

Modelling and Measuring Learning Capabilities: The Case of Architectural and Engineering Medium-Sized Enterprises

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Abstract

This paper deals with innovation and the role of Absorptive Capacity in Knowledge Intensive Medium-Sized Enterprises. Absorptive Capacity has become a core construct in organisational literature. It helps explain how firms achieve competitive advantage through innovation of products, processes and services based on external information new to the firm. In the seminal paper of Cohen and Levinthal (1990) R&D-expenditure is taken as the main indicator for Absorptive Capacity. Because Medium-Sized Enterprises often lack R&D-expenditure but do produce innovation we need alternative variables that can help explain the level of Absorptive Capacity of Architectural and Engineering Medium-Sized Enterprises. In this paper we discuss two alternative indicators of Absorptive Capacity, i.e. Internal Knowledge Base, and External Knowledge Base. A conceptual model and hypotheses are developed in which these indicators are related to each other. Their possible explanatory power towards innovation output is specified. In 2003 data was collected in empirical research on Architectural and Engineering Medium-Sized Enterprises in the Construction sector in the Netherlands. Results of statistical analyses are discussed.

Keywords

absorptive capacity of medium sized enterprises, learning capabilities, innovation

Introduction and overview

The Absorptive Capacity (AC) of a firm is "...the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends..." (Cohen & Levinthal, 1990: 128). It was originally operationalised in case of large firms by using R&D-expenditure as a proxy or indicator. Cohen and Levinthal position their research as a new perspective on learning and innovation. The construct of Absorptive Capacity focuses on how firms sustain and improve their competitive position through innovation of products, processes and services. According to Lane et al. (2002) Absorptive Capacity encompasses not only the ability to imitate other firms' products or processes, but also the ability to exploit less commercially focused knowledge such as basic scientific research. It has therefore become a core-construct in the literature on organisational learning, knowledge management, strategic alliances and innovation management.

According to Nelson (1991) and Nelson and Winter (1982), successful firms can be understood in terms of practised organisational routines, which define lower order organisational skills, and how these are co-ordinated. Next to this, there are higher order decision procedures for choosing what is to be done at lower levels. Routines are related to productive behaviour that is learned, highly patterned, repetitious, or quasi-repetitious, founded in part in tacit knowledge, with specific objectives. Through routines the firm is capable to execute its tasks. Actors in the organisation have certain skills. The set of skills that can be deployed to fulfil a certain task is called the repertoire of that actor. The combination of skills of actors, together with the use of material resources, adds up to routines at the level of the firm or one of its departments. Because of knowledge integration through co-ordination and communication, skills of individual actors are linked in such a way that the parts function as a whole, to achieve the tasks of the organisation confidently and with certain ease. The quality of routines depends on the skill-level of actors involved. Routines are developed through learning.

One way of learning is Absorptive Capacity, which is a problem-solving repertoire of routines to integrate, build, and reconfigure internal and external routines composed of distinctive activities in the use of firm-specific resources based on *external information new to the firm*. The best example of investment in Absorptive Capacity is probably R&D-expenditure. However, Absorptive Capacity does not equal R&D-expenditure. R&D-expenditure is nothing more than a proxy of R&D-activity or problem-solving behaviour in firms. Kleinknecht (1987) states that activity related to developing knowledge for innovation in Small and Medium-Sized Enterprises is severely underestimated if R&D-expenditure is used as a proxy of this activity. Furthermore, a substantial number of Medium-Sized Enterprises lacking R&D-expenditure do produce innovation (Halman, 2004).

In section two we explore Absorptive Capacity. We include a short review of Absorptive Capacity research and a number of criticisms on this literature are discussed. In section three two alternative variables of Absorptive Capacity Internal Knowledge Base and External Knowledge Base are proposed which are based on learning behaviour of actors in firms. In section four we trace the locus of Absorptive Capacity in Medium-Sized Enterprises such as Architectural and Engineering firms. Absorptive Capacity of these kinds of firms is modelled in section 5. In section six we present eleven hypotheses on relations in the model. These refer to our main variables Internal Knowledge Base and External Knowledge Base and their sub-variables. In section seven we present our empirical research design. Results are presented in section eight, followed by our conclusions in section 9.

Absorptive capacity explored

Cohen & Levinthal (1990) consider the capacity to explore external knowledge as a critical component of innovative capabilities. They argue that the ability to evaluate and utilise outside knowledge is largely a function of the level of prior related knowledge. At the most elementary level, this prior knowledge includes basic skills or even shared language but may also include knowledge of the most recent scientific or technological developments in a given field. Prior related knowledge confers to the ability to recognise the value of new information, assimilate it, and apply it to commercial or organizational ends.

An organisation's Absorptive Capacity will depend on the absorptive capacities of its individual members, but is not resident in one single individual only: it depends on the links across a mosaic of the capabilities of various individuals, inside as well as outside the company. Critical knowledge to the firm is more than only technical knowledge. Marketing knowledge and production knowledge is also needed to assess whether an innovation can be exploited to commercial ends. The development of a network of internal and external business and communication relations facilitates the awareness of individuals about the knowledge and capabilities of other individuals, resulting in an enlargement of the Absorptive Capacity of the organisation.

