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ORGANIZATIONAL DESIGN FOR ABSORPTIVE CAPACITY LINKING INDIVIDUAL AND ORGANIZATIONAL LEVELS

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Abstract

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1. Introduction

Firms increasingly source external knowledge sources to support their innovation process (Chesbrough, 2003, Laursen & Salter, 2006). Partly as a reflection of this, absorptive capacity (henceforth, "AC"), the "ability to identify, assimilate, and exploit knowledge from the environment" (Cohen & Levinthal, 1989: 589), has emerged as one of most important concepts in the management and organization fields. However, in spite of its popularity, "the AC concept is still surrounded by considerable ambiguity" (Volberda, Foss & Lyles, 2010: 13). The ambiguity attaches to "its definitions, components, antecedents and outcomes" (Zahra & George, 2002: 185; see also Lane, Koka & Pathak, 2006), which calls for a focused research effort.

In this article we address a critical and under-researched issue in absorptive capacity research (cf. Volberda et al., 2010), the organization design antecedents of AC, that is, how organizational structure, decision systems, and management practices influence AC. We show that different organizational configurations (i.e., different combinations of specific organization design elements) have different impact on AC. The reason is that organizational configurations differ with respect to how they influence the motivation, ability and opportunity of organizational members to engage in actions that influence AC. Thus, we bridge analytical levels in our approach to AC.

In their distinction between potential and realized absorptive capacity, Zahra and George (2002: pp) explicitly point out that the ability of firms to successfully acquire and assimilate knowledge depends on the ability with which individual organizational members who are in touch with external knowledge sources perform the gate-keeping task (e.g., Allen, 1977). However, such "outward-looking" (Cohen and Levinthal, 1990) AC has no value to the firm if the in-sourced external knowledge is not communicated to other organizational members, so that it can be transformed and deployed to new value creating activities. Understanding these processes require

careful attention to the organizational design of the firm. However, current AC research has not made much progress with respect to understanding the organizational design antecedents of AC, as Volberda et al. (2010) point out.

To fill this void, we develop a simple theoretical model of external knowledge absorption, building primarily on the information processing stream of the organizational design literature (Marschak and Radner, 1972; Galbraith, 1975; Sah and Stiglitz, 1986) and neglecting agency problems. The model examines the impact on the returns firms reap in absorbing external knowledge of three key aspects of organizational design—namely, 1) organizational structure, specifically, the specialization of the gate keeping task; 2) decision systems, specifically, the delegation of decision authority over knowledge absorption to individual employees who perform gate keeping tasks; and 3) human resource management practices, specifically, the adoption of knowledge sharing practices. We compare the returns a firm obtains under different organizational configurations. In so doing, we highlight that the "optimal" organizational design for AC depends on the type of knowledge that needs to be absorbed, the type of source from which this knowledge is absorbed, and the characteristics of firms' business environment. Thus, we examine the capability of firms to acquire, assimilate, transform, and exploit knowledge, as these processes are shaped by the ability of screening external knowledge possessed by individuals, the role of organizational design in allowing efficient use of this in-sourced knowledge, and the characteristics of potentially absorbable knowledge and the environment in which firms operate.

The papers that are most closely related to the present one are three empirical papers, namely Bosch, Volberda and Boer (1999), Jansen, Bosch and Volberda (2005) and Foss, Laursen and Pedersen (2011). These three papers discuss various aspects of organizational design as antecedents of AC. However, their conceptual development does not include the level of individuals, and only the Foss et al. (2011) paper includes the issue of the decision rights of organizational members. In contrast, this paper explicitly bridges the individual and organizational levels in understanding how

organizational design impacts AC. While research on AC has come a long way since Cohen and Levinthal (1989,1990), only a few of the more than one thousand papers in this research stream grapple explicitly with individual-level factors, organizational design and knowledge characteristics in the context of AC, and none grapples with all three, as recently shown by Volberda, Foss and Lyles (2010). Thus, we seek to meet some of the key challenges in AC research.

The paper is organized as follows. In the following section we present the theoretical background. The next section is devoted to the illustration of our theoretical model. We then discuss some possible extensions of the model and different interpretation of the results. In the following section, we describe a series of theoretical predictions relating to how according to the indications of our model, firms should organize for absorbing external knowledge in specific, but very common situations. The final section offers concluding remarks and suggestions for further research.

2. Theoretical background

Absorptive Capacity: The Unfinished Legacy of Cohen and Levinthal

The AC construct has precursors and it is placed in a broad space of neighboring constructs and research streams, such as organizational learning, creativity, and capabilities. However, the contributions by Cohen and Levinthal (1989, 1990) are generally seen as the founding ones. Cohen and Levinthal (1989) is fundamentally a contributions to innovation studies: AC, that is, the "ability to recognize the value of new information, assimilate it, and apply it to commercial ends," is an antecedent of innovation, and is built by investments in R&D. The 1990 paper, which (in terms of citations) is the single most influential paper in research on AC (see Volberda, Foss & Lyles [2010] for bibliometric details), offers more detail on the construct itself, including grounding it in cognitive psychology. Thus, the accumulation of prior knowledge makes it easier to arrange new knowledge in the memory and recall it. There may be synergies between learning in different domains, because it

provides a basis for learning in uncertain situations and stimulates problem-solving by associating to more and novel associations and linkages.

