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An empirical study**

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Knowledge sharing, knowledge leaking, and relative innovation performance: An empirical study

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Abstract: External knowledge sharing and knowledge leakage often pose a strategic dilemma when firms conduct innovation activities. In this study, we focus on the positive and negative effects of this phenomenon. In particular, we empirically examine the effects of a firm's external knowledge sharing on its relative innovation performance under the contingencies of accidental and intentional leakage of business-critical knowledge. Results based on a survey of 150 Finnish technology-intensive firms show that external knowledge sharing has a positive effect on innovation performance, but high levels of accidental and intentional knowledge leakage by a firm's employees negatively moderate this relationship. These results contribute to the understanding of the potentially positive and negative issues related to external knowledge sharing and knowledge leakage, which have thus far remained empirically under-researched.

Keywords: External knowledge sharing; Accidental knowledge leakage; Intentional knowledge leakage; Inter-firm collaboration; Relative innovation performance

1. Introduction

This study focuses on the effect of external knowledge sharing on firm's innovation performance, taking into account accidental and intentional leakages of business-critical knowledge. The topic of the study is important due to the growing complexity and the progressively networked nature of innovation (Dhanaraj and Parkhe, 2006; Granstrand et al., 1997; Huizingh, 2011; Laursen and Salter, 2006), as firms are increasingly acquiring the knowledge which they need to innovate from outside their own boundaries (Duysters and Lokshin, 2011; Spithoven et al., 2010). Inter-firm collaborations, where knowledge and resources are exchanged enable firms to benefit from the advantages of both knowledge integration and specialization (Brusoni et al., 2001) and subsequent innovation performance (Dharanaj and Parkhe, 2006). However, innovation benefits may also be limited due to intentional and accidental knowledge leakage. This is the topic of the present paper.

Various streams of literature have theoretically outlined and empirically confirmed a range of important outcomes of inter-firm collaboration for the collaborating firms (Hardy et al., 2003). The organizational learning literature has emphasized not only the transfer of existing knowledge but also the creation of new knowledge. The networking literature has pointed out that firms that collaborate with others can change their position and become more influential in their networks. Studies in the field of strategy have examined why and how collaborations facilitate the sharing of various resources, including knowledge. Nevertheless, these different streams of literature share the view that difficulties and limitations exist when internally developing new knowledge (Christensen and Bower, 1996; Levitt and March, 1988; Nelson and Winter, 1982), and this makes accessing external knowledge paramount (Cohen and Levinthal, 1994; Rosenkopf and Almeida, 2003). Thus, firms with diversified networks across technologies and industries usually hold major advantages through access to a rich knowledge base.

Typically, the principle of *quid pro quo* controls access to external knowledge, meaning that firms need to share some of their own knowledge in order to get access to external knowledge that may develop or enhance their innovation activities. This is essentially trading, a business transaction process (Barachini, 2009). However, firms engaging intensively in external knowledge sharing also face the risk of unwanted knowledge leakage. In fact, the risk of business-critical knowledge leakage is a major factor that hinders knowledge sharing and collaboration (Hamel, 1991; Heiman and Nickerson, 2004; Martinez-Noya et al., 2013; Ritala and Hurmelinna-Laukkanen, 2009). Firms traditionally attempt to protect their innovation-

based competitive advantages with intellectual property rights (IPRs), trademarks, copyrights or other knowledge-protecting mechanisms (Choi et al., 2004; Hurmelinna-Laukkanen and Puumalainen, 2007; Teece, 1986). Recent studies have been increasingly vocal about the concerns firms and their managers have about the potentially negative effects of knowledge sharing due to unwanted knowledge spillovers and related costs (Casimir et al., 2012; Foss et al., 2010; Husted and Michailova, 2010). Several scholars have discussed means for protecting firms from employees who leak potentially harmful knowledge (Delerue and Lejeune, 2010; Hurmelinna et al., 2007; Hurmelinna-Laukkanen and Puumalainen, 2007) and from knowledge loss due to staff turnover (Lowman et al., 2012).

It is by now well established that intra-firm knowledge-sharing processes are associated with serious challenges (Ding et al., 2013; Lam and Lambermont-Ford, 2010; Witherspoon et al., 2013). These challenges are even more significant when firms share knowledge externally – in this case, knowledge crosses between organizational entities that have their own preferences, objectives and knowledge stocks (Bjerregaard, 2010; Husted and Michailova, 2010). It is therefore not surprising that fundamental differences exist between (managing) internal and external knowledge sharing (Chesbrough, 2007). Compared with research on internal knowledge sharing, research on external knowledge sharing seems to be less developed, partly because the latter is not part of the core activities of industrial firms.

In the literature, consensus occurs for the overall finding that sharing and acquiring knowledge is often a precondition for innovation in organizational and network contexts (Chesbrough, 2003a; Kogut and Zander, 1992; Sáenz et al., 2012). However, detailed examinations and an understanding of the potentially harmful effects of knowledge leakage for firms that share knowledge externally are still lacking. Questions remain open, especially in relation to the types of and motivations for knowledge leakage, as well as the effects of such leakages on external knowledge sharing and firm-level innovation performance.