We assume that in the firm context individuals in general prefer 'easy' solutions to problems that can be obtained in the network of the firm: most innovation on the firm level is 'lend or developed' (March and Simon, 1958). These solutions will be applied before they will try to learn new skills, because learning is difficult. If the firm tries to learn and develop knowledge, for instance by undertaking R&D it is in need of the dynamic capability of organisational learning. As a consequence of the behaviour of individual actors in firms, firms are reluctant to deploy R&D since this is difficult, involves risks and is costly (Smith, 1995).

Co-operation in groups such as firms leads to a problem-solving scope that exceeds the scope of individual members, because problems too complex for an individual to solve can be addressed in groups of people. The scale of information processing is enlarged relative to that of one individual. The organisational absorption- and innovation process is a knowledge development process in which problems are solved. In the organisational context actors develop their knowledge in co-operation through joint experiences with the execution of organisational tasks. The result of knowledge development is, in the firm context, improved or new routines for task execution, producing innovation as outcome.

There are several literature reviews available, of which Lane et al. (2002) is probably the most extensive. They counted 189 papers that cite Cohen & Levinthal (1990) and conclude that there are three major shortcomings of this literature: "(...) limited attempts to revise the definition of Absorptive Capacity, little attention to the actual process underlying absorptive capacity, and few attempts to measure it outside the R&D context." Jones & Craven share the criticism of Lane et al. with regard to the explanatory variable R&D expenditure, and argue that in case of smaller firms others ways of measuring Absorptive Capacity are needed. Liao et al., 2003 in their review of the literature conclude in addition to this, or maybe as a consequence of the fact that other measures than R&D are lacking, that Absorptive Capacity research on the level of MEs is scarce.

The three general criticisms of Lane et al. are addressed in this research. We adopt the re-conceptualisation of Zahra and George (2002); we look in particular at individual learning and measure (co-operative) problem solving behaviour of individual actors in firms in stead of expenditure on Research and Development. We do measure Research and development in our research in addition to our alternative variables, and positioned as a control variable to find out whether the R&D-expenditure is related to the level of innovation activity in case of Architectural and Engineering Medium-Sized Enterprises.

The internal and external knowledge base of the firm

The combined knowledge of individual actors in firms is the Internal Knowledge Base of the firm. It contains the firm-specific routines producing the capability of the firm. The knowledge base of an individual and that of a firm differ because of three main reasons. In developing knowledge, the cognitive scope of the individual is enlarged with contextual information embedded in machines, other constructs and other individuals. Without this contextual information, individuals will be less effective in improving their task execution. Secondly, specific knowledge needed for task execution can in some cases only be retrieved by performing certain tasks, but is ultimately held by the individual. Thus individual cognition in the firm context offers an increased potential for learning to the individual.

The alignment of individual cognition through routines enlarges the scope for knowledge development. The available pool of knowledge in the firm of other actors can be accessed, which increases the diversity of information available to the individual. These knowledge connections increase the potential of novel associations and combinations, which can result in innovation. A third reason why the scope of a collection of actors in the firm is larger than that of an individual is that tasks of organisations are often too complex to be handled by individuals alone. The combined work of many specialists is necessary to fulfil the complex tasks of firms. For these reasons the claim of Cohen and Levinthal (1990) that organisations are able to innovate beyond the scope of individuals, can be justified.

The knowledge base of the firm can now be defined. It contains a repertoire of both operating and problem-solving routines that connect the individual skills of actors to each other and at the same time to the context provided by the organisation (including 'external memory', machines and computers and other inputs). The knowledge base of an organisation is a dynamic entity containing the firm specific internal prior related knowledge (routines) crucial to its task execution and its competitive position. The knowledge base can be developed through organisational learning. Firms learn if actors in firms learn. Actors in firms learn through experiential learning (Kolb, 1984). The direct experience with the operating and marketing process inside the firm is stored in the routines of the firm, which in turn are stored in the Internal Knowledge Base of the firm. This internal Knowledge Base is developed through organisational learning. According to Nooteboom (1996), learning is growth of knowledge. In this process more interpreted data (information) are gained, or understanding (claims of deductive or causal ordering) is gained, or skill to perform. Within economic and organisational literature different degrees of learning are recognized. The distinction between 'single loop' versus 'double loop' (Argyris & Schon, 1978) is perhaps the most widely known (Nooteboom, 1996). Other similar distinctions include 'first order' versus 'second order' learning (Fiol & Lyles, 1985, Hedberg, Nystrom and Starbuck, 1976) and 'exploitation' versus 'exploration' (March 1991).

Nooteboom (1996) holds these distinctions to be synonymous to first and second order learning. "First order learning refers to the refinement of existing practice ('doing things better'), while second order learning refers to the emergence of a novel practice ('doing better things'). The first seems to be related to learning in the form of increased efficiency of an existing practice, and the second is related to new combinations in a newly emerging practice." Both kinds of learning are important to each organisation and potentially contribute to turnover and profit. First order learning or exploitation and second order learning or

exploration behaviour have to be balanced: a firm that solely explores cannot exploit the found knowledge to commercial ends and will fail. On the other hand, a firm that solely exploits is not susceptible to changes in the environment and might lose its competitive position in the long run because of a lack of strategic flexibility (March, 1991).

