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ABSTRACTIVE CAPACITY OF NON-R&D-INTENSIVE FIRMS IN THE GERMAN MANUFACTURING INDUSTRY

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Abstract

This paper analyses and compares different dimensions of non-R&D-intensive and very R&D-intensive manufacturing firms? absorptive capacity (AC). The empirical analysis is based on firm level data obtained by a telephone survey in early 2010 among more than 200 non-R&D-intensive firms and 88 firms with a high R&D intensity in the German manufacturing industry. Both groups of firms were asked to indicate the level of their AC in terms of the perceived ability to recognize and implement current relevant trends and developments with regard to both, scientific, technology-based as well as market or customer-based knowledge and information. Based on this broad operationalisation, the AC of firms is measured by two categorical indices considering both the absorption of external scientific knowledge as well as customer-related trends and impulses. The results of multivariate regression analysis show that there is surprisingly little difference in the level of AC between R&D-intensive and non-R&D-intensive firms - if the firm specific relevance of such external impulses is being taken into consideration. Both very R&D-intensive and non-R&D-intensive firms are equally able to recognize and also successfully implement new scientific technological trends, if this matches their competitive strategy and is therefore considered to be relevant. This is a surprising finding in so far, as it indicates that a low R&D intensity might not be a limiting factor for firm´s ability to recognize and implement scientific knowledge per se.

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ABSORPTIVE CAPACITY OF NON-R&D-INTENSIVE FIRMS IN THE GERMAN MANUFACTURING INDUSTRY

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Abstract
This paper analyses and compares different dimensions of non-R&D-intensive and very R&D-intensive manufacturing firms' absorptive capacity (AC). The empirical analysis is based on firm level data obtained by a telephone survey in early 2010 among more than 200 non-R&D-intensive firms and 88 firms with a high R&D-intensity in the German manufacturing industry. Both groups of firms were asked to indicate the level of their AC in terms of the perceived ability to recognize and implement current relevant trends and developments with regard to both, scientific, technology-based as well as market or customer-based knowledge and information. The results show that there is surprisingly little difference in the level of AC between R&D-intensive and non-R&D-intensive firms - if the firm specific relevance of such external impulses is being taken into consideration. Given that not all firms (be it R&D or non-R&D-intensive firms) compete on the basis of a first-mover strategy, there are significant differences to be found between firms as regards the individually perceived importance of the early adoption of new technological trends. On the one hand, a relevant share of very R&D-intensive firms does not perceive a high necessity to monitor and implement newest technological developments. On the other hand, quite a number of non-R&D-intensive firms do consider the recognition and implementation of the latest scientific knowledge from R&D organisations to be relevant for their business and therefore engage in practices that allow for the successful absorption of these trends. The results indicate that the level of a firm's R&D intensity does not critically influence its science-based AC. Both very R&D-intensive and non-R&D-intensive firms are equally able to recognize and also successfully implement new technological trends, if this matches their competitive strategy and is therefore considered relevant. This is a surprising finding in so far, as it indicates that R&D intensity might not be a limiting factor for firm´s ability to recognize and implement scientific knowledge per se. No significant difference is to be found between R&D-intensive and non-R&D-intensive firms as regards their ability to perceive and implement new market demands and customer requirements, once these are perceived to be highly relevant for the firm´s overall business strategy.

Key Words:
low-tech, absorptive capacity, innovation, non-R&D-intensive firms, manufacturing industry

Introduction

In today´s hypercompetitive business environment, innovation as a "core business process" (Tidd/Bessant 2009) is arguably the most effective and promising way for firms to secure their long term business success in all sectors and sizes. However, despite the recognition of different types of innovation (OECD 2005), R&D activities are still widely considered as the main driver of innovation. While R&D certainly plays an important role, nevertheless a too strong emphasis on R&D might ignore the great variety of innovation that can be found in firms. Within this context, one particular group of firms, namely manufacturing firms with little or no own R&D activities, are running the risk to be systematically underestimated regarding their capacity for innovation (Arundel et al. 2008; Santamaría et al. 2009). Given that – by definition – they do not perform any or many R&D activities, this fact can be easily interpreted as a structural weakness regarding the ability for innovation. However, previous research has shown that non-R&D-intensive firms are not less innovative or competitive per se compared to their R&D-intensive counterparts (Santamaría 2009, Barge-Gil et al. 2008, Kirner et al. 2009a). They just do not often pursue a first mover strategy and tend to focus more strongly on customer and market driven innovations (Kirner et al. 2009b, Som et al. 2010, Som 2012).

In the light of the growing connectedness and exchange between different actors of the innovation system (Lundvall 1992, Edquist 1997, Nelson 1991), the permeability of firm boundaries, and the increasing openness of innovation processes (Chesbrough 2003), accessing external sources of knowledge has become a key element of innovation. Thus, both R&D-intensive and non-R&D-intensive firms face the increasing necessity to successfully assess and – if required – adopt and implement external knowledge. This ability has been characterized as “absorptive capacity” (AC) by Cohen and Levinthal (1989, 1990). But as they linked the AC of firms to the R&D intensity of firms, assuming that a large number of highly qualified R&D personnel increase the AC of new technological knowledge from external R&D organisations, it can be assumed that non-R&D-intensive firms show a significant less AC, are therefore isolated from such scientific knowledge and in the end suffer from competitive disadvantages compared to very R&D-intensive firms.

However, this assumption might be questioned for two reasons: Firstly, the type of strategic relevant external knowledge might differ greatly according to the particular form of innovation at hand. For instance, non-technological fields of innovation like product-related service innovation or organisational innovation as sources of competitive advantage are not primarily rooted in R&D or science-based knowledge. Instead, these types of innovation might be stronger stimulated by practical or customer-based knowledge. Secondly, the absence of R&D needs not necessarily to be equated with a lack of technological competence or the knowledge intensity of firms (Som 2012, Hirsch-Kreinsen 2007). Non-R&D-intensive firms might be able to develop their AC along other channels than R&D, if they consider science-based knowledge to be relevant for their competitive success, for instance by further developing existing technological solutions or transferring them into new contexts of application (Bender 2008).

For these reasons, this paper aims to explore the AC of non-R&D-intensive firms. To develop and implement their innovations, non-R&D-intensive firms also require the general ability to access and assimilate relevant external knowledge. Given that they have little or no own internal R&D competences, the question arises whether these firms are still able to access and absorb science-based knowledge, or whether they instead focus more strongly on the recognition and assimilation of mainly customer-related forms of external knowledge. This research question of this paper can be subdivided as follows:

- Are non-R&D-intensive firms characterised by a lower AC of science-based knowledge than very R&D-intensive firms?
- Do non-R&D-intensive firms show a higher AC with regard to market- or customer-based knowledge than very R&D-intensive firms?
- To which degree is the AC of firms influenced by the strategic importance of the corresponding external knowledge?

Besides these points, this paper wants also to contribute to the further development of a measurement concept of firms’ AC by distinguishing various forms of AC and presenting and testing an empirical approach to capture these two dimensions.

To answer its research questions, the paper starts which a brief overview on the state of research considering the presumptive AC of non-R&D-intensive firms. Secondly, it develops a theoretical framework of AC which will serve as the starting point for the measurement approach of the empirical analysis. The third section provides an overview on and a brief discussion of the empirical findings. The paper closes with a short conclusion and outlook on needs of future research.

The role of external knowledge for the innovation strategies of non-R&D-intensive firms

The acquisition and purchase of innovative machinery and equipment or intermediate goods from external sources with little or no further work required represents an important source of innovation for non-R&D-intensive firms (Arundel et al. 2008, Santamaría et al. 2009, Tsai/Wang 2009, Heidenreich 2009). They are thereby relatively more dependent on the diffusion of external knowledge than R&D-performing firms, particularly through knowledge embodied in acquired products and processes. However, such adoptions of external technologies may also involve the incorporation of high-technology products and technologies (Hirsch-Kreinsen 2008b, Arundel et al. 2008). The development and availability of AC plays a major role for non-R&D-intensive firms, as it enables them to manage and implement such technology adoption successfully (Bender/Laestadius 2005, Bender 2008, Hirsch-Kreinsen 2008b).