Zahra and George (2002), the second-most influential contribution to the AC literature, made a number of conceptual breakthroughs, in particular their distinction between potential absorptive capacity and realized absorptive capacity. They define AC as "a set of organizational routines and processes by which firms acquire, assimilate, transforms and exploit knowledge to produce a dynamic organizational capability."

Volberda, Foss and Lyles (2010) review 1,213 papers in the AC literature and identify a number of research gaps. Thus, they specifically argue that research on AC should "be explicit about what kind of knowledge is being absorbed" (p.); "address the varying nature of knowledge, the knowledge stock and flow of knowledge" (p.); explain the impact of individuals on the AC process" (p.); explain the origin of organization-level AC" (p.); "how AC existing on different levels of analysis (individual, organizational, dyadic, etc.) are related" (p.); and "systematically explore how formal organization influences the level, formation, and dynamic nature of AC and the retrieval of prior knowledge" (p.). They find existing AC research deficient with respect to all these research themes.

Interestingly, the research gaps identified by Volberda et al. (2010) are more characteristic of the post-Cohen and Levinthal literature than it is of the original Cohen and Levinthal papers themselves. Thus, particularly in their 1990 paper, Cohen and Levinthal explicitly seek to ground firm-level AC in individual level AC: "The premise of the notion of absorptive capacity is that the organization needs prior related knowledge to assimilate and use new knowledge. Studies in the area of cognitive and behavioral sciences at the individual level both justify and enrich this observation" (1990: 129). They go on to detail these "studies," particularly studies in the field of memory development, and build on them to argue that an "… organization's absorptive capacity will depend on the absorptive capacities of its individual members. To this extent, the development of an

organization's absorptive capacity will build on prior investment in the development of its constituent, individual absorptive capacities, and, like individuals' absorptive capacities, organizational absorptive capacity will tend to develop cumulatively" (p.131). They quickly point out, however, that an organization's AC is not merely the aggregation of individual ACs. Organizational structure intervenes:

> Absorptive capacity refers not only to the acquisition or assimilation of information by an organization but also to the organization's ability to exploit it. Therefore, an organization's absorptive capacity does not simply depend on the organization's direct interface with the external environment. It also depends on transfers of knowledge across and within subunits that may be quite removed from the original point of entry. Thus, to understand the sources of a firm's absorptive capacity, we focus on the structure of communication between the external environment and the organization, as well as among the subunits of the organization, and also on the character and distribution of expertise within the organization (p.131-2).

In this connection, they introduce a distinction between "external absorptive capacity" and "internal absorptive capacity," the former referring to the actual acquisition of externally held knowledge, the latter referring to the internal transfer and exploitation of the acquired knowledge. In the context of knowledge acquisition, they make explicit reference to Allen's (1977) work on gate keepers, and relates it directly to issues of centralization and decentralization of decision authority:

> A difficulty may emerge under conditions of rapid and uncertain technical change, however, when this interface function is centralized. When information flows are somewhat random and it is not clear where in the firm or subunit a piece of outside knowledge is best applied, a centralized gatekeeper may not provide an effective link to the environment. Under such circumstances, it is best for the organization to expose a fairly broad range of prospective "receptors" to the environment. Such an organization would exhibit the organic structure of Burns and Stalker (1961 : 6).

Unfortunately, in their development of organization level AC from insights into individual cognition, Cohen and Levinthal do not go beyond metaphorical reasoning (i.e., arguing that firms possess AC just as individuals do), and hence they do not show how firm-level AC emerges from individual level AC. Moreover, in spite of several references to organizational structure variables, they did not systematically link AC to organizational design. Because we explicitly highlight the individual-level and organizational design antecedents of AC, this article may be seen an attempt to address this unfinished legacy from Cohen and Levinthal.

3. Building Theory on the Individual and Organizational Design Antecedents of AC

Recent surveys on AC (Lane, Koka & Pathak, 2006; Volberda, Foss & Lyles, 2010: 13; Zahra & George, 2002) have pointed to many ambiguities and problems in extant AC research. We here specifically highlight the problems of insufficient attention to the anteceding roles of individuals and organizational design, although these were clearly singled out as potentially important by Cohen and Levinthal.