In respect to the importance of networks in learning processes Tidd et al. (1997) remark the following: “The conversion of tacit to explicit knowledge is a critical mechanism underlying the link between individual and organisational learning. Through a process of dialogue, discussion, experience sharing and observation individual knowledge is amplified at the group and organisational levels. This creates an expanding community of interaction, or ‘knowledge network’, which crosses intra- and inter-organisational levels and boundaries. These knowledge networks are a means to accumulate knowledge from outside the organisation, share it widely within the organisation and store it for future use. Therefore the interaction of groups with different cultures, whether within or beyond the boundaries of the organisation, is a potential source of learning and innovation.” Pavitt (1984) estimates that forty percent of information, needed for innovation, stems from the environment of the firm. This means that the existing corps of scientific and technological knowledge and the market together are the potential *external* knowledge base of the firm. If the firm is linked to parties in this environment through co-operation in its widest sense, this can be seen as an external knowledge base of the firm. The scope of the firm can be enlarged through collaboration (strong ties) and through its counterpart, informal cooperation in the network of the firm (weak ties).

Because of the empirical evidence of scope enlargement through collaboration (Teece et al, 1997, Nooteboom, 1998, 2000) we include the number of collaborations on innovation in our construct External Knowledge Base. Knowledge contacts in collaboration are intense; they enlarge the accessible prior related knowledge, while the pool of accessible knowledge is more diversified than that of a single firm. The picture for weak ties and how they contribute to the ability to develop knowledge is less clear. Efforts are in general less intense, but also diversity of knowledge is an important ingredient for innovation. We hypothesise that the use of both strong and weak ties is positively related to innovation on the level of the firm. The External Knowledge Base is an explanatory variable of Absorptive Capacity because it is a source of learning and innovation. We hypothesize therefore that participation in - and use of the network are positively related to internal innovation activity on the level of the firm.

The locus of absorptive capacity of medium-sized enterprises

Allen (1977) reports that in engineering agencies, information does not enter directly into the organization. The knowledge base of firms is divers in terms of capabilities, while these capabilities on average consist of the skills of more than one individual actor. The interface with the environment is concentrated in one or a few boundary spanners. The stream of information is indirect, involving at least two steps. Firstly, external information enters the organisation through ‘technological gate keepers’, who read more, including relevant professional literature. These persons have more internal and external contacts than average employees. Secondly, boundary spanners have to translate outside information before it can be recognised and becomes useful to the production and marketing competencies of the organisation.

In Architectural and Engineering Medium-Sized Enterprises, the responsibility for formal innovation projects (either of an incremental or radical nature) on the level of the firm, is centralised in one or only a few gate keepers and boundary spanners. In Medium-Sized Enterprises the head of the R&D-department will fulfil the two roles of gatekeeper and boundary spanner, if the company is large enough and such a department is installed. In the case of a small company, there might not be such a department, and it is possible that there is no formal R&D budget. In this case it is probable that the owner/manager fulfils both roles and can be considered as the 'Chief Innovation Manager'. We focus on the 'Chief Innovation Manager' who facilitates or initiates change and acts as a gatekeeper and a boundary spanner. He or she has the formal responsibility to engage in innovation projects. His or her search behaviour in terms of knowledge gathering and development are a crucial part of the Absorptive Capacity of the firm, yet this cannot tell the whole story.

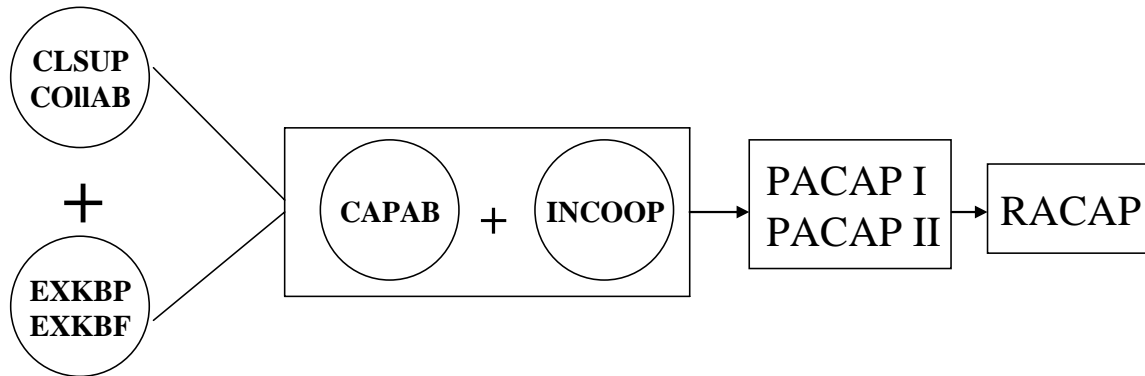
The ability of managers to extend existing capabilities depends on the mobilisation of broader organisational resources (Jones & Craven, 2001). Effective internal knowledge sharing and integration is a critical part of Absorptive Capacity. (Zahra and George, 2002). Through internal cooperation with actors involved in production and marketing, innovations can be commercialised to have them contribute to turnover and profit. The main actor in the innovation process in a Medium-Sized Enterprise is considered to be the Chief Innovation Manager; his or her knowledge gathering and development skills, are the focus in this research. To include the influence of inside links between (leading) actors in production and marketing, the perceived satisfaction of the co-operation between the Chief Innovation Manager and these actors can serve as a proxy of the ease of realisation of potential capacity. Because of the central position of the Chief Innovating Manager, this person can report on his own knowledge development behaviour, as well as that of other relevant actors to innovation projects in his or her firm. In our empirical research the focus is therefore on the Chief Innovation Manager (CIM).

