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Abstract

Absorptive capacity (ACAP) enables firm to adjust to a rapidly changing environment and achieve sustained competitive advantage. This study contributes to the existing body of knowledge on ACAP by providing a comprehensive literature review of the various conceptual attributes of the construct, its determinants, outcomes, and positive and negative consequences of using its input-oriented, output-oriented, and perceptive measurement modes. Proposals for constructing ACAP based on the Community Innovation Survey (CIS) empirically illustrate for the conceptual part of the paper. Additionally, combining concepts of absorptive capacity and open innovation (which is still rare in the literature) provides a new perspective on the role of absorptive capacity in opening up the innovation process. This advances the understanding of both inter-related proposals. The article also identifies key problems and formulates future research directions to improve the multi-level characteristics of absorptive capacity.

Keywords: knowledge absorption, capability, open innovation.
JEL: M10, O31, O32.

Introduction

In this theoretical paper, the notion of *absorptive capacity* (ACAP), its determinants, outcomes, measurement modes, and role in open innovation are presented.

To increase their competitive potential in the current environment, firms have to open up their processes and apply knowledge from outside sources. An important factor that influences the ability to acquire this knowledge is *absorptive capacity*, defined as “the ability of a firm to recognize the value of new external information, assimilate it and apply it to commercial ends” [Cohen, Levinthal, 1990, p. 128].

Literature concerning what *absorptive capacity* is, and its basic characteristics (e.g., components, determinants, measurement modes, and outcomes) is extremely varied. Moreover, many empirical researchers use R&D intensity as an indicator for *absorptive capacity*, assuming that higher levels of R&D investments directly improves a firm’s ability to exploit external knowledge, which is not always the case, especially in low technology industries or among small and medium-sized enterprises.

The importance of a firm’s competence to acquire and assimilate knowledge is critical, as many enterprises shift their innovation models from closed towards the open ones, where the importance of combining internal and external knowledge as part of firms’ innovation strategy [Chesbrough, 2003]. Although both *absorptive capacity* and open innovation (OI) are two concepts based on the idea that companies can leverage the knowledge generated externally to improve their innovation performance, and are obviously connected, they have only recently been discussed jointly in the literature [Flor et al., 2013].

This paper is organized as follows. Part one summarizes the most influential conceptualizations of *absorptive capacity*. In part two, determinants, as well as outcomes of *absorptive capacity* are discussed. Part three of the paper provides insight into different quantitative methods of *absorptive capacity* measurement. In part four, a discussion about connections between *absorptive capacity* and open innovation is presented. Conclusions and directions for further research appear in the final section.

The Idea of Absorptive Capacity

The term *absorptive capacity* (ACAP) is associated mainly with Cohen and Levinthal’s works [Cohen, Levinthal, 1989, 1990, 1994], but it is rooted in earlier publications in development economics. It has much in common with the notion of *social capability* used in the developing countries context, to improve capabilities (such as: technical competences, financial institutions and markets, stability of government, honesty and trust) that allow them to catch-up with more developed economies [Abramovitz, 1986]. *Absorptive capacity* was also widely understood as the ability of the developing country to absorb new investments [Adler, 1965]. Later, as the role of knowledge has become more important for economic growth and development, *absorptive capacity* has also been understood as the “ability to absorb knowledge,” explained by Rostow, who states, that “middle income countries have to build up the stock of trained man-power (including entrepreneurs) to a position where they can accelerate the rate of absorption of the existing

stock of knowledge” [1980, p. 267–277]. Both, the concept of *social capacity* and *absorptive capacity* were first associated with the national economy level. Many researchers subsequently applied it to understand as firm’s ability to acquire knowledge from its external environment [Tilton, 1971; Allen, 1984].

Cohen and Levinthal explained (based on industrial organization economics) the main determinants of a firm’s motivation to invest in *absorptive capacity*, such as the scope of technological opportunities available to the firm, the nature of technological opportunity, and the degree of improvement in technological performance through using external knowledge. These authors also empirically tested this reasoning, and defined *absorptive capacity* as “the ability of a firm to recognise the value of new, external information, assimilate it and apply it to commercial ends” [Cohen, Levinthal, 1990, p. 128].