The results of Hauknes and Knell (2009) based on CIS data indicate that firms within low- and medium-low-tech industries collaborate with external actors in their innovation projects to a greater extent than firms in high-tech industries. Bender et al. (2005) and Hirsch-Kreinsen (2004, 2008a) also underline the importance of network relations between companies and supportive social networks at a regional level as important knowledge resources, particularly for increasing non-R&D-intensive firms' innovation capabilities. Thus, non-R&D-performing or less R&D-intensive firms may gain innovation success from external knowledge sourcing or formal cooperation with external partners, particularly with customers, suppliers and competitors (Huang et al. 2010, Rammer et al. 2009, Barge-Gil 2010). However, Arundel et al. (2008) found no statistically significant difference between low- and high-tech firms regarding the percentage of firms that report technology adoption. Twice as many firms that perform R&D in-house collaborate in product or process innovations, compared to non-R&D innovators. This is also supported by Tsai and Wang (2009) who found that the level of internal R&D investment contingently impacts the innovation performance that is achieved by collaborating with different types of external partners. Firms with higher internal R&D investment thereby gain higher innovation returns from collaboration with external partners than firms with fewer internal R&D investments. More thoroughly, Kirner et al. (2009b) show that non-R&D-intensive firms are indeed less likely to cooperate with external partners than R&D-intensive firms, particularly in the fields of R&D and service. But there are no differences to be stated regarding collaborations in production or supply. Based on matched-pair analyses, they provide evidence that non-

R&D-intensive firms participating in R&D cooperation are more likely to develop product innovations than their structurally similar counterparts without R&D cooperation.

Another major point refers to the aspect of knowledge that is primarily used by non-R&D-intensive firms. In contrast to “science-based” modes of innovation (Mowery/Rosenberg 1998), innovation in low-tech enterprises is suggested to be rather driven by customer-related and practical knowledge (Heidenreich 2009, von Tunzelmann/Acha 2005, Hirsch-Kreinsen 2004, 2008a, 2008b). Non-R&D-intensive innovation is usually not the outcome of the latest scientific or technological knowledge. The centre of the debate about low-tech innovations involves attempts to include innovation processes that are not primarily based on systematic research and technological development, but on practical, experience-based, often implicit knowledge. Especially creativity and innovation-enabling capabilities, which are related to the abilities required to identify and assimilate the potentially relevant knowledge and translate it to fit the specific conditions of the firm, are seen as major assets of these firms (Bender/Laestadius 2005). Kirner et al. (2009b) have found empirical evidence that non-R&D-intensive firms are characterised by an above-average share of low- and unskilled employees; a result which may suggest that these firms put forth alternative paths of knowledge generation and accumulation than science-based modes of expert knowledge. In the terminology proposed by Lundvall and Johnson (1994), “learning-by-doing, learning-by-using, learning-by-interacting, learning-by-producing and learning-by-searching” should be recognised as essential sources of non-R&D-based innovation. As Arundel et al. (2008) show, non-R&D innovators are likely to source ideas from alternative sources within the firm, like production engineers or design staff. Internal organisational practices, knowledge management and personnel policy, in particular, play a vital role for innovation and the innovation performance of low-tech firms (Bender 2006, Hirsch-Kreinsen 2008b, Rammer et al. 2009). Based on a sample of 4,500 firms from 13 European countries, Grimpke and Sofka (2009) found that search patterns in low-technology industries focus on market knowledge and that they differ from technology-sourcing activities in high-technology industries.

As this short overview outlines, there a good reasons to assume that non-R&D-intensive firms are indeed able to successfully recognise and exploit external sources of knowledge if they have decided to pursue a collaborative or ‘open’ innovation strategy. It could also be suggested on the basis of the existing empirical findings that non-R&D-intensive firms tend to be less focused towards science-based stocks of external knowledge, but rather on customer-based information and impulses of practical, solution-oriented knowledge.

The absorptive capacity of firms

The seminal conceptualisation of firm´s AC has been developed by Cohen and Levinthal (1989, 1990). They described the AC of firms as the ability to recognize the value of new, external information, assimilate it and apply it to commercial ends. The AC of a firm can be distinguished by two interdependent dimensions (Zahra/George 2002, Cassiman/ Veugelers 2006, Arbussa/Coenders 2007):

- the capability to search and acquire new, external information about technological trends, and
- the capability to adapt internal processes and resource configurations in such a way that their competitive potential is fully exploited.

The basic assumption is that those firms which manage external knowledge flows more efficiently, stimulate innovative outcomes and thus obtain superior competitive advantage (Escribano et al. 2009). Given that external sources of knowledge are becoming increasingly important for innovation, the capacity of firms to absorb relevant external knowledge is equally gaining relevance (Camsión/Forés 2010).

Although the original concept of AC allows for a multidimensional understanding, many studies have linked AC predominantly to firm`s R&D activities (Veugelers 1997, Oltra/Flor 2003, Leahy/Neary 2007, Therin 2007, Zahra/Hayton 2008). Internal R&D competences are believed to serve as an enabler for the firm's ability firstly to recognize external trends and developments in technology, secondly to evaluate them correctly, and thirdly to identify adequate solutions to implement such external technological developments successfully into the own enterprise. Hence, AC is argued to be a cumulative result of internal R&D activities, suggesting that internal R&D capacity and practices of external knowledge sourcing are complementary to each other (Ebersberger/Herstad 2010, Schmiedeberg 2008) rather than substitutes (Chesbrough 2003). However, this understanding of AC has been increasingly criticized. Authors like Murovec and Prodan (2009), Spithoven et al. (2010) or Escribano et al. (2009) emphasize that, against the backdrop of the systemic nature of innovation processes in which firms are embedded in social systems of multiple actors and forms of knowledge (Lundvall 1992, Foray 2006, Nooteboom 2009), the AC of an enterprise should not be merely constrained to the recognition and implementation of R&D- or science-based knowledge. Thus, it is also important for firms to have the ability to recognise, evaluate and benefit from external developments, trends and information regarding their market environment and customers (Murovec/Prodan 2009, Escribano et al. 2009). Against this background, the AC needs to be understood and measured as a multidimensional construct which encompasses both, science-based capacities as well as customer- or market-based competencies and resources that could be absorbed from external partners, e.g. strategic alliances, collaborations or networks with different stakeholders (Schmid 2005, Spithoven et al. 2010, Murovec/Prodan 2009). Following this line of argumentation advocating a more holistic understanding of firm´s AC, this paper explores these four distinct aspects of AC along the two main dimensions:

- science vs. customer
- perception vs. implementation.

According to Zahra and George (2002) AC can be differentiated according to its potential and realization. While potential includes searching and acquiring relevant competences, realization means that these competences can be successfully assimilated and exploited by the firm. Our distinction between recognition and implementation is in line with Zahra and George´s differentiation, only we do not consider the acquisition of competences as part of recognition phase in relation to AC. We argue that the decision whether a certain competence is going to be acquired by the firm is rather already a part of the implementation phase. Recognition in our understanding only includes becoming aware of relevant new science- and customer-based opportunities, trends and developments which then might or might not be adopted and implemented by the firm, depending on its ability and/or strategic decision. Both the successful recognition of relevant new trends and developments, as well as the implementation of new competences can be conceptualized as processes of organizational learning (Nonaka 1994, Cohen/Levinthal 1990, Jiménez-Jiménez/Sanz-Valle 2011). In terms or organizational learning, the two dimensions of recognition and implementation closely correspond to the two different types of learning: explorative vs. exploitative learning (March 1991, Bishop et al. 2011). Explorative learning takes place when a firm is able to identify, recognize and access new sources of information that are potentially relevant for its business. Exploitative learning occurs when this new information is being actually applied and implemented by the firm. Both types of learning, just as both types of corresponding AC, are equally relevant for innovation and competitive success. Based on previous findings showing that innovation in non-R&D-intensive firms is rather driven by customer-related and practical knowledge (Heidenreich 2009, von Tunzelmann/Acha 2005, Hirsch-Kreinsen 2004, 2008b), the following hypotheses can be formulated:

> H_{1a}: Non-R&D-intensive firms have a lower AC of science-based external knowledge than R&D-intensive firms.
>
> H_{1b}: Non-R&D-intensive firms have a higher AC of customer- or market-based external knowledge than R&D-intensive firms.