In this paper, we empirically examine the effect of external knowledge sharing on innovation performance under the contingencies of accidental and intentional leakages of business-critical knowledge. We position our study in the ongoing and increasingly active scholarly conversation on external knowledge sharing, and we intend to make two key contributions to that conversation. First, while previous studies tend to treat knowledge leakage as a general, aggregated phenomenon, we differentiate between accidental and intentional knowledge leakage. Accidental knowledge leakage occurs when a company's employee coincidentally exposes business-critical knowledge not meant to be shared with external parties. Intentional knowledge leakage, on the other hand, refers to an employee's deliberate

action to expose such knowledge to other parties. Our study clearly differentiates between these two types of knowledge leakage, and we propose respective measurements for these two constructs. Second, we suggest that there is a need for a more thorough understanding of the moderating effects of knowledge leakage (whether accidental or intentional) on the relationship between external knowledge sharing and firm innovation. Knowledge leakage is a serious concern for many firms, and our results provide new evidence on this moderating effect. These results could help firms to allocate their resources better in terms of handling knowledge leakage in the context of external knowledge sharing.

We have structured the remainder of this paper as follows. First, we discuss our overall research framework and develop a theoretical argument and hypotheses for three specific relationships. In particular, we hypothesize that external knowledge sharing is positively associated with firm-level innovation performance. We also develop two moderating hypotheses, through which we argue that accidental and intentional knowledge leakage negatively moderate the relationship between external knowledge sharing and innovation performance. We then discuss our data collection and methods, followed by the empirical results. Finally, we outline theoretical and practical implications of our analysis and discussion, as well as future research directions.

2. Theory and hypotheses

As mentioned, in this study, we focus on the interplay between knowledge sharing, knowledge leakage and innovation. In general, scholars have recognized knowledge sharing as a source of innovation and value creation in both intra- and inter-organizational contexts (Dhanaraj and Parkhe, 2006; Dyer and Singh, 1998; Grant, 1996; Kogut and Zander, 1992). External knowledge sharing is an essential precondition for a firm's innovation outcomes since innovation by nature implies combining existing, often external bodies of knowledge in novel ways (Chesbrough, 2003a; Crossan and Inkpen, 1995; Huizingh, 2011). External knowledge sharing therefore requires designated attention in order to be successful (Dhanaraj and Parkhe, 2006; Rivette and Kline, 2000). Nevertheless, while knowledge sharing is necessary for innovations in a networked context, firms collaborating with external partners also risk losing knowledge that is critical for the company, such as trade secrets, core technologies and other types of strategically important knowledge (Baughn et al., 1997; Hannah, 2005). Leakage of confidential knowledge could be harmful for an innovative firm, as it might lead to lost competitive advantages. In fact, such leakages – or even the threat of such leakages – may

overshadow the benefits of knowledge sharing between firms (Hamel, 1991; Heiman and Nickerson, 2004). In the following sections, we develop arguments for hypotheses concerning these issues, starting with the effect of external knowledge sharing on innovation performance, and following that, on the role of knowledge leakage in this process.

2.1. External knowledge sharing and innovation performance

Although external knowledge sharing is often subject to false starts, disruptions and different interpretations of the same idea (Zellmer-Bruhn, 2003), it offers an excellent opportunity to explore and test the potential value of the knowledge shared and the potential markets for that knowledge (Chesbrough, 2003b). Both factors are important for a firm's innovation. For instance, passing knowledge to external partners is an efficient way for a firm to signal to other firms, including competitors, that the firm possesses knowledge of potential value to them (Husted and Michailova, 2010). This increases the attractiveness of the firm as a potential collaborative partner in innovation-related inter-firm projects. Thus, firms that share external knowledge are more likely to establish and engage in more inter-organizational collaborations specifically aimed at enhancing innovation.

Since external knowledge sharing often demands resources and depends on patience and numerous iterations, when firms repeatedly engage in such activities, they also tend to learn how to improve the ability of acquiring knowledge in return for knowledge shared. Such interactions facilitate the development of core competencies necessary for innovation (Quinn, 2000). If firms do not share knowledge externally, they may never achieve the full potential of their intended strategy. Not only would it mean that a firm might miss the opportunity to gain access to external knowledge but also that the firm's own knowledge might remain unused. This implies that although firms may refrain from external knowledge sharing because of the potential risk of knowledge leakage (Gans and Stern, 2003; Silverman, 1999), they may, in fact, achieve the opposite effect and hinder their own innovation efforts and performance in the process. Thus, strong competition in knowledge markets signals the opportunity for external knowledge sharing (Rivette and Kline, 2000; Teece, 2006) and can foster knowledge diffusion (Fosfuri, 2006).

When a firm shares external knowledge, it might improve its strategic network position. More centrally located parties tend to receive earlier warnings of upcoming promising results when compared to players located in the periphery (Clarysse et al., 1996) and have the opportunity to draw on the depth and breadth of a range of innovation capabilities and processes (Brusoni et al., 2001). This, in turn, can improve firm innovation performance as the

firm relies on knowledge and competencies that are not developed in-house (Gupta and Polonsky, 2014). Overall, we formalize this argument in the following hypothesis:

Hypothesis 1: External knowledge sharing is positively associated with relative firm-level innovation performance.

2.2. Knowledge leakage in inter-firm collaborations

While knowledge sharing involves various potential benefits for a firm's innovation activities, knowledge may also flow outside organizational borders in an uncontrollable, unwanted and even harmful manner. We refer to this phenomenon as *knowledge leakage*. Knowledge leakage is different from knowledge sharing. Sharing certain knowledge is in most cases an expected and desired behavior for a firm's employees to achieve certain strategic goals through the firm's collaborations – innovation being one such strategic goal. Leaking knowledge, on the other hand, is unwanted (accidental or intentional) behavior by employees who share knowledge that the firm would rather reserve internally.

