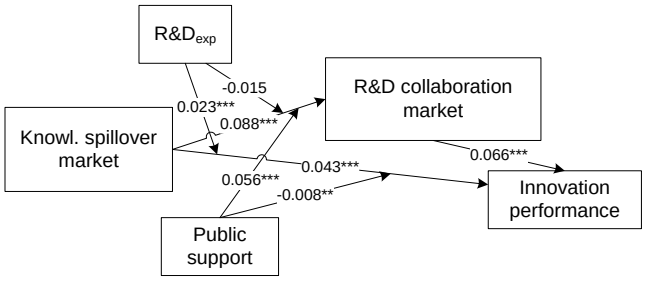

Figure 3. Effects of market knowledge spillovers.

Finally, institutional knowledge spillovers positively influence both innovation performance and institutional R&D collaboration. In addition, the effect of institutional R&D collaboration on innovation performance was also significant. Again, public financial support plays a critical role in supporting institutional R&D collaboration.

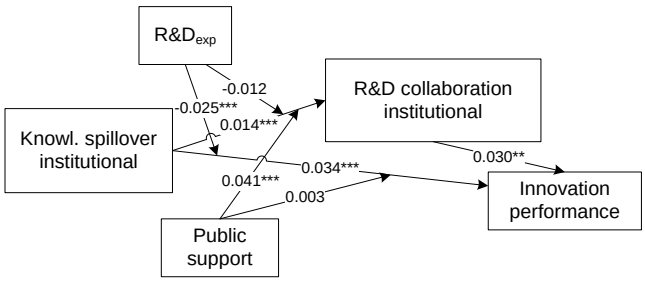

Figure 4. Effects of institutional knowledge spillovers.

V CONCLUSION

The research results confirm that all kinds of knowledge spillover effects have a positive impact on innovation performance. The bidirectional relationship of knowledge effects and collaboration was unveiled in German knowledge-intensive industries. Unveiling of (a) knowledge spillovers role and (b) public sector influence on innovations can help to define with greater precision the public policy and strategy. The effectiveness and outcomes´ efficiency will be increased of various government interventions. It will improve both the competitive advantages of economic entities and increase the welfare of the whole society.

The direct and indirect ties were revealed, thanks to them, the innovation performance is realized in practice. All our models confirmed the direct impact of knowledge spillover effects and innovation performance. For the direct tie we further certify that R&D expenditures allocated to direct support of innovative performance have no positive effect. In almost all cases, a negative effect of R&D expenditures was occurred (only in case of the market spillovers, R&D expenditures has positive effects; .023***). Weak and ambiguous effects of public subsidies were identified here.

Further, we analyzed the situation when all selected determinants (spillover effects, collaboration, R&D expenditures, and public support) are involved in innovative activities. The highest effects were measured in case when firms used the market acquisitions (.066***) and institutional collaboration (.030**). Spillover effects are in all three cases positive. The strong positive tie was observed in public subsidies, which aims to innovation collaboration (again, the strongest effects are in market spillovers). R&D expenditures once again have a significant impact. In this case, it should be noted that only in the case of institutional spillovers positive synergy effects were registered. In remaining two cases, there the lower effects were registered due to combination of determinants (even non-significant effect was resulted for indirect market spillover). All results are summarized in Table 4.

The results confirm that different determinants influence the innovative performance with varying degrees. The positive impact of cooperation and public support was shown. Further research should be oriented on investigating of various innovation determinants what are used in high developed countries. The leaders in innovation can provide a benchmark for further continuous improvement.

Table 4. Summary of knowledge spillovers effects (direct/indirect) on innovation performance (+ signif. positive, – sign. negative, 0 – not signif.).

effect	internal	market	institut.
direct	+	+	+
via collab.	+/0	+/+	+/+
R&D exp.	–/0	+/0	–/0
Public supp.	+/+	–/+	0/+

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