However, it might not always be necessary for a firm to implement every newly explored opportunity. Whether it makes sense to implement/exploit a certain newly recognized trend will depend on the firm´s overall business strategy. Not every new opportunity is equally promising for every firm. It is important not to ignore relevant new developments and trends, but it is equally important to distinguish which of the new development holds the potential to realistically lead to successful innovation outcomes, depending on own strategic priorities, existing capabilities/resources and market choices. Thus, we propose to analyse and interpret a firm´s AC in close connection with its specific strategic priorities and choices. Whether the distinction regarding priorities refers to generic cost leadership and differentiation strategies (Porter 1985), or to so called “value disciplines” like product leadership, operational excellence or close customer relationship (Treacy/Wiersema 1995), firms follow different strategic paths with quite different managerial and business implications. It is to be expected that this will also have an implication on their AC. Firms also possess very different types of firm internal resource bundles and resource combinations devoted to the accumulation and exploration of innovation knowledge which account for their respective competences and thus competitive advantage (Penrose 2009, Wernerfelt 1995). All these factors lead to major differences between firms regarding the perceived importance of certain innovation knowledge forms. If for example access to external scientific knowledge is relevant for a firm´s competitive strategy, it will very likely be perceived as being of high importance and thus more effort will be put into accessing and assimilating it. However, the question still remains whether “make or buy” (Williamson 1981) is the best way of incorporating the required knowledge. Depending on the transaction costs involved regarding asset specificity, the level of investments, the level of uncertainty, etc., firms might opt for different strategic combinations between buying in external knowledge and developing or building up an own knowledge base. These strategic decisions will be influenced by the individual firm´s frame conditions and are therefore highly firm specific.

For non-R&D-intensive firms, recent empirical results from Germany show that these firms are quite heterogeneous regarding their competitive strategy, despite the fact that they all have a lack in internal R&D investments in common (Som 2012). The result of a cluster analysis has revealed five distinct types of non-R&D-intensive firms, among them one group named “knowledge intensive product developers. Non-R&D-intensive firms of this particular type strongly rely on multiple external sources of R&D knowledge, while this does not seem to play a significant role for firms from other clusters. Looking at firms from the cluster called “customer driven technical process specialists” a different pattern can be observed regarding the absorption of external knowledge. These firms´ proximity to their customers and their ability to successfully access and assimilate demand side customer knowledge is the key factor for their competitiveness. (Som 2012). This observed heterogeneity of innovation paths among non-R&D-intensive firms suggests that different firms make different strategic choices related to their innovation activities. This also could affect the respective relevance of different external information and knowledge sources. Some firms might consider customers´ feedback a central source of external knowledge, while other firms might establish close collaborations with research institutions in order to gain access to the latest technological developments – even if they are not intensively engaged in internal R&D themselves. For this reason, we expect that firms´ R&D intensity will not be the main explanatory factor. Instead, we assume that individual innovation paths and priorities will affect the level of firms´ AC, because it is to be expected that firms will channel their efforts mainly into accessing and assimilating those types of external knowledge that they consider important. In consequence we can formulate a second set of hypotheses:

> H_2: The AC of a firm is influenced by the strategic relevance of external knowledge.

More specifically, in the context of the research question of this paper this means:

> H_{2a}: The AC of non-R&D-intensive firms regarding external stocks of science-based innovation knowledge is equal to R&D-intensive firms if external science-based knowledge is considered to be of strategic relevance for the firm's competitive strategy.

> H_{2b}: The AC of R&D-intensive firms regarding external stocks of customer- or market-based innovation knowledge is equal to non-R&D-intensive firms if external customer- or market-

based knowledge is considered to be of strategic relevance for the firm's competitive strategy.

A measurement framework for the AC of firms

While R&D intensity is an established way to operationalise AC when new product development is of primary interest (Stock et al. 2001), it falls short of capturing learning capabilities that relate to other forms of innovation, e.g. market, process or organizational innovations, where R&D is not of equally high importance. This distinction seems particularly relevant for capturing those firms´ AC, whose strategy focuses primarily on customer specific (often incremental) product innovations, process innovations or organisational innovations (Schumpeter 1934), which is frequently the case for non-R&D-intensive firms (Kirner et al. 2009a, Som et al. 2010, Rammer et al. 2011).

To analyse the AC of non-R&D-intensive firms we therefore propose to deploy a comprehensive, broader understanding of the AC of manufacturing firms which distinguishes not only between different phases of AC (recognition vs. implementation), but also between science-based and demand-side forms of external knowledge that is being accessed, respectively assimilated and transferred into practical solutions. This conceptualisation leads to four different forms of AC (table 1):

Table 1: Different dimensions of firms' AC (own illustration)

	Perception / recognition of external knowledge, information and trends	Implementation and exploitation of external knowledge
Externally available knowledge of technological solutions from R&D organisations	“laser welding”	Installation of a new laser welding device on the arm of an existing industrial robot in the production line
Externally available knowledge of current developments and trends in market demand and customer preferences	“increased flexibility requirements”	Segmentation of the internal production system into product or customer related lines

Firms can be differently positioned along these four dimensions depending, on the one hand on their ability to recognize and implement new technological and market developments, on the other hand on their strategic choice to pursue a certain innovation path which requires different types of external knowledge. In the empirical analysis we distinguish between these four dimensions and compare the AC of two different groups of firms: firms with high, respectively low R&D intensity.

Database

To empirically capture the concept of AC and to test its interaction with firm performance and technological orientation, we analyse firm-level data from a research project on non-R&D-intensive firms in the German manufacturing industry. These data were obtained by a computer-aided telephone survey (CATI) in early 2010 among more than 200 non-R&D-intensive firms and 88 firms with high R&D intensity in German manufacturing industry. [1]

According to previous studies (Kirner et al. 2009a; Som et al. 2010; Rammer et al. 2011; Som 2012), the sectoral classification based on R&D-intensity only partially reflects the actual R&D-intensity of firms, as non-R&D-intensive firms as well as R&D-intensive firms can be found at relevant shares in all industrial sectors. Thus, so-called low-, medium- or high-tech sectors do not represent homogeneous agglomerations of firm-level R&D intensity. To avoid generalisations about the R&D-intensity of firms by looking only at industry aggregate level, firms were screened regarding their expenditure on R&D by applying the OECD-based sector classification of R&D-intensity by Legler and Frietsch (2007) on firm level as selection criteria. The aim was to cover two populations:

- Non-R&D-intensive firms: firms with less than 2.5% expenditure on R&D
- Very R&D-intensive firms: firms with more than 7% expenditure on R&D.

By contrasting both groups and leaving out the group of mean R&D-intensive firms, these comparisons can indentify easily differences based on R&D intensity at firm level.

For sampling, in a first step two samples of manufacturing firms with more than 20 employees were randomly drawn. The sample size was estimated based on data of the German European Manufacturing Survey 2009 considering the distribution of R&D expenditures at firm level among the so called low-, medium- or high-tech industries (Kirner et al. 2009a). In a second step, firms were screened according their R&D intensity at the beginning of the interviews. Thereby, firms with more than 3% (for reasons of feasibility) and less than 7% share of R&D expenditures were excluded. In the end, 220 interviews with non-R&D-intensive firms as well as 88 interviews with very R&D-intensive

[1] The complete standardised questionnaire of the telephone survey is provided by the authors on request.

firms have been conducted. Both groups cover the whole range of manufacturing industries as well as the whole range of firm sizes (see table 2).