Knowledge leakage has various negative effects on firms, including loss of revenue, damaged reputation, loss of productivity and costs arising from breached confidentiality agreements (Ahmad et al., 2014). It also decreases bargaining power and even creates new competitors for the original knowledge owner (Baugh et al., 1997). Therefore, when an employee leaks knowledge that is rare, inimitable and non-substitutable, recovery from such leakage can be very challenging (Ahmad et al., 2014; Barney, 1991, 1996).

IPRs and other mechanisms usually protect innovations in the process of commercialization. These mechanisms help the innovator to appropriate value from the particular innovation (Teece, 1986). Consequently, knowledge leakage is particularly harmful when related to innovations that have not yet reached legal protection through IPRs or other corresponding mechanisms. For example, leaking knowledge about a forthcoming product can be devastating for an innovative technology company, especially if the knowledge associated with it is easy to explicate. In such cases, the potential imitator would be able to copy and/or innovate around this knowledge, making the original innovator lose critically important lead-time. Therefore, not all knowledge can be protected by applying the above-mentioned mechanisms, especially knowledge related to inventions yet to be commercialized.

The knowledge management literature draws heavily on Polanyi's (1966) distinction between explicit and tacit knowledge. It is outside of the purposes of the current paper to engage in a thorough discussion of knowledge types, but we note that whereas explicit

knowledge can often be patented or otherwise formally protected because it can be documented, tacit knowledge is impossible or difficult to represent, is sticky and bound to its possessors, which is why it is perceived to be less vulnerable to leakages than explicit knowledge is (Wu and Lin, 2013) and difficult to operationalize (Ambrosini and Bowman, 2001). Tacit knowledge is best used in an environment where personal experience is needed and encouraged. The explication of tacit knowledge is like subconscious memory recall, which then develops into a “feeling” about the situation (Agor, 1986). Polanyi (1966) refers to this connection as “the basic structure of tacit knowing”, meaning that we are consciously aware of the memory recall only as it relates to the current cue, which could be either internal or external to the person.

While both explicit and tacit knowledge are valuable to firms that engage in inter-firm collaborations, it is explicit knowledge that is unlikely to be a crucial source of competitive advantages because it can be sold to other firms. Therefore, collaborations allowing also for the sharing of tacit knowledge assets are particularly beneficial (Reid et al., 2001) and collaboration partners must have access to tacit knowledge to add value to the partnership. However, allowing such access increases the risk of opportunism. Thus, trust and positive reciprocity serve as important moderators between shared tacit knowledge and innovation. Significant trust among collaborative partners enhances knowledge sharing because it allows the partners to put more effort into knowledge sharing and less effort into formal partner-monitoring activities (Dhanaraj et al., 2004; Nielsen and Nielsen, 2009). Ultimately, the norm of reciprocity is one of the underlying principal components of moral codes within social systems (Černe et al., 2014; Gouldner, 1960). In other words, in close interaction between people, both explicit and tacit knowledge can be transferred effectively.

A firm does not want to share everything it knows with its collaboration partners, as this can hinder the reaping of benefits from its innovation. On a strategic level, managers are generally likely to determine the rather clear limits of knowledge sharing. However, such limits may not be as clear to employees (e.g. R&D engineers) who are actually part of the collaborative interface and make decisions about what to share. The individuals in the collaborative interface are those who actually affect the success of the knowledge sharing activities and eventually affect the innovation performance of the firm as a whole.

Some existing studies provide evidence regarding the effects of knowledge leakage through collaboration. Quinn and Hilmer (1994) note the possible loss of vital knowhow, in particular regarding core competencies, as a major risk factor in outsourcing. The more strategic the partnership, the bigger the risks related to knowledge leakage (Hoecht and Trott, 2006). If

collaborative partners or third parties access firm-specific critical knowledge, they can use it to their benefit and at the expense of the original owner (Hannah, 2005). Furthermore, the extent to which a partner can take advantage of the knowledge gained is dependent on the absorptive capacity of the partner (Lane and Lubatkin, 1998), as well as other, firm-specific appropriability conditions and mechanisms (Hurmelinna-Laukkanen and Olander, 2014; Teece, 1986). The strength of a partner's or rival's capability to absorb knowledge assets has an effect on the harmfulness of the leakage. In the case of working with a partner with high absorptive capacity, the innovating firm risks losing its core knowledge assets and gaining rents from the innovation if its partner takes advantage of a knowledge leakage (Hurmelinna-Laukkanen and Olander, 2014). Liebeskind (1996) argues that the threat of a competitor imitating one's innovation limits investments in R&D and thus innovativeness.

Opportunism is another related issue that plays a role in a partner's decision whether to take advantage of leaked knowledge. Although different kinds of governance mechanisms, such as contracts and social governance, can control opportunism in general, it still may attenuate the risks of knowledge leaking (Olander et al., 2010). The negative consequences could be substantial for the company; hence, firms actively need to implement measures that reduce the risk of knowledge leakage. Employees are key actors in sharing external knowledge; thus, they are also in a key position to protect critical knowledge from leaking (Baughn et al., 1997; Hannah, 2005).

Finally, we divide knowledge leakage into two distinct types: accidental and intentional. Intentional knowledge leaks include a dimension of consciousness, whereas accidental knowledge leaks refer to an unintentional mishap. In the following section, we discuss these types of knowledge leaks from the perspective of their moderating effect on the relationship between knowledge sharing and innovation performance.