It may be argued that while AC theory per se pays little attention to individuals, other related theories highlight individuals, for example, work on boundary spanning and gate-keeping (Allen, 1977; other refs) and that these insights partly remedy the lack of attention to individuals in AC research. However, while indeed such work lends insight into the acquisition and assimilation of knowledge, it speaks less directly to the other key processes of AC, namely transformation and exploitation of this knowledge. Understanding these processes also requires that attention is paid to individuals. Specifically, a full model of AC means identifying how the motivations, opportunities and abilities of individuals in an organization to acquire, assimilate, transforms and exploit knowledge within an organizational framework that provides incentives and coordinates behaviors, and how this influenced by organizational values and beliefs, leadership styles, and environmental contingencies. Modeling this in its entirety is a task of forbidding complexity. To reduce complexity,

we focus on a select set of issues. Specifically, we concentrate on … This is illustrated graphically as in figure 1. The figure serves as our overall research figure in the following.

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Insert Figure 1 Here

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Thus, the model depicts … In the following sections we unfold the model illustrated in Figure 1 in a simple formal model that highlights the antecedents of firms' absorptive capacity at both individual and intra-organizational level. Specifically, we compare the returns from external knowledge absorption depending on the characteristics of firms' organizational design, focusing, in particular, on the role played by individual organizational members within it. Thus, the model provides the integration of the level of analysis called for by Volberda et al. (2010). In addition, the model addresses a number of the contingencies that Volberda et al. (2010) argued has been neglected in extant research. Thus, the optimal organizational design for external knowledge absorption depends on the characteristics of the 1) external knowledge firms aim to absorb, 2) source of this knowledge, and 3) environment in which firms operate.

4. Individual and organization level determinants of absorptive capacity: a theoretical model

Assumptions

We assume that a steady flow of information arrives over time from external sources (e.g. users, communities of practices, databases, etc.) that the firm need to acquire and assimilate in order absorb. Once this external knowledge has been acquired and assimilated, it is used in production in combination with internal knowledge. We consider the simplest organizational designs, that is, configurations of structure, decision systems, and management practices, that allow for the absorption of external knowledge.

Accordingly, we model a firm that is assumed to be engaged in only two operating activities (or tasks): Absorption of external knowledge (i.e., the gate keeping task) and production. These two activities are complements (i.e., they are linked by an input-output relation). Notably, in absence of external knowledge in-sourcing, there is no production output (i.e. the value of production is zero). This assumption captures Zahra and George's intuition that potential absorptive capacity, which consists in the capability of acquiring and assimilating external knowledge, is a precondition for, but does not guarantee the transformation and exploitation of this knowledge, which depends on firm's realized absorptive capacity (i.e., the use of this knowledge in production).

The value of the firm's production output, Y, is given by the product, TK, of the time employees spend in production (T), and the value K of the external knowledge that is absorbed. K depends on the amount and quality of the absorbed external knowledge. We normalize to 1 the sum of the time each employee spends either in production or in external knowledge in-sourcing.

We assume that there are two types of external knowledge which differ in quality. Good quality external knowledge generates a return for the firm equal to $z_1>0$ per unit of time devoted to production when it is absorbed and used in production. Conversely, absorbing and using bad quality external knowledge results in a negative return for the firm equal to $-z_2$ per unit of production time. The proportion of good quality external knowledge out of the available external knowledge is equal to β. The probability that a given piece of external knowledge is judged to be beneficial for the firm by individuals who perform the gate keeping task, and therefore is absorbed (i.e. acquired, assimilated, transformed and exploited in production), is greater if the quality of the knowledge is good, and lower if it is bad. In any case the probability of accepting good quality external knowledge is greater than 1/2 and lower than unity, while the probability of accepting bad quality external knowledge is lower than ½ and greater than 0. This means that there is always a non-null probability that good quality external knowledge gets discarded, while it should have been absorbed by the firm (i.e. a non-null probability of a Type-I error, see Sah and Stiglitz 1986). Similarly, there also is a

non-null probability that bad quality external knowledge is acquired, assimilated and used in production, while it should have been discarded (i.e. a Type-II error). We assume that in spite of the negative returns of absorbing bad quality external knowledge, the probability of accepting external knowledge is such that the expected returns from absorbing external knowledge is positive. As will be shown below, the fact that external knowledge absorption is not always beneficial to the firm has important implications for the firm's organizational design.

Organizational Design

The firm's organization is composed of two hierarchical layers. At the bottom of the firm's hierarchy there are two employees who are engaged in operating tasks and report to their boss. The boss performs strategic tasks and eventually monitors the use in production of external knowledge. The two employees have no task other than in-sourcing external knowledge and producing goods, respectively (i.e., strategic activities can only be performed by the boss). Hence, their salary is not considered in our model. Conversely, using the time of the boss in monitoring employees' decisions about external knowledge absorption, has a non-null opportunity cost. In accordance with the information processing stream of the organizational design literature (Marschak and Radner, 1972; Galbraith, 1975; Sah and Stiglitz, 1986), we assume that the two employees and the boss make decisions that maximize firm value, given their information sets. In other words, we neglect agency issues that arise if individuals pursue private objectives.