Table 2: Description of CATI firm sample (source: telephone survey, own calculations

	non-R&D intensive firms		very R&D intensive firms	
Secotral affiliation	N	%	N	%
Food and textile industry	20	9%	3	3%
Manufacture of chemicals, rubber and plastic products	22	10%	9	10%
Metal industry	27	12%	2	2%
Machinery and equipment	55	25%	27	31%
Manufacture of electrical equipment (except NACE 33)	33	15%	21	24%
Manufacture of medical, precision and optical instruments etc.	21	10%	16	18%
Manufacture of transport equipment	13	6%	3	3%
Others (furniture, jewellery, music instr., sports equipment etc.)	29	13%	7	8%
Total	220	100%	88	100%
Firm size classes				
20 to 49 employees	105	48%	43	49%
50 to 249 employees	94	43%	35	40%
more than 249 employees	21	9%	10	11%
Total	220	100%	88	100%

Nevertheless, when interpreting the results the limitations of the data have to be taken into account. it should be kept in mind that the ratio of both samples does not represent the ratio of both firm groups in manufacturing. However, as the data cover the whole range regarding firm size as well as sector affiliation it is possible to analyse differences between R&D-intensive and non-R&D-intensive manufacturing firms on a solid database.

Operationalisation of the AC-dimensions

Following the theoretical discussion, the measurement of the firms' AC distinguishes between a "science-based" dimension of R&D knowledge and information stemming from external R&D organisations ("AC_science"), and a dimension of customer-based knowledge about demands and trends on the market side ("AC_customer"). Additionally, it also differentiates between the ability to recognise relevant knowledge and information on the one hand, and, on the other hand, the ability to implement this knowledge successfully into concrete solutions and concepts to increase the firms' competitive advantage (table 3).

Table 3: Operationalisation of AC dimensions (source: telephone survey, own illustration)

	Perception	Implementation
AC_science	"To what extent does your company succeed in recognising important scientific knowledge, findings and information from external R&D organisations?"	"To what extent does your company succeed in capturing such important scientific knowledge, findings and information and manages to implement them into new internal solutions?"
AC_customer	"To what extent does your company succeed in recognising important knowledge, trends and impulses from its customers?"	"To what extent does your company succeed in capturing such important knowledge, trends and impulses from its customers and manages to implement them into new internal solutions?"

Both aspects of AC were captured regarding scientific knowledge as well as regarding customer-based knowledge on a self assessment scale ranging from "succeed very well" over "rather succeed", "rather not succeed" to "nearly never succeed". Additionally, the respondents were asked to assess to which extent the respective types of knowledge (science as well as customer-based) are of strategic importance for their firms' competitive success using a scale ranging from "very important" to "unimportant".

Empirical findings - descriptive statistics

First of all, it has to be validated whether the different dimensions of AC which can theoretically be assumed are reflected in the empirical data. We conducted a principal component analysis to test whether the two types of science- and customer-based AC regarded in this paper represent distinct dimensions. Tests before revealed that the observed correlation matrix differs not only by random from the identity matrix (according to Bartlett's Test of Sphericity significant at a level below 0,1%). Moreover, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.57, only a bit below the suggested minimum value of 0.6, indicating that a principal component analyses is feasible. Figure 1 shows that the four variables used to measure the AC of firms indeed constitute two distinct dimensions.

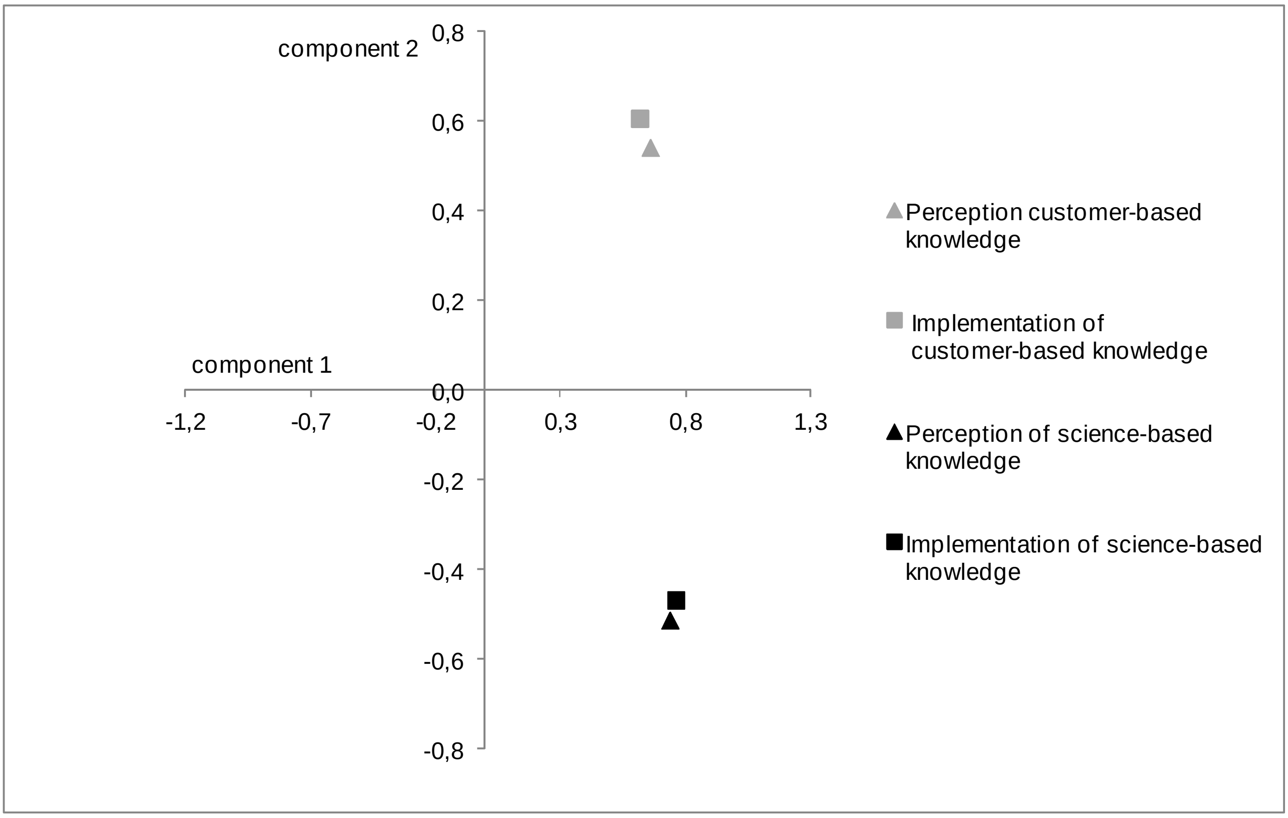

Figure 1: Principal component analysis on AC dimensions (source: telephone survey, own calculations)

Based on the four variables it is possible to distinguish between the firms' AC of customer-based knowledge and their AC of science-based knowledge. Mainly due to the second component both dimensions are clearly differentiated. Both dimensions together account for 76.9 % off the total variance of all four variables. This results is repeated also by analysing non-R&D-intensive firms and very R&D-intensive firms separately. Additional non-parametric correlation analyses validate this finding, statistically significant high correlations can only be observed between those two variables (perception variable and implementation variable) which jointly constitute a common dimension of AC (Kendall's tau b = 0.453 with p< 0.0001 for customers knowledge; Kendall's tau b = 0.543 with p< 0.0001 for scientific knowledge), while the inter-correlations between the science and customer dimensions are relatively low (Kendalls tau b between 0.142 and 0.205 with p> 0.001).