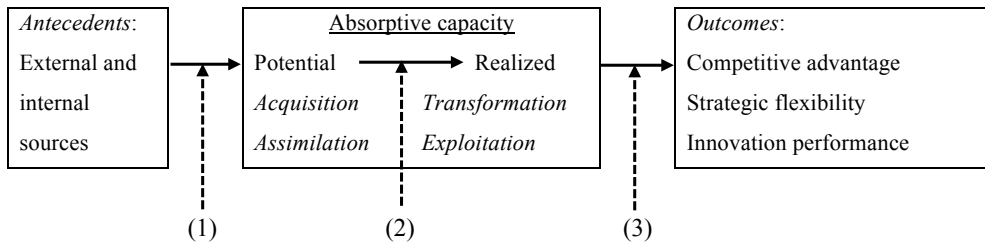
ACAP has two essential features: first – *absorptive capacity* is “cumulative” [Cohen, Levinthal, 1990, p. 130]: firms with a given level of technological, market and organisational knowledge may be more successful in those areas than in others. Second – prior knowledge affects anticipation: firms can forecast future events with greater accuracy in fields where they have previous experience.

Tracking the work of Cohen and Levinthal, Zahra and George [2002] argued that “firms can acquire and assimilate knowledge, but might not have the capability to transform and exploit the knowledge for profit generation” [Zahra, George 2002, p. 191] and thus deconstructed *absorptive capacity* into *potential absorptive capacity* (PACAP) and *realized absorptive capacity* (RACAP). PACAP consists of knowledge *acquisition*, which “refers to a firm’s capability to identify and acquire externally generated knowledge that is critical to its operations” [Zahra, George, 2002, p. 189] and knowledge *assimilation* which “refers to the firm’s routines and processes that allow it to analyse, process, interpret and understand the information obtained from external sources” [Zahra, George, 2002, p. 189]. RACAP is made up of *transformation* capability, defined as “a firm’s capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge” [Zahra, George, 2002, p. 190], and *exploitation* capability, which is “organizational capability based on the routines that allow firms to refine, extend, and leverage existing competencies or to create new ones by incorporating acquired and transformed knowledge into its operations”. [Zahra, George, 2002, p. 190]. *Potential* ACAP is more outside-oriented [Fosfuri, Tribo, 2008], whereas *realized* ACAP refers to the internal processes of external knowledge assimilation. By the combination of *potential* ACAP and *realized* ACAP, a firm increases the uniqueness of its innovation [Yli-Renko et al., 2001] and builds competitive advantage.

Drawing on management and organisation studies, in the analysis of ACAP antecedents (external sources of knowledge coming from acquisition and inter-organisational relations and internal sources, steaming from past experience and learning by doing) and outcomes, authors have considered the “moderating” role of specific internal processes (such as “activation triggers,” “social integration mechanisms” and “regimes of appropriability”),

which help knowledge flow within the firm. “Activation triggers” incorporate not only a firm’s internal crises, but also external market fluctuations; “social integration mechanisms” cover social arrangements encouraging employee interactions, whereas “regimes of appropriability” provide effective protection against imitation and facilitate returns on innovation investments.

FIGURE 1. Firm’s absorptive capacity- conceptual model



Source: adapted from Zahra and George [2002].

Todorova and Durisin [2007], in their later publications, demanded a return to the classical definition of Cohen and Levinthal, but extended ACAP from its original three dimensions: *identification*, *assimilation*, and *exploitation* – to five separate concepts: *recognition*, *acquisition*, *assimilation*, *transformation*, and *exploitation*. According to authors, these steps can influence each other but do not necessary occur linearly from one to the other [Todorova, Durisin, 2007]. Therefore they argued, that the new concepts of *potential* and *realized absorptive capacity* should be removed from the theory [Todorova, Durisin, 2007, p. 775].

A concept that is used in the same sense as *absorptive capacity* (although narrowed to the technological knowledge), is *technological capability*, defined as “the ability to make effective use of technological knowledge in efforts to assimilate, use, adapt, and change existing technologies. It also enables one to create new technologies and to develop new products and processes” [Kim, 1997, p. 4]. Tsai uses the term *technological capability* instead of *absorptive capacity* in one paper [Tsai, Hsieh, 2009], while in other, in a very similar context, exchanges it for *absorptive capacity* [Tsai, 2009].