2.3. The moderating effect of knowledge leakage

There are several situations in which an employee could accidentally leak knowledge to an external collaborator in the context of intentional knowledge sharing. First, accidental knowledge leakage could occur when employees are unclear about what they can actually disclose to partners (Husted and Michailova, 2010). Second, employees could reveal more than what is necessary when they meet with colleagues from a partnering firm due to a lack of organizational control over collaborative environments in which knowledge is too readily available to partners, or by employees unthinkingly granting exhaustive information about designs, products and processes (Jiang et al., 2013). This could happen at professional fairs,

exhibitions, code committees or other formal or informal occasions. Third, over-enthusiasm about a new idea or innovative prospect could cause temporary negligence of protection responsibility when perceiving the other party as trustworthy. To that end, professional pride can affect eagerness and willingness to share knowledge (van den Hooff et al., 2012), as can curiosity and passion (Sié and Yakhlef, 2009). Given that employee leakage of business-critical knowledge leaves the employee's firm in the unfavorable situation of losing the benefits of its knowledge or the value of its innovations, we argue that accidental leaks to collaborative partners or third parties negatively moderates the positive effect of external knowledge sharing on innovation performance.

Hypothesis 2: Accidental knowledge leakage negatively moderates the positive effect of external knowledge sharing on relative firm-level innovation performance. The higher the accidental knowledge leakage, the lower the positive effect of external knowledge sharing.

Intentional knowledge leakage is an employee's purposeful action to expose her/his firm's critical knowledge to other parties. Even though we recognize that firms may intentionally leak some knowledge to create interest in the markets (e.g. leaking certain information about a product soon to be launched, thus creating more publicity or increasing anticipation), we suggest that this is a strategic (marketing) decision. In this paper, we focus on non-strategically planned, employee-level knowledge leakage. This refers to employees' intentional knowledge leakage due to misbehavior or, in extreme cases, betrayal (Hoecht and Trott, 2006).

Intentional leakage could be the result of employee frustration with the firm in terms of politics, organizational barriers, lack of trust (Casimir et al., 2012; Holste and Fields, 2010), personal benefit in the form of gaining "expert status" among peers (Husted et al., 2012) or aligning oneself with a collaborating partner rather than with one's own firm (Husted and Michailova, 2010; Husted et al., 2013). In addition, intentional leakages could relate to temporary negligence of an employee's protection responsibility due to over-enthusiasm and, thus, willingness to take self-decided risks in sharing knowledge.

As intentional leakage is a deliberate act of disloyalty or negligence, we argue that the resulting damage negatively moderates the positive effect of external knowledge sharing on innovation performance. This means that the firms in which employees intentionally leak business-critical knowledge do not gain as much innovation benefits from external knowledge sharing as do firms in which leakage is not an issue.

Hypothesis 3: Intentional knowledge leakage negatively moderates the positive effect of external knowledge sharing on relative firm-level innovation performance. The higher the intentional knowledge leakage, the lower the positive effect of external knowledge sharing.

3. Methods

A number of studies on knowledge and knowledge processes are positioned in a positivist space and we consider this study to be part of that tradition. (For an elaborated analysis of the differences between a positivist, social constructionist and social-cognitive approach towards the study of knowledge and knowledge transfer, see Ringberg and Reihlen, 2008). Unlike studies from a constructionist perspective, we assume that “objects in the world have meaning independently of consciousness” (Crotty, 2003: 27). From this epistemological position, we view knowledge as an objective entity, an objectified commodity that can be shared, leaked and managed. This does not imply that knowledge and knowledge processes are independent of meaning; it rather implies that meaning exists apart from the mind that perceives it. Such a position invites a quantitative approach to the phenomenon of interest.

Another argument for the appropriateness of a quantitative approach is Edmondson and McManus’s (2007) “methodological fit” – the internal consistency between the research question, the prior state of the literature and the methodology. Our research question is narrowly focused (i.e. not open-ended) – it examines the relationship between knowledge sharing/leaking and relative innovation performance – and the goal of our data analysis is formal hypothesis-testing. Furthermore, we have based our formulated hypotheses on existing constructs. The prior state of the related literature is mature in the sense that scholarly conversations on knowledge sharing, firm performance and the links between them have been taking place for a long time and have generated substantial knowledge already. These combined factors clearly point towards a quantitative empirical examination.

Accordingly, we collected the data for this study using a survey conducted in Finland during 2012. The initial sample included all members of the Federation of Finnish Technology Industries, a national industry association. This association represents the most important industrial sectors in Finland, as its members account for 80% of total Finnish R&D investments and 55% of total Finnish exports (Federation of Finnish Technology Industries, 2014). The initial sample included 1273 firms in the machinery and metal, electronics, information technology and planning and consulting industries. The sample selection had a threshold of at least 10 employees per firm.

Prior to conducting the survey, we pre-tested it with industry practitioners representing various areas of senior-level expertise. The rationale behind the pre-testing was to ensure that the potential respondent group would clearly understand all survey questions. During pre-testing, we rephrased several items to achieve greater clarity and comprehensiveness, and we left no ambiguous items.

Following key informant logic (Kumar et al., 1993), we wanted to send the survey to persons with a sufficient level of seniority to respond to the questions. Therefore, we sent the questionnaire to the Chief Executive Officer (CEO) of each firm. The survey included a cover letter, which discussed the informant's role as the key respondent of their respective organizations, and it stressed that the responses should represent the whole organization, using the informant's best available knowledge and judgment. Eventually, we received responses from 150 firms.