We consider three building blocks of firm's organizational design that relate to firm's organizational structure, decision systems, and human resource management practices, respectively—and which influence firm's absorptive capacity: 1) the specialization of operating tasks (i.e., knowledge in-sourcing and production), 2) the delegation of decision authority over external knowledge absorption, and 3) the adoption of knowledge sharing practices. These three organizational design components have been discussed in the AC literature (e.g., Cohen and Levinthal, 1990; Foss et al., 2011), but not systematically linked to AC in terms of modeling.

Task specialization. When tasks are specialized, employee A specializes in acquiring and assimilating external knowledge, while employee B specializes in production. Employee A, after screening external knowledge, transmits it to employee B, who transforms this knowledge and uses it in production. There are two potential advantages from task specialization. First, there is learning-by-doing in performing the gate keeping task. In our model, this is reflected in better individual decisions as regards external knowledge in-sourcing. Hence, the likelihood of both Type-I and Type-II errors decreases with task specialization. r_1 and r_2 are the probabilities that the specialized gate keeper accepts external knowledge of good and bad quality, respectively. p_1 and p_2 are the corresponding probabilities when tasks are not specialized. We assume $r_1 > p_1$ and $r_2 < p_2$.[1] Second, there are knowledge-related economies of scale arising from task specialization. As the specialized gate keeper devotes all her time to external knowledge in-sourcing, she processes N pieces of external knowledge in any given period.

When the gate keeping task is not specialized, the two employees devote to this task half of their time, while in the remaining half they use their time for production of goods. Accordingly, each of them can process and eventually use in production N/2 pieces of external knowledge. Hence, with other things being equal—specifically, the screening ability of employees being kept constant, and assuming that no knowledge sharing practices are adopted by the firm—the total amount of external knowledge used in production is half than the one that is used with task specialization. While specialization of the gate keeping task thus increases the amount of external knowledge that can be deployed to production, a potential drawback is that acquired external knowledge must be passed by employee A to employee B who uses it in production. Knowledge transmission is costly, as there are leaks (Keren and Levhari 1979, 1983,1989) and delays (Radner, 1993; Bolton and Dewatripont 1994; van Zandt 1999) in communicating knowledge from employee A to employee B. Accordingly,

[1] As was mentioned earlier, we assume that independently of whether tasks are specialized or not, the expected returns of external knowledge absorption are positive. That is: $\square\square z_1 r_1 - (1 - \square) z_2 r_2 > 0$ and $\square\square z_1 p_1 - (1 - \square) z_2 p_2 > 0$.

we assume that if tasks are specialized, the amount of external knowledge that is transformed and exploited in production, and thus the value of the production output, decrease by a factor $\alpha<1$.[2]

Delegation of decision authority. Decision authority over use in production of in-sourced external knowledge may be delegated to employees or centralized in the hands of the boss. In the former case, the employees performing knowledge in-sourcing tasks (i.e. employee A if tasks are specialized; both employees if they are not) decide autonomously whether the knowledge they have acquired and assimilated is to be used in production or not. The boss rubberstamps their decisions, and devotes all her time to valuable strategic tasks. With centralization of decision authority, the employee performing external knowledge in-sourcing tasks make proposals to the boss as regards use in production of in-sourced external knowledge. The boss double-checks the quality of this knowledge. External knowledge is used in production only after approval by the boss. The advantage is that in order for bad quality external knowledge to be used in production, it must be mistakenly judged as good twice (i.e., by both the employee who made the proposal and the boss who approved it). Hence the likelihood of incurring Type-II errors decreases.

Centralization of decision authority over external knowledge absorption has two drawbacks. First, it increases the likelihood of Type-I errors. In fact, good quality knowledge is absorbed by the firm only if its quality is judged as good twice (cf. Sah and Stiglitz, 1986). Second, the examination of subordinates' proposals is costly in terms of the use of the boss' time. We assume that examining a given proposal takes one unit of the time of the boss, which is diverted from her other duties, at an opportunity cost equal to δ. For the sake of simplicity, we initially assume that the screening capabilities of the boss are the same as those of firm's employees.

[2] Factor corresponds to the *efficiency factor* defined by Zahra and George (2002) as the ratio of realized to potential absorptive capacity. Should the firm be able to use in production all the external knowledge that is acquired and assimilated by its employees, a situation where =1, realized absorptive capacity would equal potential absorptive capacity. Hence, we argue that the communication of in-sourced knowledge within the firm, and the associated leaks and delays, are a major source of the divergence of realized from potential absorptive capacity. One important objective of the design of firm's organization is to reduce these communication inefficiencies.