Modelling absorptive capacity of MEs

Zahra & George (2002) propose to divide the concept of Absorptive Capacity in potential Absorptive Capacity and realised Absorptive Capacity (PACAP en RACAP respectively). "Potential capacity comprises knowledge acquisition and assimilation capabilities, and realized capacity centres on knowledge transformation and exploitation." They posit that potential capacity provides firms with the strategic flexibility and the degrees of freedom to adapt and evolve in high-velocity environments. By doing so, potential capacity allows firms to sustain a competitive advantage even in a dynamic industry context. In terms of knowledge, PACAP is related to exploring the in- and external knowledge environment (the search of knowledge), while RACAP focuses on the effective exploitation and implementation of knowledge to achieve actual production and subsequent added value (the use of knowledge). We define PACAP (I and II) as the number of innovation projects started on renewal (PACAP I) and on things new to the firm (PACAP II), respectively. These innovation projects can possibly be translated into business opportunities contributing to commercial ends. On the other hand they can also fail to deliver the promise: for this reason PACAP is not the same as Realised AC (RACAP). In the case of Realised AC turnover of the firm related to innovation can be measured, by which a contribution to commercial ends is realised. Only then the phenomenon of Absorptive Capacity, as originally defined by Cohen and Levinthal (1990), is fully grasped.

We discussed two main variables of Absorptive Capacity that can be measured independently of R&D-expenditure. Our main hypothesis is that higher scores on Internal Knowledge Base and External Knowledge Base positively affect innovation activity in terms of PACAP (number of innovation projects) and RACAP (contribution to turnover). In the model (figure 1) two main variables Internal Knowledge Base and External Knowledge Base are subdivided into two sub-variables. These sub-variables are summed into our two main variables Internal Knowledge Base and External Knowledge Base.

Strong ties



Weak ties

Figure 1. A model of absorptive capacity of medium-sized enterprises

The variable Internal Knowledge Base (INTKB) consists of the competence level of the Chief Innovation Manager (CAPAB) summed with the score on internal cooperation with marketing and production (INCOOP). High-level capabilities of the Chief Innovation Manager are of no use if the level of internal cooperation is low; good ideas can not be exploited if internal cooperation malfunctions. By summing both sub-variables we obtain an index that is a proxy of the capability of the firm to innovate. The External Knowledge Base (EXTKB) measures strong ties and weak ties. We obtain the variable External Knowledge Base by summing the score on strong ties and weak ties in one total score.

The sub-variables strong ties and weak ties both consist of two elements. Strong ties are ties with Clients and Suppliers (CLSUP) and ties through collaboration (COLLAB), weak ties relate to informal network contacts of the Chief Innovation Manager (External Knowledge Base Personal; EXKBP) and the level of information use of his or her colleagues out of the network of business relationships of the firm (External Knowledge Base of the Firm; EXKBF). The obtained score measures the intensity of interaction with the network of business relationships of the firm (formal and informal ties). A high score on this variable implies that the firm uses a high amount of external information of which we hypothesise that this positively affects innovation activity on the firm level. The Internal Knowledge Base and External Knowledge Base are our two main independent explanatory variables of Absorptive Capacity of MEs.

Three control variables are used. The first control variable is R&D-expenditure (RDEXP). The second variable is the size of the firm. Since we know from innovation literature that there is a relation between firm size and innovation (larger firms are found to innovate more

than small ones), in our analysis we control for firm size (SIZE). The third control variable is experience. Theoretically experience is an important contributor to the quality of innovation routines. The control variable experience (EXPER) measures both the experience of the Chief Innovation Manager and the experience of the firm (the age of the firm as a proxy of its experience is included in this measure). In section four on the design of our research the construction of underlying constructs of External Knowledge Base and Internal Knowledge Base is discussed, and control variables are described in more detail.

Hypotheses

A number of hypotheses on both our main variables Internal Knowledge Base and External Knowledge base and sub-variables of these two main variables can now be formulated.