Hence, it can be stated that the variables used to measure the different dimensions of firms' AC are valid indicators to capture the two different dimensions of AC. Furthermore, this result justifies condensing the two variables (perception and implementation) into an index for each of the two AC dimensions (science-based and customer-based) (see the following paragraph). Moreover, the findings underline that both dimensions of firms' AC should not be equated as they describe different dimensions of their ability to recognise and transfer externally available knowledge into internal solutions. The fact that both AC_science and the AC_customer of firms are not completely independent from each other appears reasonable as they might be jointly affected by the firm's general ability to handle and management its internal and external stocks of knowledge.

Developing multiplicative indices of firms' AC of science- and customer-based knowledge

As discussed above, the AC of firms is understood by the combination of the ability to recognise important external stocks of knowledge and information on the one hand, and the ability to capture this knowledge and transform it into concrete practical solutions within the own firm to increase its competitiveness on the other hand. Based on the findings from the principal component analysis, the two dimensions of AC were captured as a multiplicative index allowing a range from 1 to 16 points with 1 indicating the lowest AC and 16 indicating the highest AC in the respective dimension.

As the descriptive statistics show (table 4), the mean AC_science is 12.0 with a standard deviation of 3.1; 90% of the firms have an AC between 7 and 16. The average on AC_customer is much higher with 14.4 and a standard deviation of 1.6. For this dimension of customer-based knowledge the constructed index differentiates less as the AC of 90% of the firms lies between 13 and 16. However, even if the construct does not discriminate so much at a high level of AC it does allow the description of this bi-dimensional concept.

Table 4: Multiplicative indices (perception x implementation) of the firms' AC_science and AC_customer (source: telephone survey, own calculations)

		Mean	Min.	Max.	Median	Range	Std. Dev.	N	Variance
All firms	AC_science	12.0	1.0	16	13	15	3.1	272	9.6
	AC_customer	14.4	5.0	16	13	11	16.0	302	2.5
non-R&D-intensive firms	AC_science	11.7	1.0	16	13	15	3.3	187	10.7
	AC_customer	14.3	5.0	16	13	11	1.6	214	2.7
very R&D-intensive firms	AC_science	12.7	1.0	16	13	15	2.5	85	6.4
	AC_customer	14.6	8.0	16	15	8	1.4	88	2.1

Regarding the two different groups of firms' R&D intensity, it can be seen that the non-R&D-intensive firms' mean AC of science-based knowledge is only slightly lower (11.7) than that of very R&D-intensive firms (12.7), which at a first glance supports the widespread assumption that non-R&D-intensive are less capable of absorbing externally available science-based stocks of knowledge. This picture is also supported by looking at the distribution of the AC_science index for both firm groups (figure 2).

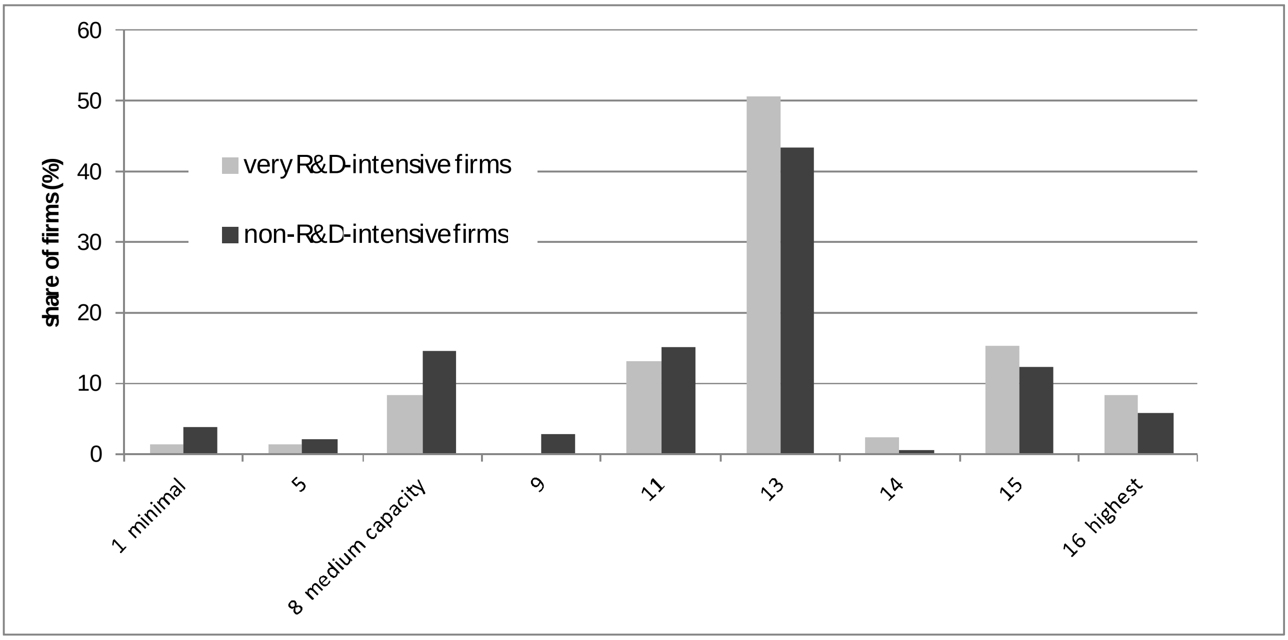

Figure 2: AC index of science-based knowledge (source: telephone survey, own calculations)

The shares of non-R&D-intensive firms on lower and middle values of the AC_science index are higher, while the group of very R&D-intensive firms have higher shares in the top categories of the AC index. Nevertheless, it has to be noticed, that almost 20 % of the non-R&D-intensive firms located their AC of science-based knowledge in the two highest categories which mean that they succeed very well in the perception as well as the implementation of such knowledge. Last but not least, the variance of the AC_science is much greater for non-R&D-intensive firms (10.7) than for very R&D-intensive firms (6.4). This might indicate that the AC_science of non-R&D-intensive firms shows a high level of inter-firm heterogeneity depending on the different innovation strategies that can be found among them (Som 2012, Hirsch-Kreinsen 2007). This aspect will be addressed more closely in the next section when the strategic importance of the knowledge dimension will be taken into account.

Looking deeper into the data reveals, that very R&D-intensive firms rather succeed in the implementation and exploitation of science-based information within their enterprise. More than 80 % of the very R&D-intensive firms state that they succeed (very well or well) in the implementation which is significantly higher compared to the group of non-R&D-intensive

firms (69 %). In contrast, the difference in the share of firms who state that they are able to monitor and recognise science-based external knowledge (very well or well) is slightly lower and accounts for about 9 % in favour of very R&D-intensive firms. The circumstance, that the implementation and exploitation seems to cause bigger problems for non-R&D-intensive firms might be due to the fact that non-R&D-intensive firms frequently do not have an internal R&D department which often results in the lack of an institutionalised innovation process to systematically promote the internal realisation of innovation projects (Som/Zanker 2011).

Regarding the customer or market dimension of the firms' AC shows a much more homogeneous picture (figure 3), which is also reflected by the low variance of the AC_customer index varying around 2.1 in the case of very R&D-intensive firms and 2.7 for non-R&D-intensive firms. Compared to AC_science the AC_customer of R&D and non-R&D-intensive firms is consistently higher (14.6 respectively 14.3). Obviously, it is easier for both groups of firms to handle "familiar" stocks of knowledge within the common knowledge culture along the economic value chain, because they talk the same language as their customers.

Furthermore, there are no clear differences in the AC_customer between R&D and non-R&D-intensive firms in the distribution across the index categories. Looking more closely into the index data confirms this finding. The differences between both firm groups regarding their perception and implementation abilities are marginal and do not even account for 1 %. Hence, the few differences between very R&D-intensive firms and non-R&D-intensive firms in the AC_customer should not be over interpreted. Instead, it has to be feared that the operationalisation of the customer dimension of AC used in our telephone survey is not able to differentiate sufficiently. We will see if this suspicion will still hold when the strategic importance of customer-based knowledge is taken into account.