Schmidt [2005], distinguishes between science-based knowledge and knowledge from the private sector, proposing three types of *absorptive capacity* namely: *absorptive capacity for intra-industry knowledge*, *absorptive capacity for inter-industry knowledge* and *absorptive capacity for scientific knowledge*. He argues (based on Nelson and Wolff [1997]), that organisational *absorptive capacity* hangs on the characteristic of acquired external knowledge and that science-based technological knowledge requires a higher level of *absorptive capacity* than knowledge from business sources, such as customers, suppliers

or competitors. The proposed distinction between different types of knowledge and, thus, different types of *absorptive capacity* was confirmed by Mangematin and Nesta [1999], who found that higher *absorptive capacity* increases the proficiency to use fundamental (as opposed to applied) external knowledge, and that firms with highly developed *absorptive capacity* have more interactions with research institutes than firms with lower *absorptive capacity*. This supposition is derived from Cohen and Levinthal's conclusions [1990, p. 152], that a "firm is better capable to acquire and use external knowledge from areas it has some prior experience or related knowledge in" (path-dependency of *absorptive capacity*).

Building on Schmidt findings, Murovec and Prodan [2009] dropped the first type of ACAP in favour of *demand-pull absorptive capacity* and *science-push absorptive capacity*. At this point it should be mentioned, that both Schmidt [2005] and Morovec and Prodan's [2009] of ACAP operationalization can be also used to operationalize the *non-pecuniary inbound open innovation* – that is, acquisition of external sources of knowledge not done in exchange for any pecuniary gratification, which may result in misleading outcomes.

Absorptive capacity has many characteristics of dynamic capabilities, firm's assets that are scarce and difficult to be replicated. Zahra and George [2002] were the first to explicitly conceptualize ACAP as a dynamic capability. They argued that four capabilities, namely: knowledge *acquisition*, *assimilation*, *transformation* and *exploitation* – build upon each other to produce a dynamic organisational capability.

First order dynamic capabilities are defined as capabilities that permit firm's to change fundamental capabilities and resources [Teece, et al., 1997; Eisenhardt, Martin, 2000]. By contrast, ordinary, or *zero order capabilities* [Collis, 1994, Winter, 2003; Zahra et al., 2006], refer to routines that empower firms to deploy their resources to earn a living in the present. Collis [1994] identified *second-order dynamic capabilities* ("learning-to-learn capabilities") as those that can be used to develop *first-order dynamic capabilities* [Schilke, 2014].

Summing up this brief literature review, it should be underlined that despite different names and conceptualizations, all of the above-mentioned works define *absorptive capacity* (ACAP) as a firm's capability to address a rapidly changing environment. It is supposed to be a competence comprising individual capabilities building on each other and potentially give the firm a basis for obtaining competitive advantage.

The term *absorptive capacity*, used in different contexts and at different levels of analysis, has also attracted the interest of Polish scholars. Truskolaski [2014], in his book on the importance of knowledge transfer in enterprises' innovative activities, speaks of the "social capabilities" of countries, defined, similarly to Abramowitz as "potential that reflects these countries' greater opportunity to advance by borrowing and adapting the best practice technology and organization of more productive economies" [Abramovitz, 1994b, p. 87]. Runiewicz-Wardyn [2013, p. 51] defines *absorptive capacity* as the "ability to imitate foreign advanced technologies" and argues that, together with innovative capability, ACAP determines a region's ability to narrow technological gaps and improves productivity growth.

The importance of *absorptive capacity* in the context of inter-organisational linkages is raised by Czakon and Lenart [2011], whereas Lenart [2011] describes the relation between firms' knowledge base and its *absorptive capacity*.

Pietrewicz [2012] raises an important issue of the link between *absorptive capacity* and cooperation, as well as potential benefits for a firm's *absorptive capacity*, resulting from EU financial support. Based on empirical results for Polish enterprises, he found that firms' low *absorptive capacity* results in low openness for cooperation with institutional partners, and that in many cases financial support from EU funds is not used properly by supported enterprises and does not result in firms' higher *absorptive capacity*.

Światowiec-Szczepańska [2012], using Cohen and Levinthal's classical definition, argues that *absorptive capacity* is inevitable in the process of knowledge sharing and exchange among enterprises in networks, and thus positively impacts relational rent potential, defined as "supernormal profit jointly generated in an exchange relationship, that cannot be generated by either firm in isolation and can only be created through the joint idiosyncratic contributions of the specific alliance partners" [Dyer, Singh 1998, p. 662].