- 1 If firms have R&D-expenditure (RDEXP) this will positively affect innovation in terms of PACAP I and II and RACAP.
- 2 Experience (EXPER) of the Central Innovation Manager and the firm positively contribute to the innovation capability.
- 3 Larger firms (SIZE) in the sample having a higher number of employees have higher innovation activity in terms of PACAP I and II and RACAP than smaller ones.
- 4 The capability level of the Chief Innovation Manager (CAPAB) is positively related to innovation outcomes on the firm level
- 5 An above average level of internal cooperation with marketing and production (INCOOP) results in above average scores on innovation in terms of PACAP I and II and RACAP.
- 6 Higher scores on the Internal Knowledge Base (INTKB) result in higher innovation production in terms of PACAP I and II and RACAP.
- 7 Higher scores on the use of Information Index of Clients and Suppliers (CLSUP) positively affect the innovation production in terms of PACAP I and II and RACAP.
- 8 Collaboration projects (COLAB) contribute to the innovation production in terms of PACAP I and II and RACAP in the positive sense.
- 9 Higher scores on the External Knowledge Base Personal (EXKBP) result in higher innovation production in terms of PACAP I and II and RACAP.
- 10 Higher scores on the External Knowledge base of the firm (EXKBF) are positively related to the number of innovation projects PACAP I and II and their contribution to turnover, RACAP.
- 11 Higher scores on the External Knowledge Base of the firm (EXTKB) result in higher Innovation production in terms of PACAP I and II and RACAP.

Empirical research design

The data has been gathered by means of a telephonic survey into the population of Architectural and Engineering MEs in May 2003. The response rate was 28% out of 585 existing firms in the size class of 10-100 employees in the Netherlands. Of these 164 firms 96 or 59 percent of firms reported innovation projects. We are interested in these innovating firms. In this section our variables are described in detail, starting with the dependent

variables of the model. Subsequently, the Internal Knowledge Base is described. After this we turn to the External Knowledge Base. Lastly, three control variables are briefly discussed.

In this research, we define the output of Absorptive Capacity in terms of innovation projects and their effects on turnover. It may concern either incremental or radical innovation. We are interested in the factors that determine both Potential and Realised Absorptive Capacity (PACAP and RACAP). We define PACAP (I and II) as the number of innovation projects started on renewal (PACAP I) and on things new to the firm (PACAP II), in the last three years respectively. These innovation projects can possibly be translated into business opportunities contributing to commercial ends. On the other hand they can also fail to deliver the promise: for this reason PACAP is not the same as Realised Absorptive Capacity (RACAP). In the case of Realised Absorptive Capacity contribution to turnover (in percentages) of the firm is measured which is the contribution to commercial ends of innovation projects.

The Internal Knowledge Base consists of two sub-variables relating to the competence of the Chief Innovation Manager and the quality of his or her internal cooperation. The first sub-variable, the competence of the Chief Innovation Manager (CAPAB), is measured using questions used in earlier competence research in the construction sector (Triam, 2001). Questions measure the perceived level of competence of technical qualities, marketing qualities and organisational qualities of the CIM (a self-reporting measure). The second sub-variable is internal cooperation (INCOOP). It measures the perceived quality of internal cooperation of the CIM with the marketing and production departments. Internal Knowledge Base is the sum of these two sub-variables. The resulting index is a proxy of the capability of the firm for innovation and is related to the quality of prior related knowledge of the firm. The quality of prior related knowledge of the firm is seen as predictor variable of innovation activity (Cohen and Levinthal, 1990).

The External Knowledge Base consists of two sub-variables, relating to strong and weak ties of the firm. Indicators are based on the work of Landry (2002) on social capital and innovation. Respondents rate their level of agreement on statements such as "I know personally managers involved in regional economic development", "I participate a lot on the regional level" or "I use a lot of information of clients". Strong ties of the firm in our research are ties with Clients (Hertogh, den, 2000) and Suppliers (Hippel, von, 1988) (CLSUP) plus ties through collaboration (COLLAB) on innovation in the last three years. In case of collaboration we count the number of projects with the specific aim of developing innovations. Scores on the intensity and participation of strong ties are summated into one score on strong ties. The score on weak ties is partly individual (EXKBP, Cronbach Alpha 0,7) and partly organisational (EXKBF, Cronbach Alpha 0,7) and is also in this case based on the work of Landry (2002). Measurement involves the level of agreement to statements as illustrated before on the use of information of organisations of the knowledge infrastructure supportive to the innovation process of firms. The sub-variable weak ties is obtained by summing two indices EXKBP and EXKBF. EXKBP measures the participation and the intensity of interaction of the Chief Innovation Manager in his personal network. EXKBF measures the use of the knowledge infrastructure for innovation by other firm members. Summation of the total score on strong ties and the total score of weak ties leads to one overall score on External Knowledge Base.

Three control variables are used. We include measurement of R&D-expenditure (RDEXP). The second control variable is size in terms of the number of employees of the firm (SIZE). The third is experience of the Chief Innovation Manager and the firm (EXPER). We measure this by asking for the age of the respondent, the number of years of working experience in the construction sector, the number of years of experience in the current firm and the age of the firm. These four data are summed to obtain one total score. The weight of personal experience of the CIM is thus larger than the weight of the experience of the firm. This is a conscious choice that relates to the weight of the competence of the CIM in the Internal Knowledge Base; his or her competence is built first of all by his or her personal experience.