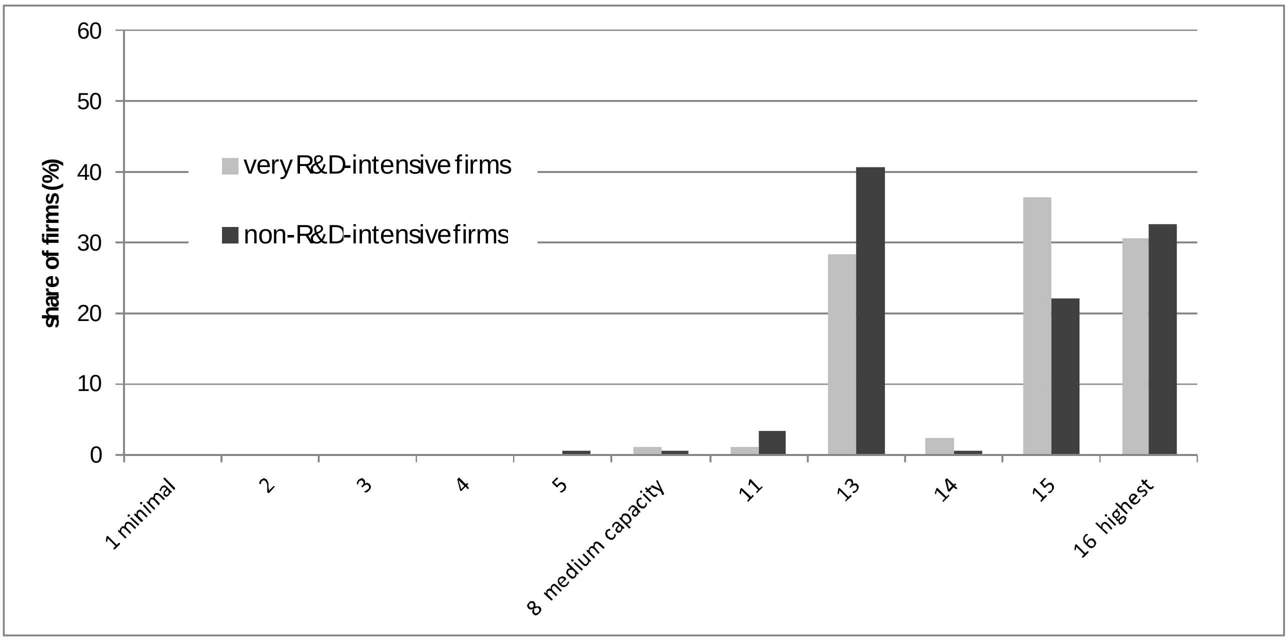

Figure 3: AC index of customer-based knowledge (source: telephone survey, own calculations)

The AC of firms in the context of the importance of external science-based and customer-based knowledge

Hanging on to the previous presented argument that heterogeneous innovation strategies of firms constitute different abilities to explore and exploit different types externally available knowledge (Srholec/Verspagen 2008, Som 2012), the development of an AC makes only sense, if the firms considers the respective knowledge to be of strategic importance for its innovativeness and competitive success. Otherwise, the build-up of the corresponding type of AC seems not very reasonable from an economic perspective because the availability of personnel and organisational interfaces is very cost-intensive. Therefore, the firms in the telephone survey were asked about the importance of science-based and customer-based knowledge as a source to gain competitive advantage.

The following table (5) depicts that the importance of both types of external knowledge is significantly different between the two firm samples of different R&D intensity. The findings have also been controlled for firm size and sector affiliation, but both factors do not play a significant role in the explanation of the differences. Most surprisingly and contradicting our previous expectation, customer-based knowledge seems to be of less importance for non-R&D-intensive than for very R&D-intensive firms. This might be due to the fact that R&D-

intensive goods and products of higher complexity are more often manufactured in close coordination with customers and users.

Table 5: Strategic importance of external science-based and customer-based knowledge (source: telephone survey, own compilations)

		non-R&D-intensive firms*		very R&D-intensive firms		Total	
		N	%	N	%	N	%
Strategic importance of science-based external knowledge, findings and information	very important	27	12.6	16	18.2	43	14.2
	partially important	99	46.0	54	61.4	153	50.5
	rather unimportant	67	31.2	17	19.3	84	27.7
	unimportant	22	10.2	1	1.1	23	7.6
Total		215	100.0	88	100.0	303	100.0
Strategic importance of customer-based knowledge, trends and impulses	very important	147	67.7	71	80.7	218	71.5
	partially important	54	24.9	14	15.9	68	22.3
	rather unimportant	16	7.4	3	3.4	19	6.2
	unimportant	,	,	,	,		
Total		217	100.0	88	100.0	305	100.0

* $p < 0.05$

However, against the backdrop of appropriate measurement, it has to be remarked again that the customer dimension seems not to differentiate very well. In both groups, at least three thirds of all firms in the subsample indicate that customer-based knowledge, trends and impulses are very important for their competitive success; over 90 % assessed this kind of knowledge as at least partially important. Thus, the distribution is very right tailed and might not leave enough variance. Asking for the importance of external customer-based knowledge in this way seems to cause the obvious result that almost every firm which is seriously interested in selling their products would sign the statement that knowledge about their customers and clients is important.

Proceeding to the dimension of the importance of science-based knowledge and information shows also interesting findings. The assumption that this type of external knowledge might be of lesser importance for non-R&D-intensive firms is reflected by the significant lower shares of non-R&D-intensive firms that attribute high importance or importance to this kind of external knowledge compared to the very R&D-intensive ones. In turn, the share of non-R&D-intensive firms which reported science-based knowledge and information to be rather unimportant or unimportant is considerably higher than for strong R&D performers. Nevertheless, almost 60 % of the non-R&D-intensive firms see science-based knowledge and information as important or very important for their competiveness which is, interpreted in absolute terms, quite remarkably. Thus, a low R&D

intensity of firms should not necessarily be equated with the absence or the lower relevance of science-based stocks of knowledge and information per se.

It should be added at this point that three firms were set to missing and were excluded from subsequent analyses, because they neither report science- nor customer-based knowledge to be important for their competitiveness. Hence, it has to be assumed that they in consequence do either not need to develop the corresponding types of AC or, respectively, their score on AC seems not to be based on reliable estimations. Consequently, the assessments of AC are not analysed for firms who rated the respective type of knowledge as of no interest at all, following the idea that AC is only meaningful when the knowledge has a certain importance for the competitiveness of the firm.

Conclusively, integrating the aspects a) of the importance of the respective knowledge dimension, and b) its corresponding level of AC results in the following findings (table 6 and table 7).

Table 6: AC_science of firms depending on the strategic importance of external science-based knowledge (source: telephone interviews, own calculations)

		non-R&D-intensive firms				very-R&D-intensive firms				Total			
		Mean	Std. Dev	Median	N	Mean	Std. Dev	Median	N	Mean	Std. Dev	Median	N
Strategic importance of external scienced-based knowledge, findings and information***	very important	12.9	1.5	13	33	13.2	2.9	13	31	13.1	2.3	13.0	64
	partially important	12.2	3.0	13	85	12.4	2.4	13	37	12.2	2.8	13.0	122
	rather unimportant	10.3	3.8	11	64	12.5	2.0	13	17	10.7	3.6	11.0	81
	unimportant	13.0	3.1	13	5	,	,	,		13.0	3.1	13.0	5
Total		11.7	3.3	13	187	12.7	2.5	13	85	12.0	3.1	13.0	272
Strategic importance of external scienced-based knowledge, findings and information (dummy)***	rather important	12.9	1.52	13	33	13.2	2.9	13	31	13.1	2.3	13.0	64
	rather unimportant	11.4	3.49	13	154	12.4	2.2	13	54	11.7	3.2	13.0	208
Total		11.7	3.28	13	187	12.7	2.5	13	85	12.0	3.1	13.0	272

*** p < 0.001

To start with the science-based dimension, it shows up that the importance of external, science-based knowledge and information is the main determinant for the level of AC_science for non-R&D-intensive as well as for very R&D-intensive firms. This means that the importance which is ascribed to the externally available science-based knowledge significantly influences the corresponding AC of firms, regardless their firm size or sectoral affiliation as non-parametric tests show. Moreover, as can be seen from the table, the ascribed importance offsets the previous differences of the AC_science between non-R&D and very R&D-intensive firms. Regardless their R&D intensity, those firms who state that external science-based knowledge is very or partially important, show the same level of AC. Thus, if needed for their competitive success, non-R&D-intensive are able to develop the same AC of science-based knowledge than very R&D-intensive firms. Looking at those firms stating that science-based knowledge is only of partial importance for their competitiveness underlines that the development of AC_science in the case of non-R&D-intensive firms represents a strategic decision, because it strongly decreases as soon as science-based knowledge is ascribed less importance. In contrast, very R&D-intensive firms seem to have some kind of a “basic” AC of science-based knowledge causing them less effort to maintain. In the case that external science-based knowledge is regarded to be of rather little importance, very R&D-intensive firms still show a considerably high AC compared to those firms who regard such knowledge as important.