Lastly, Ryszko [2015], following the proposal of Gluch et al. [2009], constructs an *absorptive capacity* model for green innovation, arguing that it is the inevitable base for the eco-innovation business model of an enterprise, and compliments firm's basic activities.

Determinants and Outcomes of Absorptive Capacity

Determinants of *absorptive capacity* can be widely divided into those from intra-firm level and those related to inter-firm level of analysis. *Absorptive capacity* can only be fully explained when both the internal structures and processes of a company as well as its interaction with other entities are taken into account.

The intra-firm level of ACAP largely depends on the amount of prior, related knowledge within organisations and internal mechanisms of formalization and social integration within a firm; that is, the organization's ability to organize knowledge flow across the firm's departments, as well as to individual employees. At the inter-firm level, inter-firm mechanisms – that is, external communications structures and the character and distribution of expertise and knowledge – form the antecedents of *absorptive capacity* (see table 1 for details).

The influence and outcomes of *absorptive capacity* can be investigated in the context of different aspects of innovative performance / innovation output. Innovative performance can be understood narrowly and broadly [Hagedoorn, Cloudt, 2003]. Innovative performance in the narrow sense refers to results to a firm's introduction of inventions into the market, measured by the rate of sales resulting from introduction of new products in total sales [Freeman, Soete, 1997]. A broader definition of innovative performance

encompasses the whole path from conception to launching of the invention on the market [Ernst, 2001], which covers all stages from R&D investment (*technological performance*) to patenting (*inventive performance*) and new product introduction [Ahuja, Katila, 2001].

TABLE 1. Antecedents of absorptive capacity

Antecedents of absorptive capacity	Reference
Intra-firm level of analysis	
• <i>Prior related knowledge within organisation</i>	
General knowledge of related domains; skills and problem solving means; prior learning experience; shared language similarity of certain attributes	Van den Bosch et al. [1999]; Gupta, Govindarajan [2000]
A unit's R&D intensity	Tsai [2001]
Organizational form, combinative capabilities	Van den Bosch et al. [1999]
Internalized experience	Trispas, Gavetti [2000]
• <i>Internal mechanisms of formalization and social integration within firms</i>	
Structure of internal communication (shared internal language)	Van den Bosch et al. [1999]
Knowledge flow formation (horizontal versus vertical)	Van Wijk et al. [2001]
Inter-firm level of analysis	
• <i>Inter-firm mechanisms</i>	
Structure of external communication	Van den Bosch et al. [1999]
• <i>Character and distribution of expertise and knowledge</i>	
Type of new knowledge; similarity of compensation practices and organizational structures; awareness of organizational problems	Lane, Lubatkin [1998]

SOURCE: own elaboration based on Van den Bosch et al. [1999, p. 553]; Van den Bosch et al. [2003].

Absorptive capacity should be investigated not only as related to innovative performance, but also in the context of firms' competitive advantage. From a resource-based view (RBV), knowledge appears to be the most strategic resource a firm can possess. Peteraf [1993] points out, that the main parts of long term competitive advantages are based on information, on tacit and complex understandings, that are not easily available for individuals external to the organization. The important role of tacit knowledge is especially underlined, as it allows to maintain a competitive advantage [Grant, 1996], and is also connected with organizational learning and innovation [Nonaka, Takeuchi, 1995]. What's more, firms gain competitive advantage not only by utilizing key resources, but also by using capabilities that facilitate the firm's reconfiguration of its resource base and adjustment to fluctuating market conditions [Kleinschmidt et al., 2007]. Therefore, the ability to obtain, share, and use knowledge, which constitutes the core of a firm's *absorptive capacity*, can be considered critical to acquiring and maintaining a competitive advantage [Barney, 1986; Cohen, Levinthal, 1990].

Modes to Measure Absorptive Capacity

Even though a significant number of empirical studies have used ACAP, an applicable, standardised measure integrating its diverse aspects has not yet been established. Lane, Koka, and Pathak [2006] observe that most researchers measure ACAP with simple R&D proxies, as was proposed by Cohen and Levinthal [Cohen, Levinthal, 1989], disregarding the variety of its dimensions. Table 2 provides an overview of the various proposals for measuring ACAP.