Knowledge sharing practices. When there is no specialization of tasks and employees perform both the gate keeping and production tasks, the firm may adopt knowledge sharing practices. These practices, like the organization of formal knowledge sharing meetings between the employees or informal socialization events, are aimed at allowing employees to exchange the external knowledge they have in-sourced. In the absence of such practices, there is no communication between the two employees (we assume). When decision authority is delegated to employees, each employee uses in production only the external knowledge that she has acquired and assimilated. When decision authority is centralized, the same occurs after approval by the boss. Conversely, we assume that when the firm adopts knowledge sharing practices, the external knowledge that employee *i* (i=A,B) accepts is always passed to employee *j*. If employee *j* accepts this knowledge, she uses it in production, eventually after approval by the boss. Because of the leaks and delays in communicating knowledge, the value of this knowledge decreases by a factor $\gamma < 1$.

The organizational design configurations that are obtained by combining the organizational variables illustrated above are synthesized in Figure 2. In the following we compare the returns to the firm of adopting these different organizational configuration for external knowledge absorption.

[Insert Figure 2 Here]

Results

Comparing specialization and non-specialization. We first assume that the firm has a decentralized decision system in which the boss simply rubberstamps subordinates' decisions. We also assume that the firm does not adopt any knowledge sharing practice. We compare the returns to the firm of an organizational configuration which relies on *task specialization* (and therefore gate-keeping) with the net benefit the firm obtains in the absence of a specialized gate keeper. Y^1 and Y^{2a} are the returns associated with these two organizational configurations, respectively:

$$Y^1 = (\alpha N (\beta z_1 r_1 - (1 - \beta) z_2 r_2)) \cdot 1,$$

$$Y^{2a} = 2 (\tfrac{1}{2} N (\beta z_1 p_1 - (1 - \beta) z_2 p_2) \cdot \tfrac{1}{2}.$$

Indicating with Δ^{1-2a} the difference in the returns of the two organizational configurations, one obtains:

$$\Delta^{1-2a} \geq 0 \leftrightarrow \alpha \geq a = \tfrac{1}{2} (\beta z_1 p_1 - (1 - \beta) z_2 p_2)/ (\beta z_1 r_1 - (1 - \beta) z_2 r_2) \qquad (1)$$

Expression (1) indicates that the specialization of the gate keeping function leads to an increase of firm's returns if parameter α is above a given threshold, α reflecting the efficiency with which the gate keeper communicates to the other employee (who is in charge of production) the external knowledge she has acquired and assimilated. The value of this threshold depends on the other parameters of the model. It is easy to show that (see the Appendix for calculations):

$$da/dp_1>0,\ da/dp_2<0,\ da/dr_1<0,\ da/dr_2>0,\ da/dz_1>0,\ da/dz_2<0,\ \text{and}\ da/d\beta>0.$$

Not surprisingly, the benefits of the specialization of the gate keeping function crucially depend on communication costs: The higher these costs, the less beneficial the specialization of tasks. It is also not surprising that given communication costs, the gains from the specialization of the gate keeping task increase with the ability of the gate keeper to assess the quality of external knowledge in comparison with the corresponding ability of production employees (i.e., they are very high when $r_1 >> p_1$ and/or $r_2 << p_2$). More interestingly, these gains are larger, making task specialization more profitable, 1) the *lower* is the return z_1 the firm obtains from absorbing good quality external knowledge, 2) the *lower* is the likelihood of external knowledge being of good quality, and 3) the *more negative* is the return $-z_2$ the firm obtains from absorbing bad quality external knowledge.

These results highlight that if external knowledge is predominantly of good quality and the benefits for the firm generated from its absorption are substantial, inefficiencies arising from communicating knowledge are very detrimental to the firm. In this situation, the firm obtains better returns if external knowledge is acquired and assimilated by the same individuals who transform and exploit it (i.e. if tasks are *not* specialized). Conversely, communication inefficiencies quite paradoxically are beneficial when the external knowledge the firm absorbs is of bad quality. This

argues in favor of the specialization of the gate keeping task, which partially "protects" the firm from using in production very bad quality external knowledge.

Comparing centralization and delegation. We now examine under what circumstances centralization in the boss' hands of the decision authority over external knowledge absorption outperforms delegation of this authority to subordinates. We first assume that tasks are specialized. With centralization of decision authority, the returns to the firm of external knowledge absorption (Y^3) are given by the difference between the benefits the firm reaps from external knowledge absorption when the gate keeper's proposals are double checked by the boss on the one hand, and the expected opportunity cost of this monitoring activity on the other hand:

$$Y^3 = (\alpha\, N\, (\beta\, z_1\, r_1^2 - (1-\beta)\, z_2\, r_2^2) \cdot 1) - (N\, (\beta\, r_1 + (1-\beta)\, r_2) \cdot \delta)$$