We measured the dependent variable, *relative innovation performance of the firm*, with a composite scale, on various innovation types and practices (four innovation types adapted from Weerawardena, 2003). Our approach was *relative*, in that we asked the respondents to assess their firm's performance in terms of innovation against companies operating in the same sector (=competitors). Our purpose was to examine the overall innovation performance of the firm, and in the absence of objective indicators such as patents (due to the heterogeneous nature of the firms in the sample), we believe that this measurement was a feasible solution. The reliability examination with Cronbach's alpha supported our belief, as the inter-item correlation was 0.74, which is considered a satisfactory level for reflective measures (e.g. Hair et al., 2006). In addition to the reliability examination with Cronbach's alpha, we examined the mean values and standard deviations of individual items in the dependent variable. We found them to be quite close to each other, supporting their use as part of the composite measure. The standard deviations ranged between 1.15 and 1.36, and the mean values between 4.16 (marketing practices) and 4.64 (products and services for customers).

We measured external knowledge sharing with a composite measure involving the items that concern the firms' employees sharing different types of knowledge with the firms' external partners (adapted from Choi et al., 2010). We chose this measure because it covered different types of knowledge that may be shared across organizational boundaries. The original measure (Choi et al., 2010) was used to measure internal knowledge sharing, while our measure is adapted for an inter-firm context. We expected the measure to work in the inter-firm context as well, since the knowledge types relevant to innovation are within the same range in both contexts. The Cronbach's alpha for this measure was rather high (0.82), suggesting that the

individual items reflect the underlying phenomenon well. This result supports our belief that firms' sharing a little or much knowledge do so quite consistently across different knowledge categories.

Due to the lack of validated measures for knowledge leakage, we measured it with two self-developed separate constructs: accidental and intentional knowledge leakage. In forming the items, our intuition was that the respondents can differentiate between strategically wanted and unwanted knowledge sharing (i.e. whether the knowledge is shared or leaked) and between an employee's accidental or intentional knowledge leakages. To facilitate this understanding, we defined "business-critical knowledge" for the informants as "the type of knowledge that significantly affects the possibilities of the company to operate competitively in its markets". We then used the business-critical concept as part of both accidental and intentional knowledge leakage items.

First, we measured accidental knowledge leakage with a two-item composite measure that included a) employees of a firm accidentally leaking business-critical knowledge to external partners or b) accidental leakage of business-critical knowledge in other situations. We employed these two items because the respondent may differentiate between accidental knowledge leakages to partners and in other situations. For the first item, an employee leaking knowledge to a partner might not always be regarded as harmful; it could even be considered as a positive situation if the respondent could not see a difference between knowledge sharing and knowledge leakage. For the second item, we employed the wording "in other situations" to include every other circumstance in which employees could accidentally share confidential knowledge. These include professional fairs, exhibitions, code committees and other formal or informal occasions, including the employees' free time. Due to the respondents' "other situations" being so nebulous, we did not form an item from each of them; we merely differentiated between partners and other situations. To that end, for the two items addressing accidental knowledge leakage, the value for Cronbach's alpha was very satisfactory (0.92), implying strong support for this composite measure.

For intentional knowledge leakage, we used the same logic in formulating the two items, but they involved situations in which the employees knowingly leaked the information. In this case, Cronbach's alpha also had a high value (0.86), supporting the composite measure's internal reliability. We then made a logarithm transformation to this variable to ensure that it fit the normality assumptions for the regression analysis.

To extend our examination of the empirical difference and discriminant validity between the two types of leakage, we conducted an exploratory factor analysis. We found that the items

for the two types of leakage loaded clearly to two different factors without major side-loadings. This supported our theoretical argument for the distinctiveness between the two types. Furthermore, in examining the correlations between knowledge-sharing and knowledge-leaking measures (Table 1), we observed that the correlations are not significant, which further supports our view that the informants did perceive sharing and leakage as separate phenomena. All measures, items and reliabilities are reported in Appendix A.

We also included a range of control variables in the analyses to ensure that the independent variables had their own relevant explanatory power. First, we used industry dummies aligned with the official categorization adopted by the Federation of Finnish Technology Industries. We used the manufacturing and mechanical engineering industry as the benchmark dummy, and we included industry dummies for the electronics and electrotechnical, information technology and consulting engineering industries. Second, we included control variables for firm size and age. Chandy and Tellis (2000) have shown that firm size affects innovativeness in various ways, and Henderson and Clark (1990) have suggested that firm age affects the novelty of innovation; for example, younger firms produce outcomes that are more novel. We also controlled for the focal firm's R&D intensity, as we wanted to control for the differences between firms in terms of R&D efforts on innovation performance. If a response was missing for R&D intensity, we replaced it with an industry-specific median value. We then made a logarithm transformation to the variables to ensure the normality of the distribution.

Before we attend to the results of testing the three hypotheses, we offer a note on the levels of analysis in our study. Our empirical design implies a transition from individual employee actions to outcomes at the organizational level. An organization is a salient entity composed of individuals. Beyond the sum of individual employees, however, organizational phenomena emerge via multiple pathways through which the individual and collective are interconnected and influence both the individual and collective context (Chen and Kanfer, 2006). Individuals comprising an organization are exposed to similar events, their actions are shaped by their common context and they share physical proximity and a common fate (Campbell, 1958). Furthermore, at least to a certain extent, they coordinate their efforts to achieve common goals (Chen et al., 2009). Through individual actions and interactions, shared meanings and norms emerge as organizational properties that operate to limit the variability of individual differences and perceptions. In other words, a collective interpretation of external and internal stimuli enables individuals to act collectively, which, in turn, enables collective phenomena to emerge (Morgeson and Hofmann, 1999). Thus, it is possible to aggregate individual actions to study phenomena at a higher level of analysis – in our case, the organizational level.