Results

In testing our hypotheses, we focus on the subset of 82 innovating firms that report at least one innovation project PACAP I or PACAP II. If firms reported an outlying value on either PACAP I or PACAP II (being higher than the mean plus 2,5 times the standard deviation), survey results are listwise deleted. In this procedure results on 14 firms were dropped. T-tests reveal no significant differences on scores on our control variables and the explanatory (sub-) variables of Internal Knowledge Base and External Knowledge Base. In all statistical tests that we perform, the level of significance is set at $p < 0,05$

Results on the variable RACAP are disappointing, only in nine cases data were obtained. This means that the results on the variable RACAP are not suitable for further analyses. Therefore, the hypotheses related to RACAP cannot be tested; they can neither be accepted nor rejected. Our hypotheses will be tested using several statistical analyses, starting with an inspection of the correlation table. All hypotheses suggest a positive relationship between an explanatory variable and innovation output in terms of PACAP I and II and RACAP. Because we presuppose positive relations between our explanatory variables and PACAP I and/or PACAP II, we choose to test our hypotheses one-sided and we use one-tailed significance set at the level of $p < 0,05$. First of all, the correlation table is inspected. If the supposed positive correlation is absent or not significant at the level of $p < 0,05$, the hypothesis is rejected. If we do find significant correlations, T-tests are performed with PACAP I and/or PACAP II as a dependent variable using a factor that divides the explanatory variable in an under average score (Factor value 0) and an above average score (Factor value 1).

Our first hypothesis states that "If firms have R&D-expenditure (RDEXP) this will positively affect innovation in terms of PACAP I and II. This hypothesis is not supported by the data. R&D-expenditure is not correlated to PACAP I and II. A T-test in which the research sample is divided in a group without R&D-department and a group with R&D-departments produces no significant results. The hypothesis is therefore rejected. Only one correlation of R&D-expenditure in the correlation table is significant: there is a negative correlation ($p(82) r = -0,27; p < 0,05$) with Internal Knowledge Base. The interpretation of this fact would be that if the competence of a firm is high and/or the quality of internal cooperation is high, firms tend to spend less on R&D.

Table 1. Pearson's Correlation Coefficients

| N = 82 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|------------|-------------------|-------------------|--------------------|-------------|-------------------|-------------------|------------|-------------------|-------------------|-------------------|-------------------|-------------------|----|
| 1 PACAP I | 1 | | | | | | | | | | | | |
| 2 PACAP II | .24 .02 | 1 | | | | | | | | | | | |
| 3 RDEXP | -.04 .36 | .09 .25 | 1 | | | | | | | | | | |
| 4 EXPER | -.14 .10 | .03 .39 | .02 .45 | 1 | | | | | | | | | |
| 5 SIZE | .10 .18 | .13 .12 | -.14 .13 | .12 .15 | 1 | | | | | | | | |
| 6 CAPAB | .21 .03 | .19 .05 | -.18 .08 | .08 .24 | .20 .04 | 1 | | | | | | | |
| 7 INCOOP | .01 .46 | .26 .01 | -.25 .02 | .10 .18 | .20 .04 | .14 .12 | 1 | | | | | | |
| 8 INTKB | .13 12 | .31 .00 | -.27 .01 | .13 .13 | .27 .01 | .74 .00 | .14 .12 | 1 | | | | | |
| 9 CLSUP | .05 .35 | .19 .05 | .20 .06 | -.06 .29 | .16 .07 | -.13 .12 | .14 .12 | .76 .00 | 1 | | | | |
| 10 COLLAB | .04 .37 | .22 .02 | .17 .09 | .02 .42 | .04 .37 | .07 .27 | .08 .25 | .11 .17 | .23 .02 | 1 | | | |
| 11 EXKBP | .01 .47 | .30 .00 | .04 .37 | .09 .21 | .24 .02 | .25 .01 | .06 .29 | .22 .02 | .27 .01 | .22 .02 | 1 | | |
| 12 EXKBF | -.03 .41 | .17 .07 | -.05 .33 | .04 .35 | -.05 .33 | .05 .32 | .00 .50 | .05 .34 | .17 .07 | -.02 .43 | .16 .07 | 1 | |
| 13 EXTKB | -.01 .47 | .31 .00 | .20 .05 | .09 .22 | .11 .16 | .20 .04 | .04 .36 | .18 .06 | .26 .01 | .12 .14 | .73 .00 | .80 .00 | 1 |

One-sided significant correlations at the level of $p < 0.01$ are **printed bold-faced and underlined**. Note that significance levels are rounded of. One-sided significant correlations at the level of $p < 0.05$ are printed **bold-faced**.

Our second hypothesis states that “Experience of the Chief Innovation Manager and the firm (EXPER) positively contribute to the innovation capability. We found no significant correlations, and T-testing of under average experience and above average experience produced no significant results. Our third hypothesis states that “Larger firms in the sample having a higher number of employees have higher innovation activity in terms of PACAP I and II and RACAP than smaller ones. Again, no significant correlations are found. A T-test on the result of under average size and above average size is found not to be significant. At this point we can conclude that our three control variables R&D-expenditure, Experience and SIZE are uncorrelated to innovation in terms of PACAP I and PACAP II. For this reason they will not be entered in further analysis.