The difference $\Delta^{1\text{-}3}$ of the returns the firm reaps with a decentralized or centralized decision system (and specialization of the gate keeping task) is given by:

$$\Delta^{1\text{-}3} = N\, (\, ((\beta\, r_1 + (1-\beta)\, r_2)\, \delta) + (\alpha\, (\beta\, z_1\, r_1\, (1- r_1) - (1-\beta)\, z_2\, r_2\, (1- r_2))).$$

Hence:

$$\Delta^{1\text{-}3} \geq 0 \leftrightarrow \delta \geq d = -\,\alpha\, (\beta\, z_1\, r_1\, (1- r_1) - (1-\beta)\, z_2\, r_2\, (1- r_2)) \,/\, (\beta\, r_1 + (1-\beta)\, r_2). \qquad (2)$$

The following results are easily derived from (2): (derivatives are in the Appendix):

$dd/dr_1>0$, $dd/dr_2>0$, $dd/dz_1<0$, $dd/dz_2>0$, and $dd/d\beta<0$.

According to (2), decentralization of decision authority over external knowledge absorption is driven by the opportunity costs of the time of the boss. The higher the opportunity cost, the more expensive monitoring, the lower the returns of external knowledge absorption with centralization of decision making. Hence, if the opportunity cost is higher than the threshold level d, decentralization of decision authority is preferable. With the opportunity cost of the time of the boss held constant, the advantages of decentralization increases 1) the *higher* is the return z_1 the firm obtains from absorbing good quality external knowledge, 2) the *higher* is the likelihood of external knowledge being of good quality, and 3) the *less negative* is the return $-z_2$ the firm obtains from absorbing bad

quality external knowledge. These results mimic Sah and Stiglitz's (1986) findings that centralization of decision authority is recommended when avoiding Type-II errors is important. Conversely, decentralization of decision authority is recommended when external knowledge tend to be of good quality and the benefits from absorbing good quality external knowledge are substantial, making Type-I errors very detrimental to the firm.

A similar reasoning explains why the value of the threshold d increases in r_1 and r_2, making decentralization of decision authority less beneficial to the firm. When r_1 approaches unity Type-I errors become very unlikely, thereby decreasing the cost incurred by centralizing decision authority. When r_2 approaches ½ Type-II errors become very likely, making centralization of decision authority again more beneficial.

We now compare organizational configurations 2a and 4a to assess the advantages of decentralization to firm's employees of decision authority over external knowledge absorption in comparison with its centralization in the boss' hands when there is no task specialization. Y^{2a} and Y^{4a} are the returns to the firm in the decentralized and centralized organizational configurations, and $\Delta^{2a\text{-}4a} = Y^{2a} - Y^{4a}$.[3]

$$\Delta^{2a\text{-}4a} = N\left(\tfrac{1}{2}\left(\beta z_1 p_1 (1-p_1) - (1-\beta) z_2 p_2 (1-p_2)\right) - \left(\beta p_1 + (1-\beta) p_2\right) \cdot \delta\right)$$

Hence:

$$\Delta^{2a\text{-}4a} \geq 0 \quad \delta \geq d = -\tfrac{1}{2}\left(\beta z_1 p_1 (1-p_1) - (1-\beta) z_2 p_2 (1-p_2)\right) / \left(\beta p_1 + (1-\beta) p_2\right) \qquad (3).$$

Expression (3) and (2) are very similar. Therefore, the analysis of this case follows closely that of the previous case and deserves only a short comment. Again, we find that centralization of decision authority is more efficient than decentralization when 1) most external knowledge is of bad quality, 2) absorption of bad quality knowledge is very detrimental to the firm, 3) the benefits of

[3] Remember that we assumed that the boss has the same ability to assess the quality of external knowledge as the employees. Hence, in this case the probability that the boss accepts good and bad quality external knowledge is given respectively by p_1 and p_2.

absorption of good quality knowledge are limited, and iv) the probability of accepting external knowledge, either of good or of bad quality, are both high. The rationale is the same as above.

Knowledge sharing. We now analyze the effects of the adoption of knowledge sharing practices. For the sake of synthesis, we will consider only the organizational configuration with a decentralized decision system. Indicating with Y^{2B} the returns the firm reaps from the adoption of these practices, one obtains:

$$Y^{2b} = \tfrac{1}{2} N ((\beta z_1 p_1 - (1 - \beta) z_2 p_2) + (\gamma (\beta z_1 p_1^2 - (1 - \beta) z_2 p_2^2)) .$$

The additional returns generated by knowledge sharing practices is:

$$\Delta^{2b-2a} = \tfrac{1}{2} N \gamma (\beta z_1 p_1^2 - (1 - \beta) z_2 p_2^2).$$

It results:

$$\Delta^{2b-2a} \geq 0 \leftrightarrow \pi = p_1 / p_2 \geq q = ((1 - \beta) z_2 / (\beta z_1))^{1/2} \quad (4)$$

From (4), one obtains: $dq/d\beta<0$, $dq/dz_1<0$, $dq/dz_2>0$.