4. Results

Table 1 reports the descriptive statistics and correlations of the variables used in this study. A notable issue is that the mean value of R&D intensity is relatively high. Several firms reported very high R&D intensity numbers, which skewed the distribution. As a remedy, we took a natural logarithm from the R&D intensity variable. In addition, we ran the regression analyses (as reported in Table 2) without the three firms for which this variable had significantly above-average values. The results remained similar in this case, and thus, we report here the results of the analyses using all available data.

Table 1 Descriptive statistics and correlations.

<i>Variable</i>	<i>Mean</i>	<i>S.D.</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>
1. Innovation performance	4.39	0.94						
2. External knowledge sharing	3.51	1.53	0.35**					
3. Accidental knowledge leakage	2.49	1.38	-0.11	-0.11				
4. Intentional knowledge leakage	1.74	1.24	0.07	-0.03	0.56**			
5. Firm age	18.93	14.51	-0.04	0.05	0.10	0.13		
6. Firm size (Millions of Euro)	42.06	174.07	0.11	0.08	0.00	0.02	0.01	
7. R&D intensity	85.17	979.41	0.18*	0.27**	0.02	-0.01	0.07	-0.01

* $p < 0.05$; ** $p < 0.01$

S.D. = Standard deviation

To examine our hypotheses, we conducted linear regression analyses in five steps (Table 2). The first model included all control variables. In the following models, we ran separate tests for the effects of intentional and accidental knowledge leakage because they had a sufficiently high bivariate correlation, which may create problems, inflating the coefficients when inserting them in the same model. Therefore, the second model added the variables on external knowledge sharing and accidental knowledge leakage, and it tested their direct effects, while the third model tested their interaction effect. The fourth and fifth models involved the same logic, but with external knowledge sharing and intentional knowledge leakage. Based on the F values, all the models after the control variables and the changes therein had a good and significant model fit. The R^2 values showed that adding the independent variables after adding the controls increased the explanatory power of the models.

Table 2 Results of the hierarchical linear regression analysis (standard errors in parentheses).

<i>Dependent variable:</i> <i>Innovation performance</i>	<i>Model 1</i> ($R^2 = 0.10$)		<i>Model 2</i> ($R^2 = 0.18$)		<i>Model 3</i> ($R^2 = 0.22$)		<i>Model 4</i> ($R^2 = 0.19$)		<i>Model 5</i> ($R^2 = 0.22$)	
Control variables										
Electronics and electrotechnical industries	-0.05	(0.24)	-0.11	(0.24)	-0.13	(0.23)	-0.10	(0.23)	-0.06	(0.23)
Information technology industries	0.07	(0.26)	0.02	(0.25)	0.01	(0.25)	0.03	(0.25)	0.02	(0.25)
Consulting engineering industries	0.20*	(0.22)	0.17	(0.22)	0.17	(0.21)	0.15	(0.22)	0.15	(0.21)
Firm age	-0.04	(0.10)	-0.04	(0.10)	-0.05	(0.09)	-0.06	(0.10)	-0.04	(0.09)
Firm size	0.18*	(0.05)	0.16	(0.05)	0.21*	(0.05)	0.16	(0.05)	0.17	(0.05)
R&D intensity	0.21*	(0.04)	0.14	(0.04)	0.17	(0.04)	0.13	(0.04)	0.16	(0.04)
Focus variables										
External knowledge sharing			0.29**	(0.08)	0.26**	(0.08)	0.30**	(0.08)	0.28**	(0.08)
Accidental knowledge leakage			-0.08	(0.09)	-0.14	(0.09)				
Intentional knowledge leakage							0.12	(0.08)	0.10	(0.08)
External knowledge sharing × accidental knowledge leakage					-0.23**	(0.08)				
External knowledge sharing × intentional knowledge leakage									-0.20*	(0.07)
Model F	2.12		3.19**		3.76**		3.38**		3.73**	
Change in F			5.91**		6.97**		6.60**		5.43*	

* $p < 0.05$; ** $p < 0.01$ (two-tailed)

The results of the regression analyses helped us to test empirically the three hypotheses put forward in Section 2, having controlled the set of relevant control variables. The results of Model 1 show that firm size has a positive effect on innovation performance. R&D intensity also has a positive effect on relative innovation performance, as expected. Furthermore, examination of the industry controls shows that consulting and engineering industries more strongly relate to relative innovation performance compared with the other industries in the sample. All other industries in the sample are quite similar in terms of relative innovation performance levels. Thus, utilizing industry control variables in this study is useful in order to exclude the effect of sector-specific differences in relative innovation performance. After adding these control variables to the model, we proceeded to examine the actual hypothesis-testing models (models 2–5), which calculate the effects of the independent variables on the dependent variable of relative innovation performance, having accounted for the control variables. These models include both direct and moderating effects, allowing us to test each hypothesis.

First, as expected, external knowledge sharing positively affected innovation performance, supporting Hypothesis 1. This effect is consistent through all models (models 2–5), with a very strong statistical significance. Second, the results confirmed that accidental knowledge leakage negatively moderated this relationship, supporting Hypothesis 2. That is, the higher the accidental leakage, the less beneficial the effects of external knowledge sharing were on innovation (and vice versa, the lower the accidental leakage, the more beneficial the external knowledge sharing). Third, we also found support for Hypothesis 3, in that intentional knowledge leakage negatively moderated the relationship between external knowledge sharing and innovation performance.