Our fourth hypothesis is on the relation of the skill or capability level of the Chief Innovation Manager and innovation outcomes. It states that ‘The capability level of the Chief Innovation Manager (CAPAB) is positively related to innovation outcomes on the firm level.’ CAPAB is significantly correlated to PACAP I ($r(82) = .21, p < .05$) and to PACAP II ($r(82) = .19, p < .05$). A T-test using a factor dividing CAPAB in under average scores and above average score is not significant in case of PACAP I. In case of PACAP II the result is significant at the level of $p < 0.05$. In case of an under average score on CAPAB the mean number of projects

on new things (PACAP II) is 2,6, whereas firms scoring above average have a mean number of projects of 3.9. The hypothesis that scores on CAPAB are positively related to PACAP II is therefore supported by the data.

Our fifth hypothesis is on the relation of the perceived level of internal cooperation. It states that ‘An above average level of internal cooperation with marketing and production (INCOOP) results in above average score on innovation in terms of PACAP I and II and RACAP.’ INCOOP is not significantly correlated to PACAP I. INCOOP is significantly correlated to PACAP II ($r(82) = .26, p < .05$). We perform a T-test using a factor that divides the score on INCOOP in an under average score and an above average score and obtain a significant result on the level of $p < 0.05$. Firms scoring under average on INCOOP have a mean number of projects of 1.9. Firms scoring above average on this indicator score a mean of 3,3 projects.

Our sixth hypothesis is related to our first main variable and states that “Higher scores on the Internal Knowledge Base (INTKB) result in higher innovation production in terms of PACAP I and II. Internal Knowledge Base is not significantly correlated to PACAP I. INTKB is significantly correlated to PACAP II ($r(82) = .31, p < .01$). A T-test, in which the research sample is divided in an under average score and an above average score produces no significant results in case of PACAP I. The hypothesis is therefore partly rejected. If we apply the same T-test in case of PACAP II, the result is significant at the level of $p = .02$. In case of an under average score on Internal Knowledge Base the mean number of projects on new things (PACAP II) is 2,8, whereas firms scoring above average have a mean number of projects of 4,4. The hypothesis that scores on the Internal Knowledge Base are positively related to PACAP II is therefore supported by the data.

Our seventh hypothesis is about the relation between the use of information of Clients and Suppliers and our dependent variables PACAP I and PACAP II. It states that “Higher scores on the use of Information Index of Clients and Suppliers (CLSUP) positively affect the innovation production in terms of PACAP I and II. Correlations of CLSUP and PACAP I are not significant. The correlation with PACAP II is significant ($r(82) = 0,19, p < .05$). A T-test using a factor dividing the research group in firms with under average use of information of Clients and Suppliers and above average use produces no significant results on the level of $p < 0.05$. The hypothesis is therefore rejected in case of PACAP I and II.

Our eighth hypothesis is that “Collaboration projects (COLLAB) contribute to the innovation production in terms of PACAP I and II in the positive sense. The correlation between Collaboration and PACAP I is not significant and the correlation between Collaboration and PACAP II is significant ($r(82) = .22, p < .05$). In case of T-tests on Collaboration we do not use under average scores and above average scores, but we divide the research sample in firms that do not collaborate and those that do (no collaboration = 0, collaboration = 1). The result of a T-test of Collaboration on PACAP I is not significant, as expected. The result on PACAP II is significant at the level of $p < .05$. In case of no collaboration, the mean number of projects of PACAP II is 3,2, whereas if firms do collaborate, the mean number of projects on new things is 5,9. Our hypothesis is therefore rejected in case of PACAP I, and supported in case of PACAP II.

Hypothesis number nine relates to the importance of the sharing of tacit knowledge for innovation. It states that “Higher scores on the External Knowledge Base Personal (EXKBP) result in higher innovation production in terms of PACAP I and II. The correlation of EXTKBP with PACAP I is not significant, the correlation of EXTKBP with PACAP II is ($r(82) = .31, p < .01$). A T-test of under average scores on EXKBP and above average scores in relation to PACAP I is not significant. The same test applied to PACAP II is significant at the level of $p < 0,05$. The intensity of personal contacts of the Chief Innovation Manager is related to significant differences in means: Firms of CIM’s that participate below average score a mean of 3,2 projects on new things, whereas firms of which the CIM participate above average in the network score a mean number of projects of 4,4.

Hypothesis number ten states that “Higher scores on the External Knowledge Base of the Firm (EXKBF) are positively related to the number of innovation projects in terms of PACAP I and II”. Correlations of EXKBF and PACAP I and II are not significant. The result of T-tests of under average network use versus above average network use on PACAP I and II are also insignificant. The hypothesis on the sub-variable EXKBF is therefore rejected.

Our eleventh and last hypothesis is a hypothesis on our second main variable External Knowledge Base (EXTKB). It states “Higher scores on the External Knowledge Base of the firm result in higher innovation production in terms of PACAP I and II.” EXTKB is not significantly correlated to PACAP I. It is significantly correlated to PACAP II ($r(82) = .31, p < .01$). A T-test of under average scores on this indicator and above average scores related to PACAP I does not produce significant results. Results of a T-test on PACAP II are significant at the level of $p < .05$. Whereas firms that score under average on EXTKB produce a mean number of projects of 3,2, firms scoring above average values produce a mean of 6.2 projects on new things. We therefore have to reject the hypothesis on scores on EXTKB being related to PACAP I, and accept the hypothesis that higher scores on the External Knowledge Base result in higher innovation production in terms of PACAP II.