Table 7: AC_customer of firms depending on the strategic importance of external customer-based knowledge (source: telephone interviews, own calculations)

		non-R&D-intensive firms				very-R&D-intensive firms				Total			
		Mean	Std. Dev	Median	N	Mean	Std. Dev	Median	N	Mean	Std. Dev	Median	N
Strategic importance of external customer-based knowledge, trends and impulses	very important	14.5	1.5	15	137	14.6	1.3	15	61	14.6	1.4	15.0	198
	partially important	14.1	1.5	13	50	14.4	1.9	15	21	14.2	1.6	15.0	71
	rather unimportant	13.3	2.9	13	18	15.0	1.2	15	5	13.7	2.7	13.0	23
	unimportant	14.5	1.7	14.5	4	13.0	,	13	1	14.2	1.6	13.0	5
Total		14.3	1.6	15	209	14.6	1.4	15	88	14.4	1.6	15.0	297
Strategic importance of external customer-based knowledge, trends and impulses (dummy)	rather important	14.5	1.5	15	137	14.6	1.3	15	61	14.6	1.4	15.0	198
	rather unimportant	13.9	1.9	13	72	14.5	1.7	15	27	14.1	1.9	15.0	99
Total		14.3	1.6	15	209	14.6	1.4	15	88	14.4	1.6	15.0	297

Table 7 provides an overview on the customer-dimension of AC depending on the importance of customer-based stocks of knowledge. The results are quite similar to the AC_science index. The firms’ AC of customer-based knowledge is significantly determined by the ascribed strategic importance of customer knowledge for the own competitive success, regardless the level of R&D intensity. This clearly contradicts our hypothesis (H_{1b}) that non-R&D-intensive firms might show a higher AC_customer due to their higher level of customer proximity. For the group of non-R&D-intensive firms, these findings again hold for the control of firm size and sectoral affiliation in non-parametric testing. However, due to the very low differentiation of the customer dimension, the differences in the AC_customer for the group of very R&D-intensive firms are not statistically significant. Furthermore, in contrast to their science-based AC, non-R&D-intensive maintain their level of AC_customer to some extent even if customer-based knowledge is regarded as rather unimportant. The surprisingly low differences in the level of AC_customer between R&D- and non-R&D-intensive firms might be rooted in two possible aspects. On the one hand, it might be assumed that our operationalisation of AC_customer turns out to be inappropriate, as firms generally tend to state that external customer or market knowledge is of high importance for their economic success. A possible lessons learned for future empirical studies on firms' AC of customer-based knowledge should take this into consideration and aim to develop a measurement of concept of customer-based AC accounting for the importance, which has more differentiating power. On the other hand, it might also be reasonable to argue that due to the general importance of external market and customer knowledge, the level of strategic importance does not influence the AC_customer of firms in contrast to AC_science. Anyway, due to these reasons, we decide to exclude the customer dimension of AC from the following regression analyses, and instead focus on the AC_science dimension. Unfortunately, this means that our hypotheses H_{1b} and H_{2b} cannot be tested by multivariate regression analysis.

Empirical findings - regression analysis on AC_science

Finally, in this subchapter our first hypothesis (H_{1a}) on the influence of the importance of external science-based knowledge on AC_science is tested using a multivariate regression model. Hereby the impact can be estimated controlling for firm size and sector affiliation. Additionally, a second regression will be estimated to analyse the interaction effect between R&D-intensity and the strategic importance of the external knowledge (H_{2a}). As the AC indicator can hardly be seen as a continuous response variable which fits the assumption of a simple linear model, we choose a Poisson regression model instead of an ordinary linear regression. The advantages of Poisson regression models are that a skewed, discrete distribution can be handled (Long 1997). Moreover, the predicted values are restricted to non-negative numbers which fits perfectly the value range of our AC indicators.[2]

[2] It is important to mention that while using a Poisson regression only the logarithm of the dependent variable is linearly related to the influencing factors. The regression equation links the logarithm of the dependent variable to a linear function of explanatory variables such that $\log_e(Y) = \beta_0+\beta_1X_1+\beta_2X_2$. This means, the regression coefficients indicates that a change in an independent variable causes a change in the log of the dependent variable, under control of all other factors.

As displayed in table 8, a first model (1) was calculated only controlling for R&D intensity as well as firm size and sector, while in the second model (2) the importance of knowledge as well as an interaction term between R&D intensity an importance was added. Thereby, the context variables are operationalised as categorical data, displayed already above for presenting the database. Also the importance of knowledge is operationalised as a categorical variable. The interaction term is constructed as a multiplicative combination. For very R&D-intensive firms it is 0, for non-R&D-intensive firms it is 1 starting with 1 for firms which assess scientific knowledge as rather unimportant, 2 for an assessment as rather important and 3 as very important.

Table 8: Explaining AC_science using Poisson regression models (source: telephone interviews, own calculations)

	Model 1			Model 2		
Explanatory variables	**Coef.**	**Std. err.**	**Sig**	**Coef.**	**Std. err.**	**sig**
Const.	2.637	.062	.000	2.516	.0706	.000
Firm size (1)			.037			.090
Small firms	-.094	.037	.011	-.076	.035	.028
Medium sized firms	-.062	.037	.091	-.041	.034	.224
Sector (2)			.723			.769
Food	-.083	.088	.348	-.061	.072	.394
Paper, print	-.093	.115	.419	-.117	.099	.239
Chemistry, rubber	-.132	.089	.135	-.128	.076	.092
Metal	-.026	.074	.727	-.056	.059	.348
Machinery	-.020	.059	.729	-.038	.051	.465
Electrical, electronic	-.006	.058	.914	-.024	.049	.620
Transport equipment	-.063	.108	.560	-.035	.094	.709
R&D intensity (3)						.034
less than 3%	-.069	.031	.028	-.312	.149	.034
Strategic importance of external scientific knowledge (4)						.013
Very important				.151	.071	.033
Important				.140	.048	.004
Interaction: high R&D intensity x importance				-.091	.046	.047
Model fit						
Number of observations			272			272
Likelihood-Quotienten-Chi-Quadrat			12.440			47.461
Sig.			0.257			0.000
Correlation pred. Vs. observ. Values (Pearson's r		.238	0.000		.455	0.000

Notes: Reference groups: (1) bigger firms with at least 250 employees. (2) other sectors. (3) R&D intensity at least 7%. (4) rather not important.

Even if model 1 is not significant due to the sector variables, it indicates that firm size as number of employees and R&D intensity influences AC_science. The predicted results correlate statistically significant with the observed ones, but not very strongly. As the model test indicates, the sector affiliation does not to improve the prediction of a firm's AC_science, but firm size does. According to the regression estimates, small firms possess less AC_science then big ones. Regarding the R&D-intensity of firms the results indicate clearly, that non-R&D-intensive firms have less AC_science than very R&D-intensive firms. Hence, our first hypothesis (H_{1a}) following the original argumentation by Cohen and Levinthal is clearly supported by these results so far.