Thus, the adoption of knowledge sharing practices generates the largest returns to the firm when most external knowledge is of good quality, the return z_1 the firm obtains from absorbing good quality external knowledge is large, and the return $-z_2$ the firm obtains from absorbing bad quality external knowledge is small. The adoption of these practices is also more beneficial when the probability of employees accepting good quality external knowledge is high, while the probability of accepting bad quality external knowledge is low.

In sum, if external knowledge absorption is likely to positively contribute to the value of production, knowledge sharing practices are beneficial, as they magnify the positive contribution to production output of external knowledge. Parameter γ, which captures the efficiency of knowledge sharing/communication between employees, plays a similar role to that of parameter α in the organizational configuration characterized by specialization of the gate keeping task. The efficiency of communication within the firm, that is, "inward-looking absorptive capacity," increases the returns from the adoption of knowledge sharing practices if absorption of external knowledge is

beneficial to the firm. Conversely, if z_2 is large, with better communication between employees the risk arises of spreading bad quality knowledge in production.

Extensions

The above model builds from the information processing stream of the organizational design literature. It thus ignores the problem of conflicting objectives among agents and associated agency costs. Even assuming that the boss has objectives and make decisions that are in line with the maximization of firm's value, the objectives of firm's employees are likely not to be congruent with those of their boss, e.g. because of the private (non monetary) benefits employees can obtain form absorption of external knowledge (Aghion and Tirole, 1997). Under such circumstances, when decision authority over external knowledge absorption is delegated to firm's employees, loss of control problems arise as employees make decision that diverge from the maximization of firm's value.[4]

Loss of control problems may be reduced if the firm adopts "high-powered" incentives that make the salary of the employees dependent on the monetary pay-off obtained by the firm. Indeed, previous studies have shown that high-powered incentives and decentralized decision systems are complements (for empirical evidence, see Foss and Laursen, 2005; Wulf, 2007; Meagher and Wait, 2008; Bloom et al., 2009).[5] In our model, we did not consider incentives. However, we can examine the effects of the divergence of objectives between the boss and firm's employees by relaxing the assumption that the screening capabilities of the boss are the same as those of employees. In

[4] Unless private benefits are perfectly aligned with the monetary pay-off the firm obtains from employees' decisions, a situation which clearly is unlikely.

[5] Note that incentive-based compensation schemes have their own drawbacks. First, as the available performance measures become more noisy, they become more costly (e.g. Prendergast 1999). Second, they possibly engender high social costs as the high rewards obtained by some employees may be considered unjustified or non-equitable by other employees (Holmstrom 1989, Zenger 1994). Third, when there are substantial coordination needs, high-powered "local" incentives make communication more strategic and distorted with centralization of decisions, whereas with delegation, they render coordination problems more severe (Friebel and Raith 2010, Dessein et al. 2008). To alleviate these problems, the incentives of the acquired key individuals need to be somehow "balanced" such that sufficient weight is given to the global performance of the acquiring firm.

particular, employees may be more inclined than the boss to accept bad quality external knowledge, if absorption of this knowledge allows them to capture private benefits.

We now consider the organizational configurations with specialization of the gate keeping task. Let us assume that the probability ρ_2 that the gate keeper accepts bad quality external knowledge is larger than the probability r_2 of this knowledge been mistakenly judged as good by the boss. In other words: $\rho_2 = k_2 r_2$, with $k > 1$. In this context, parameter k captures the extent of loss of control problems. Given these assumptions, we obtain:

$$\Delta^{1\text{-}3} = N (((\beta r_1 + (1 - \beta) k_2 r_2) \delta) + (\alpha (\beta z_1 r_1 (1- r_1) - (1 - \beta) z_2 k_2 r_2 (1- r_2))),$$

and:

$$\Delta^{1\text{-}3} \geq 0 \leftrightarrow \delta \geq d = - \alpha (\beta z_1 r_1 (1- r_1) - (1 - \beta) z_2 k_2 r_2 (1- r_2)) / (\beta r_1 + (1 - \beta) k_2 r_2) \qquad (5)$$

It results: $dd/dk_2>0$, indicating that an increase of agency costs makes delegation of decision authority over external knowledge absorption less profitable to the firm.[6]

Alternatively, in spite of agency costs, adoption of a decentralized decision system may increase the returns to the firm of external knowledge absorption if employees enjoy an advantage over their boss in assessing good quality external knowledge. Indeed, building on the seminal work of Hayek (1945), the delegation literature (e.g. Aghion and Tirole, 1997; Dessein, 2002; Marino and Matsusaka, 2005; Alonso and Matouschek, 2008) has emphasized that employees often enjoy an information advantage over their boss and that delegation to them of decision authority serves the purpose of using this personal information in decision-making (see also Jensen and Meckling 1992). Again, we can accommodate this situation in our model by relaxing the assumption that the screening abilities of good quality external knowledge of the boss is the same as that of employees. For this purpose, let us again consider the case with specialization of the gate keeping task, and let us indicate with ρ_1 the probability of the gate keeper accepting good quality external knowledge. Let us