Those measurements can be broadly divided into three groups: *input-oriented indicators*, *output-oriented indicators* and *perceptive instruments* – specific constructs that are compilations of different indicators. In this section, the possible indicators of ACAP that can be derived from *Community Innovation Survey* are also presented.

Input-Oriented Indicators

Input-oriented indicators are those related to *R&D effort*, *professionalism of R&D* and *R&D human capital*.

R&D effort (R&D expenditures divided by annual sales) as a proxy of ACAP, was introduced by Cohen and Levinthal [1989], and is widely used by other researchers (see table 2 for details). Those researchers underline the role of expenditures on R&D in both building absorptive capacity (ACAP) and generating new knowledge.

Professionalism of R&D as a proxy of ACAP goes beyond the simple financial view of R&D and uses such indicators as the existence of a formalized, or fully staffed R&D department.

R&D human capital is another input-based measure of ACAP that captures the path-dependency nature of *absorptive capacity*, underlined in later work by Cohen and Levinthal [1990]. It assumes that better educated and trained employees possess the higher ability to assimilate and use new knowledge, and that a firm's *absorptive capacity* level depends on the general level of education, experience and training of its employees, reflecting the cumulative nature of knowledge.

Unfortunately, these proxies may lead to contradictory and confusing findings about the role of ACAP. R&D spending, for example, is only one source of ACAP. Employee skills, new machinery and equipment, prior organizational experience, and knowledge can also significantly contribute to a firm's overall ACAP, so taking only R&D spending into account simplifies the notion of ACAP. Also, the *absorptive capacity* of a firm is not only the sum of its employees absorptive capacities, but is also based on "transfers of knowledge across and within subunits within enterprises" [Cohen, Levinthal, 1990, p. 129].

Furthermore, many firms that routinely innovate do not undertake R&D. An analysis of Innobarometer 2007, Survey No. 215 showed, that over half of 4,395 analysed innovative firms did not undertake in-house R&D or sponsor contract R&D [Arundel et al., 2008].

Output – Oriented Indicators

The most frequently used measure of *absorptive capacity* (ACAP) in the group of output-oriented indicators is raw patent count. It should be noted, however, that in much of the economic literature, raw patent count is still generally accepted as one of the most appropriate indicators of inventive or innovative performance of firm in terms of new technologies, new processes and new products [Freeman, Soete, 1997; Kowalski, Michorowska, 2013]. Although use of patents as a *absorptive capacity* or performance indicator seems appropriate in high-tech sectors, in other cases it may produce conflicting results, since firms differ in their propensity to patent innovations, and patents significantly differ in terms of their knowledge content.

Perceptive Instruments

Because ACAP is potentially a multi-dimensional construct, many researchers try to build their own measurements of ACAP based on scales. This allows different dimensions of ACAP to be captured, as most constructed dimensions are derived from the most prominent ACAP definitions. Unfortunately, these measurements are too complex, and have too many data constraints, to permit international comparability.

The summary of different measurements modes of ACAP is presented in table 2, whereas the evaluation of different measurement proposals of *absorptive capacity* is presented in table 3.

TABLE 2. Absorptive capacity – measurement proposals divided into input based, output based and perceptive instruments

Proxy for measuring absorptive capacity	Author
Input-based measurements of ACAP	
R&D intensity (R&D expenditure divided by annual sales)	Cohen, Levinthal [1990]; Stock et al. [2001], Tsai [2001]; Oltra, Flor [2003]; Belderbos et al. [2004]; Zahra, Hayton [2008]
Existence of the firm's own R&D departments with full-time personnel; postgraduates in R&D; proportion of R&D in basic research	Veugelers [1997]
Percentage of technical and professional personnel divided by the total number of employees in the organization analysed	Luo [1997]
R&D expenditure; number of researchers; duration of R&D activities; number of R&D laboratories; links with public research institutes; number of publications	Mangematin, Nesta [1999] George et al. [2001]
R&D effort (expenditure on R&D/annual sales) and the effort in training personnel (expenditure on training personnel/annual sales)	Petroni, Panciroli [2002]
Degree of employees assigned to R&D activities or in-house education	Muscio [2007]