Including the strategic importance of external scientific knowledge for the firm's competitive success as well as the interaction effect between the R&D-intensity and this assessment does considerably improve the model (see model 2). The Omnibus Test indicates that the model as the totality of all of the estimated coefficients is statistically significant. The according p-value is close to 0. Additionally, the goodness-of-fit chi-squared test indicates that the Poisson model fits reasonably well ($p>0.89$). Not only becomes the model statistically significant, but also the correlation between the observed and the predicted values of AC_science is considerably increased. Pearson's r^2 is doubled.

Looking at the different constructs, the model tests indicate that AC_science is mainly influenced by the effects of importance of scientific knowledge and R&D-intensity. Considering firm size increases the model fit only at a 10% significance level, the influence direction remains the same. Small firms possess less AC_science then larger ones. Similar to model 1, sector affiliation remains of no importance. Besides, the results indicate, that there is still a slight independent effect of R&D-intensity. Moreover, for all firms we can state that the more important external scientific knowledge is, the higher the AC_science will be.

Finally, when considering the strategic importance of external scientific knowledge and its interaction with R&D-intensity, a moderating effect becomes visible. The influence of R&D-intensity on the firms' level of AC_science is considerably enlarged: Without any importance of the respective knowledge non-R&D-intensive firms have a much lower AC_science than very R&D-intensive ones. Additionally, differences between non-R&D-intensive and very R&D-intensive firms are transmitted by a different influence of the importance of the knowledge. This interaction effect is statistically significant. In figure 4 the mean predicted values are displayed for illustrating it.

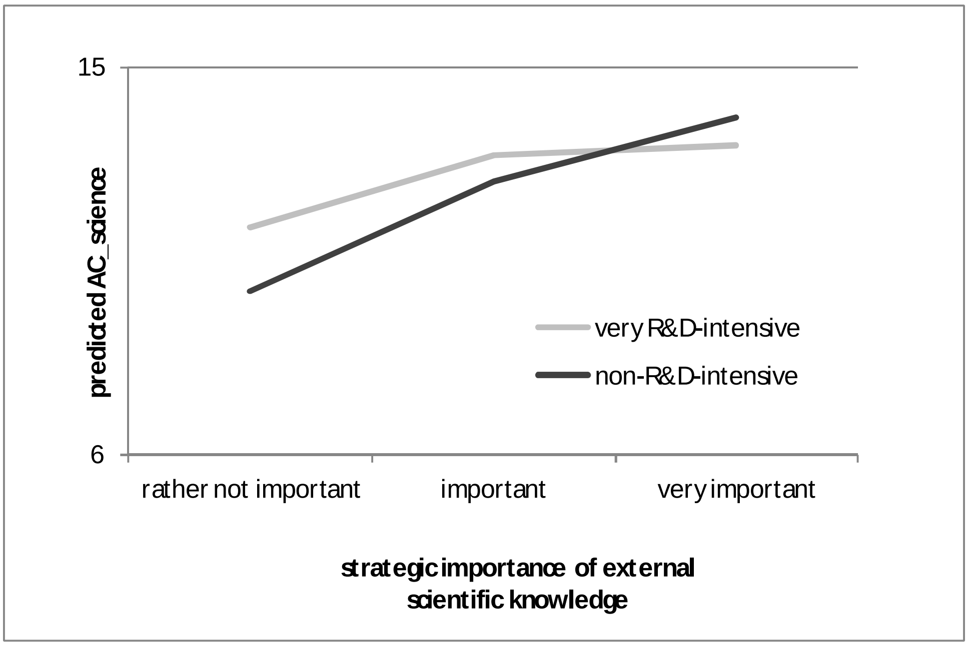

Figure 4: Mean predicted value for AC_science based on regression model 2 (own calculations)

Figure 4 shows that very R&D-intensive firms which assess external scientific knowledge rather as not important will have a higher AC_science than their non-R&D-intensive counterparts. However, when paying more strategic attention to this type of external knowledge non-R&D-intensive firms improve their AC_science to a comparable degree than very R&D-intensive enterprises. That means the importance of knowledge has a greater impact for non-R&D firms. This means that the second hypothesis (H_{2a}) assuming an interaction effect between the strategic importance of external science-based knowledge and the corresponding AC_science is also supported by our results as non-R&D-intensive firms show a similar AC_science compared to very R&D-intensive firms - if external science-based knowledge is of strategic importance to their competitive success.

Conclusion

The results show that there is surprisingly little difference between non-R&D and very R&D-intensive firms in their ability to absorb external source of knowledge, be it science-based or customer-based knowledge – if the firm specific relevance of such external knowledge is being taken into consideration. Given that not all firms (be it R&D or non-R&D-intensive firms) compete on the basis of a first-mover strategy, there are significant differences to be found between firms as regards the individually perceived importance of the early adoption of new technological trends. On the one hand, a relevant share of R&D-

intensive firms does not perceive a high necessity to monitor and implement newest technological developments. On the other hand, quite a number of non-R&D-intensive firms do consider the recognition and implementation of the latest scientific knowledge from R&D organisations to be relevant for their business and therefore engage in practices that allow for the successful absorption of these trends. Both very R&D-intensive and non-R&D-intensive firms are equally able to recognize and also successfully implement new technological trends, if this matches their competitive strategy and is therefore considered relevant. To explain the AC of firms, regardless whether AC_science or AC_customer, the strategic importance of the respective external knowledge is a much better proxy than the mere R&D-intensity of firms. This underlines the necessity of a broader understanding of firms' AC and rejects the argumentation that the AC of science-based knowledge is solely determined by the R&D intensity of firms. Thus, this paper contributes to the scientific debate on AC by providing new empirical evidence how the measurement and explanation of firms' AC could be improved by future research.

However, the results also clearly shows that non-R&D-intensive firms have to undertake much more efforts to achieve a high level of AC; in particular AC_science. While very R&D-intensive firms still show a comparably high AC_science even if the strategic importance of external science-based knowledge is weak, the AC_science of non-R&D-intensive dramatically drops in this case. Hence, the availability of strong professionalised R&D-activities has nevertheless to be considered as a strong enabler of firms' AC_science. From a managerial perspective, this means that non-R&R-intensive firms have to make clear strategic decisions whether external science-based knowledge should be absorbed or not and - if so - to consequently devote considerable internal resources and implement processes to build up and maintain such an AC_science. Besides some first contributions (e.g. Som/Zanker 2011) there is however only scarce management research on how non-R&D-intensive firms can design and implement processes and structures to increase their AC to date.

The assumed specialisation of non-R&D-intensive firms on the absorption of customer-based knowledge in contrast to the science-orientation of very R&D-intensive firms as described by previous research could surprisingly not be confirmed on basis of the available data. Beside the fact, that this might be due to operationalisation problems resulting in low differentiating power of the findings, this could also be an indicator that the mechanisms of firms' AC_customer are somehow different compared to AC_science, as the strategic importance is not the appropriate explanatory variable. For future research, this implies both, the development of a more refined measurement of AC_customer as well as more conceptual research to improve our understanding about this dimension of firms' AC.

Last but not least, this paper of course has some limitations which also could serve as starting point for future research. First of all, the limited number of observations somehow constrain the analytical possibilities in terms of complex multivariate modelling (e.g. in terms of the available control variables). Therefore the findings presented have to be confirmed by large-scale empirical data. Secondly, the R&D-intensity of firms is only available as a dummy variable that indicates whether a firms is below (< 3%) or above (>7%) a certain threshold of R&D expenditure. A metric R&D variable would clearly be more preferable. Finally, the AC was measured in terms of subject self-estimations of the interviewed firm representatives. For future research, it is thus necessary to clarify to what extent this perceived estimations correspond to the actual openness of the firms' innovation processes, and to supplement them by objective facts and figures.

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