[6] For the sake of synthesis, we do not examine the organizational configuration with no task specialization (and consequently we also do not examine the adoption of knowledge sharing practices). Results are similar to those illustrated above and are available from the authors upon request.

assume that this probability is k_1 time the probability of the boss accepting this knowledge, that is, $\rho_1 = k_1 r_1$, with $k_1 > 0$. It results:

$$\Delta^{1\text{-}3} = N (((\beta k_1 r_1 + (1 - \beta) k_2 r_2) \delta) + (\alpha (\beta z_1 k_1 r_1 (1- r_1) - (1 - \beta) z_2 k_2 r_2 (1- r_2))),$$

$$\Delta^{1\text{-}3} \geq 0 \leftrightarrow \delta \geq d = - \alpha (\beta z_1 k_1 r_1 (1- r_1) - (1 - \beta) z_2 k_2 r_2 (1- r_2)) / (\beta k_1 r_1 + (1 - \beta) k_2 r_2) \quad (6)$$

and $dd/d k_1 < 0$.

In accordance with the delegation literature, our model indicates that the larger the information advantage of the specialized gate keeper over her boss, the more profitable is adoption of a decentralized decision system.[7]

5. Empirical predictions

Our model offer empirical predictions with depend on the source of knowledge that a firm is targeting. Empirical predictions are reported in the following table.

Synthesizing table

	Search in patent databases	**Lead customer**				**OSS community**
		High-velocity environment		Stable environment		
Parameter		New customer	Established customer	New customer	Established customer	
α	Most knowledge codified: High	Tacit knowledge important: Low	Tacit knowledge important: Low	Tacit knowledge important: Low	Tacit knowledge important: Low	Part of knowledge is codified (software code), part is tacit. Intermediate value
β						Most knowledge not relevant to the firm: Low
r1	Economies of specialization and learning: High					Economies of specialization and learning high

[7] If an employee enjoys an information advantage in screening external knowledge, she is a natural candidate for the gate keeping task. Under these circumstances, it is obviously profitable for the firm to specialize the gate keeping function. So there is no point in examining here the organizational configuration with no specialization of tasks.

r2	Same: Low					Same : low
p1						
p2						
z1		Knowledge very valuable: High	Knowledge very valuable: High	Knowledge very valuable: High	Knowledge very valuable: High	Knowledge very valuable to the firm
z2	Difficult to make big damages while absorbing external knowledge from this source: Low	External knowledge absorption may lead to big mistakes: high		External knowledge absorption may lead to big mistakes: high		Difficult to make big damages while absorbing external knowledge from this source: Low
γ	High	Most knowledge tacit: low	Most knowledge tacit: low	Most knowledge tacit: low	Most knowledge tacit: low	Intermediate value
δ		High opportunity cost of the time of the boss	High opportunity cost of the time of the boss	Low opportunity costs of the time of the boss	Low opportunity costs of the time of the boss	
Prediction	***Specialization of the gate keeping task. Decentralized decision system.*** ***If the gate keeping function is not specialized (which is unlikely), use of knowledge sharing practices.*** ***Y1 (or Y2b)***	***No specialization of the gate keeping task because of the low α.*** ***In spite of high q, if z2 is high, centralization of decision systems is better.*** ***No knowledge sharing practices as the risk arises of spreading bad quality knowledge.*** ***Y4a***	***No specialization of the gate keeping function because of the low α.*** ***As z2 is low (established lead customer does not generate very low quality valuable knowledge), delegation of decision authority.*** ***Knowledge sharing practices help spread good quality knowledge.*** ***Y2b***	***No specialization. Centralization. No knowledge sharing practices.*** ***Y3***	***No specialization. Centralization more likely to be optimal than in a high-velocity environment.*** ***Knowledge sharing practices as the risk of spreading bad quality knowledge is limited.*** ***Y4b***	

6. Concluding remarks

TO BE DEVOLOPED

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Figure 2. Organizational design configurations for absorbing external knowledge

		Delegation of decision authority relating to external knowledge in-sourcing decisions	
		YES	**NO**
	YES	**Case 1: Y1**	**Case 3: Y3**
Specialization of the gate keeping task	**NO**	**Case 2a: Y2a** **No adoption of knowledge sharing practices**	**Case 4a: Y4a** **No adoption of knowledge sharing practices**
		Case 2b: Y2b **Adoption of knowledge sharing practices**	**Case 4b: Y4b** **Adoption of knowledge sharing practices**

Yk: net benefit to the firm in case k.