Conclusion

The results of our empirical research indicate that we were wrong about the fact that the process of renewal (PACAP I) and the process of developing things new to the firm (PACAP II) are alike. We hardly found significant results related to PACAP I, while at the same time our explanatory variables of Absorptive Capacity are significantly related to results on PACAP II. We expected that because of feedback loops to for instance the market we would be able to relate renewal processes and the context of the firm as a source of learning. It turns out that this is only the case if things new to the firm are involved.

We can now conclude that the variable R&D-expenditure is of no use in measuring Absorptive Capacity of Medium-Sized firms. We did not find a relation between the size of a Medium-Sized Enterprise and innovation. More important in the light of theory is that we did not find a relation between experience and innovation outcomes on the firm level. What we did find are new explanatory variables of Absorptive Capacity related to new products, processes and services on the level of the firm. The variables Internal Knowledge Base and

External knowledge Base are both significantly related to PACAP II: projects on products, processes and services new to the firm. In case of the External Knowledge Base our results indicate that in case of new products, processes and services, external sources of information and knowledge are indeed a critical component of innovation capabilities, as originally claimed by Cohen and Levinthal (1990).

References

- Allen, T.J. 1977. *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D organization*, Cambridge MA: MIT Press
- Argyris, C. & Schon, D. 1978. *Organizational Learning: A Theory of Action Perspective*, Reading, MA: Addison Wesley
- Cohen, W.M. & Levinthal, D.A. 1990. Absorptive Capacity: A new perspective on learning and innovation, *Administrative Science Quarterly*, vol. 35
- Fiol, C.M. & Lyles, M.A. 1985. Organizational Learning, *Academy of Management Review*, Vol. 10 no.4,
- Hedberg, B.L.T., Nystrom, P.C. & Starbuck, W.H. 1983. Camping on seesaws: prescription for a self-designing organization, *Administrative Science Quarterly*, no. 21
- Halman, J.I.M. 2004. Platformgedreven innoveren in de bouw, (inaugural lecture), Universiteit Twente
- Hertog, P. den 2000. Knowledge Intensive Business Services as Co-producers of Innovation, *International Journal of Innovation Management*, dec.
- Hippel, E. von 1988. *The sources of innovation*, New York: Oxford University Press
- Jones, O & Craven, M 2001. Expanding Capabilities in a Mature Manufacturing Firm: Absorptive Capacity and the TCS, *International Small Business Journal* 19, 3
- Kleinknecht, A.H. 1987. Measuring R&D in small firms: How much are we missing?, *The journal of Industrial Economics*, Vol. XXXVI
- Kolb, D.A., Rubin, I.M. & McIntyre, J.M. 1984. *Experiential learning*, Englewood Cliffs, NJ: Prentice-Hall
- Landry, R., Amara, N., Lamari, M. 2002. Does social capital determine innovation? To what extent?, *Technological Forecasting and Social Change* 69
- Lane, P.J., Koka, B & Pathak, S. 2002. A thematic analysis and critical assessment of absorptive capacity research, *Academy of Management Proceedings*
- Liao, J., Welsch, H & Stoica, M. 2003. Organizational Absorptive Capacity and Responsiveness: an Empirical Investigation of Growth-Oriented SMEs, *Entrepreneurship Theory and Practice*, Fall
- March, J.G. 1991. Exploration and exploitation in organizational learning, *Organization Science* Vol. 2, No. 1,
- March, J., Simon, H.A. 1958 *Organizations*, New York: Wiley
- Nelson, R.R. & Winter, S. 1982. *An evolutionary theory of economic change*, Cambridge MA: Harvard University Press
- Nelson, R.R. 1991. Why Do Firms Differ, and How Does It Matter?, *Strategic Management Journal* 14
- Nooteboom, B. 1996. *Towards a cognitive theory of the firm, issues and a logic of change*, Groningen: SOM-School
- Nooteboom, B. 1998. *Management van Partnerships – Over allianties tussen bedrijven*, Schoonhoven: Academic Service
- Nooteboom, B. 2000. *Learning and Innovation in Organizations and Economies*, Oxford: Oxford University Press
- Pavitt, K. 1984. Sectoral patterns of technical change: Towards a taxonomy and a theory, *Research Policy* 13

- Smith, K. 1995. Interactions in knowledge systems: foundations, policy implications and empirical methods, STI Review, no.16, OECD
- Teece, D.J., Pisano, G. & Shuen, A 1997. Dynamic capabilities and strategic management, Strategic Management Journal, Vol. 18, no.7
- Tidd, J., Bessant, J. & Pavitt, K. 1997 Managing Innovation: integrating Technological, Market and Organizational Change, Chichester: John Wiley & Sons Ltd
- Zhara, S.A. & George, G. 2002. Absorptive Capacity: a review, re-conceptualisation, and extension, Academy of Management Review 27, nr. 2