Proxy for measuring absorptive capacity	Author
Output-based measurements of ACAP	
Level of technological overlap between the future members of an alliance before the agreement takes place (measured as the number of patents of firm "j" cited in the patents of firm "i" divided by total number of citations present in the patents of firm "i" before the agreement takes place between firms "j" and "i")	Mowery et al. [1996]
The total number of publications based on dollars spent on research annually	Cockburn, Henderson [1998]
Number of patents	Ahuja, Katila [2001]; George et al. [2001]
Perceptive instruments – individual proposals to measure ACAP	
Knowledge management of information technology (IT) in business processes	Boynton et al. [1994]
Scale of 9 items to measure global absorptive capacity	Szulanski [1996]
Set of binary variables used to measure organizations' propensity to transfer knowledge from their allied partners relative to their own knowledge bases	Shenkar, Li [1999]
Incentive system for the employees	Van den Bosch et al. [1999]
Adaptation of scales from other related studies and creation of a new scale of 24 items to measure the comprehension, assimilation and application of knowledge	Lane et al. [2001]
Scale of 15 items to measure capacity for adaptation, production and application of knowledge	Lin et al. [2002]
Scale of 5 items to measure the firm's ability to assimilate and reproduce new knowledge obtained from external sources	Chen [2004]
Knowledge management (flow of information) developed on the management level	Lenox, King [2004]
Scale of 21 items to measure potential absorptive capacity and realized absorptive capacity	Jansen et al. [2005]
Scale of 32 items to measure communication with the environment, the organization's level of knowledge and experience, the diversity and coincidence of structures of knowledge and strategic position	Nieto, Quevedo [2005]
Multidimensional construct that incorporates organizational issues as well as human capital	Thuc Anh et al. [2006]
Wage-level of foreign companies compared to the level of domestic companies	Nielsen, Pawlik [2007]
Use and importance of different sources of information needed for suggesting new innovation projects or contributing to the implementation of existing projects (demand-pull and science-push absorptive capacity)	Murovec, Prodan, [2009]
Scale of 36 items to measure acquisition, assimilation, transformation and exploitation of knowledge	Flatten et al. [2010]

Proxy for measuring absorptive capacity	Author
R&D activities aimed at developing new knowledge and other activities such as knowledge intelligence and knowledge dissemination activities	Spithoven et al. [2011]
Scale of 18 items to measure potential and realized absorptive capacity	Jimenez-Barrionuevo et al. [2011]
Scale of 10 items – such as prior investment, speed and intensity of knowledge acquisition, the learning and interpretation of new information, exploitation of synergies between old and new information, the recodification of information, and the utilization of new knowledge in existing routines	Hurmelinna-Laukkanen et al. [2012]

Source: own compilation and adaptation based on Murovec, Prodan [2009]; Jimenez-Barrionuevo et al. [2011], Flatten et al. [2011] and Duchek [2013].

TABLE 3. Evaluation of different measurement proposals of ACAP

Positive aspects of different measurements of ACAP	Drawbacks of different measurements of ACAP
Input-based measurements of ACAP	
Easily measurable, usually as a percent of incomes in the period under investigation. Indicates the innovative competences of the firm. Allows for international comparisons conducted at the firm, sector or country level.	Financial data are often confidential and not readily available, mostly based on firms' declaration, and thus difficult to verify; evaluated in different currencies, which makes the comparison more complicated. Measures only actual research input, while ignoring other non – R&D expenditures and future R&D development.
Output-based measurements of ACAP	
Generally accepted measure that can be used for international comparisons. Data on patents are easily and internationally available. Allows for international comparisons conducted at the firm, sector or country level.	Purely quantitative measure. Data are not readily available. There exist international and sectorial differences in patenting behaviours. There are differences in patenting between large companies and smaller firms. The identical weight is given to very important and less important patents.
Specific constructs – individual proposals of measurements of ACAP	
Provides very accurate, individually constructed measurements of ACAP, based and strongly linked to the literature. Captures the path dependency nature of ACAP.	Suitable for specific firm or group of firms, thus a measurement that does not provide data that can be easily compared across countries. Due to the lack of one definition of ACAP, measurements are usually very complicated.

Source: own elaboration.