5. Discussion, implications and limitations

Sharing knowledge externally exposes a firm to the risk of losing core, strategically important knowledge. In terms of inter-organizational relationships, scholars have widely recognized the dilemma of knowledge sharing and leakage (Baughn et al., 1997; Hamel, 1991; Heiman and Nickerson, 2004; Ritala and Hurmelinna-Laukkanen, 2013). In particular, when sharing knowledge with external parties, there is always a risk of unintended knowledge spillovers. Furthermore, the very possibility of knowledge leaking might hamper efforts to share knowledge in collaborations (Baughn et al., 1997; Hamel, 1991; Martinez-Noya et al., 2013), let alone the actually realized harmful consequences (Quinn and Hilmer, 1994).

Therefore, firms face a serious knowledge-sharing dilemma in innovation activities. A firm must share relevant knowledge externally to be a potential receiver of another party's knowledge, but at the same time, the firm must consider the potentially harmful effects of leaking business-critical knowledge.

To shed light on these issues, we empirically examined the links between a firm's external knowledge sharing, knowledge leakage and relative innovation performance. Our results show the benefits and the challenges of external knowledge sharing and, thus, present a more balanced and refined analysis of a widespread phenomenon than earlier studies on the topic. In particular, our results show that although firms benefit from external knowledge sharing in terms of relative innovation performance, a firm's employees who accidentally or intentionally leak knowledge may curb these efforts (i.e. a negatively moderating effect). According to this logic, the best-performing firms are those that enable high-level external knowledge sharing while eliminating business-critical knowledge leakage. Acknowledging the challenges to do this is the first step in achieving successful results under such conditions.

5.1. Theoretical implications

Our results contribute to the innovation management literature in two important ways. First, this study supports the argument that knowledge sharing is beneficial for firms' innovation outcomes – firms that share more knowledge externally also benefit through improved relative innovation performance. This effect may take place through the principles of positive reciprocity; the more a firm shares knowledge, the more knowledge the firm is likely to receive in return. This is important because firms that collaborate, typically tend to possess different/complementary stocks and types of knowledge. Much of the specialized knowledge exists in a tacit (i.e. non-tradable) form, and thus, the value of external knowledge sharing often remains ambiguous for a long time.

Second, our study empirically contributes to the longstanding discussion regarding the harmful effects of knowledge leakage (e.g. Ahmad et al., 2014; Baughn et al., 1997; Hamel, 1991). Although the issue of knowledge leakage has been recognized in the literature, little empirical research has shown the links between external knowledge sharing, knowledge leakage and a firm's relative innovation performance. For instance, based on a recent systematic review, Foss et al. (2010) called for more research showing the potentially harmful effects of knowledge sharing. We have responded to this call and have contributed to the ongoing scholarly discussions by clearly differentiating between accidental and intentional

knowledge leakages, developing measures for them and empirically demonstrating that both types of leakage have a negative effect on firms that share much knowledge externally.

5.2. Practical implications

The links between knowledge sharing, knowledge leaking and relative innovation performance are a relevant topic not only in knowledge management and innovation research but also in industry practice. Our study has important implications for practitioners, particularly those with management responsibilities and those involved in orchestrating external collaborations and firms' innovation efforts and activities.

First, our findings demonstrate that firms that reciprocally share knowledge with external partners for their own innovation purposes must be especially aware of the potential for knowledge leakage and the harm such leakage can cause. By engaging in external knowledge sharing, firms increase the risk that confidential knowledge might accidentally or intentionally leak to those outside the firm's boundaries. This can happen for various reasons. For instance, an employee might develop a stronger allegiance to external partners than to her/his own firm, or employees may have difficulties assessing which knowledge might have strategic importance to their firm (Husted and Michailova, 2010). Either way, knowledge leakage is likely to happen to some extent, and the more knowledge is shared externally, the more important it is to consider the leakage issue. This is particularly relevant for firms' general managers, as they are the ones typically in charge of external collaboration initiatives and activities, as well as for employees who collaborate with external partners on behalf of the firm.

Second, our study shows that the loss associated with leaking knowledge may outweigh the benefits of getting access to external knowledge. Firms and their executives should be aware that external knowledge sharing increases the risk of associated knowledge leaks, and thus, they should manage this risk carefully. This is especially relevant for firms that do not have substantial experience in external collaborations. For instance, firms can manage such issues by tightening and specifying contractual frameworks in collaborations, increasing awareness of employees in regard to the knowledge to be protected and of the detriments from knowledge leakage, arranging training programs and/or staffing inter-organizational collaboration projects in a way that reduces the potential for knowledge leakage.

5.3. Limitations and further research

As with any study, the present one has limitations. First, the results may be bound to the geographic location of the respondent firms, in that the business and knowledge-sharing culture

in Finland may be different from that in other countries. Finland is a small economy with a tradition of trustworthy business relationships, where much of the knowledge sharing occurs through informal networks with the underlying general presumption that the parties will not take advantage of each other. This could enhance knowledge sharing in general, but it may also increase the risk of accidental knowledge leakage. Furthermore, fear of losing one's reputation in the business circles possibly decreases the motivation for opportunistic behavior or intentional knowledge leakage. This, once again, points towards the importance of distinguishing between accidental and intentional knowledge leakages.

The Finnish legal system is well known for its efficiency. This is likely to increase the awareness of an individual's responsibilities in terms of knowledge sharing and reduce the risk of accidental knowledge leakage. It can also reduce the temptation for unwanted knowledge leaks, as there could be, for example, sanctions for violating an employer's trade secrets. However, although the Finnish context may have some effect on the results of this study, we propose that the results would be similar in other Western countries with sufficiently similar legal systems. In fact, Finland is an eligible setting for an examination of knowledge-related abstract phenomena. As a small economy and a fairly homogenous country, culturally and economically, Finland is a reliable setting in which it is appropriate and meaningful to measure abstract knowledge-based variables. Homogeneity reduces the likelihood of culturally interpreted variation in the perception of abstract constructs (Autio et al., 2000; Spender and Grant, 1996).

Second, the results may also be contingent on the nature of the firms in our sample, which poses additional challenges for generalizability. The sample firms represent technology industries. This suggests that technological and, in general, advanced knowledge is of major relevance in their competitiveness. This may have specific implications for our results in terms of knowledge transferability, as well as in the measure of the potential harmfulness of knowledge leakages to innovation performance.

Third, the measures used to examine accidental and intentional knowledge leakage could be further developed for greater clarity in terms of motivational types. In this paper, when we aimed to measure the intentional actions of an employee exposing business-critical knowledge to other parties, respondents could interpret that measure in two ways: 1) as purposeful knowledge leakage to benefit the employee or hurt the company or 2) as a strategic decision to use the knowledge leak intentionally as a marketing tactic to create interest in the firm and its innovation activities. Although we defined intentional knowledge leakage to address the former issue, some respondents may have answered in the latter sense. This is evident in the slightly

positive correlation of this variable in terms of relative innovation performance in the bivariate sense and in the regression models. However, this issue should not be over-interpreted. Intentional knowledge leaks and innovation performance might also interrelate in other ways, which would explain the slightly positive relationship (although not significantly so). For instance, highly innovative firms may encounter more intentional knowledge leaks since they are innovative and their employees are thus more prone to leak knowledge for various reasons. And since the moderation effect was clearly negative (supporting Hypothesis 3), intentional leakage is harmful for innovation performance when coupled with a high level of external knowledge sharing.

The results of our study open up a number of promising avenues for further research, as well as several empirical and methodological applications. Researchers could look into the mechanisms that can prevent accidental and intentional knowledge leakage while simultaneously enabling shared collaboration-related knowledge. Mechanisms for protecting against leakage could range from formal contracts, such as non-disclosure agreements, formalized structures, strategies and systems to informal organizational social events, such as training personnel, establishing a particular organizational culture or designing specific (typically informal) communication guidelines and patterns. A trade-off does not necessarily occur between formal and informal mechanisms; in other words, a firm could apply them simultaneously. Examining such simultaneous applications is worthwhile research, potentially offering deeper insights into the issues of knowledge-sharing dilemmas (see Foss et al., 2010; Matsuo and Easterby-Smith, 2008). In addition, a strategic approach to determine what knowledge to share, when and with whom, and what knowledge to protect, when and from whom, provides a fertile area for further research.

Researchers could also conduct studies to generate in-depth qualitative data that focus on the reasons and rationales for knowledge leakage, thus better understanding the roots of this phenomenon. Conducting qualitative studies would be especially appropriate for the leakage of tacit knowledge, as it is very difficult to quantify. Finally, we see particular purpose in triangulating quantitative and qualitative methods (Flick, 1992; Jick, 1979). This combination is useful to develop more refined measures and to examine such complex issues as the different types of knowledge leakage, the motivations and objectives for leaking knowledge and the influence of knowledge leaking on innovation at the firm level and collaboration and networking level.

6. Conclusions

In a collaborative innovation context, firms share knowledge externally with their partners to reach their innovation-related goals. In this study, we argue that firms engaged in external knowledge sharing encounter the risk of potentially harmful knowledge leakage. In particular, we empirically examine the effects of a firm's external knowledge sharing on its relative innovation performance under the contingencies of accidental and intentional leakage of business-critical knowledge. Our results confirm that firms benefit from external knowledge sharing in terms of relative innovation performance, but there is a negative moderating effect of knowledge leakage. This means that a firm's employees who either accidentally or intentionally leak too much business-critical knowledge may downplay the otherwise positive innovation benefits of the intended external knowledge sharing for their firm.

The results of the study provide new understanding of the dynamic relationship between external knowledge sharing and leakage, showing that there are underlying complexities that need to be taken into account. While engaging in inter-firm collaboration and knowledge sharing is a key issue for reaching a firm's innovation outcomes, managerial and employee judgment is needed on what knowledge is shared, when it is shared and why it is shared. Based on the results of our study, we suggest that in addition to knowledge sharing, also knowledge leakage should be put on the innovation and technology management agenda.

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Appendix A: Measures

Relative innovation performance ($\alpha = 0.74$)

How would you compare your organization's performance in the creation of new innovations/practices over the last three years to that of other organizations operating in the same sector? (1 = performed very poorly, 7 = performed very well)

1. Products and services to the customers
2. Production methods and processes
3. Management practices
4. Marketing practices

External knowledge sharing ($\alpha = 0.82$)

How well do the following statements characterize your employees' activities related to knowledge sharing with people employed by the firm's partners?

(1= completely disagree, 7=completely agree)

1. Our employees share their work reports and official documents
2. Our employees share their manuals and methodologies
3. Our employees share their experience or know-how

Accidental knowledge leakage ($\alpha = 0.92$)

How well do the following statements characterize your company's personnel?

(1= completely disagree, 7=completely agree)

1. Our employees accidentally leak business critical knowledge to our partners
2. Our employees accidentally leak business critical knowledge in other situations

Intentional knowledge leakage ($\alpha = 0.86$)

How well do the following statements characterize your company's personnel?

(1= completely disagree, 7=completely agree)

1. Our employees leak business critical knowledge on purpose to our partners
2. Our employees leak business critical knowledge on purpose in other situations