Measures of Absorptive Capacity Derived from the Community Innovation Survey (CIS)

The *Community Innovation Survey* (CIS), introduced in mid-90s, is a survey on enterprise innovation activity in the EU Member States, EU candidate countries, Iceland and Norway. A common survey questionnaire and methodology, with reference to the third Oslo Manual, ed. 2005, is used to obtain comparable, harmonized, and high quality statistical results [Oslo Manual, 2005]. The CIS is designed to extract information on innovation activities within enterprises, expenditures for process and product innovations, public financial support for innovation activities, and sources of information and cooperation in innovation activities, innovation objectives. The CIS also contains data on the introduction of organizational and marketing innovation and their objectives. Based on data from the CIS questionnaire, several ACAP proxies can be derived.

R&D effort can be estimated using two CIS questions [CIS 2 (for years 1995–1998); CIS 3 (for 1998–2000); CIS 4 (for years 2001–2004); CIS 2006 (period 2004–2006); CIS 2008 (period 2006–2008); CIS 2010 (period 2008–2010); CIS 2012 (period 2010–2012)], covering R&D expenditures and total annual sales. Question 5.2 refers to estimated in-house R&D expenditures (RRDINX)¹, including capital expenditures on buildings and equipment specifically for R&D (data are in the currency of the surveyed country). Question 12.1 refers to the amount of turnover defined as market sales of goods and services (TURN10) (including all taxes except VAT) in the last year of the surveyed period (data are in the currency of the surveyed country). By dividing one digit by another, R&D effort as a proxy for ACAP is obtained.

Professionalization of R&D as a proxy of ACAP is commonly measured based on part of question 5.1 (CIS 2; CIS 3; CIS 4; CIS 2006; CIS 2008; CIS 2010; CIS 2012). Enterprises have to specify if during the three years surveyed period they engaged in internal R&D (RRDIN), defined as creative work undertaken in-house to increase the stock of knowledge for developing new and improved products and processes (including software development in-house that meets this requirement). The enterprises also have to specify if they continuously performed R&D during the three year survey period (RDENG) (e.g., with permanent R&D staff in-house) or occasionally (as needed only). Commonly, only a “Yes” for carrying on R&D continuously is used as proxy for professionalization of R&D.

R&D human capital can be measured by recently introduced question 12.3 (EMPUD) (CIS 2010; CIS 2012), where the respondent approximates the percent of enterprise employees with a university degree (ranging between 1–4%; 5–9%; 10–24%; 25–49%; 5–74%; 75–100%). Effort to train personnel (CIS 2; CIS 3; CIS 4; CIS 2006; CIS 2008; CIS 2010; CIS 2012) can be measured by using question 5.1 (RTR) – training for innovative activities (internal or external training of personnel specifically to develop and/or introduce new or significantly improved products or processes). Unfortunately, it is not possible to estimate the expenditure on training personnel as a percentage of total annual sales, as those data are not available.

Output based measure based on patents could have been measured by using question 11 from earlier CIS versions (CIS 2; CIS 3; CIS 4; CIS 2006) on patent and patent protection. Question 11.1a asked whether the enterprise or enterprise group applied for at least one patent to protect inventions or innovations developed by the enterprise. Question 11.1b concerned information about valid patents at the end of the last year of survey to protect inventions or innovations developed by the enterprise. Question 11.1.c concerned the percent of turnover in 2000 covered by valid patent owned by the enterprise or enterprise group at the end of 2000. Unfortunately, in later CIS releases, this question has been abandoned.

Based on the CIS questionnaire, *demand-pull absorptive capacity* and *science-push absorptive capacity* can also be measured.

Demand-pull absorptive capacity measurement can be derived from question 6.1 concerning the importance of different sources of information for innovation activities, such as from suppliers of equipment, materials and software (SSUP); from clients and customers (SCLI); from competitors within the same industry (SCOM); and from fairs and exhibitions (SCON; SJOU; SPRO).

Science-push absorptive capacity measurement can also be derived from part of question 6.1 concerning the importance of information from universities or other higher education institutions (SUNI) and government or public research institutes (SGMT).

Unfortunately the distinction between *absorptive capacity for intra-industry knowledge*; and *absorptive capacity for inter-industry knowledge* cannot be properly done, as the CIS questionnaire does not distinguish different sources of knowledge coming from the same or other industries.

Despite its limitations, the CIS questionnaire remains the only source of representative and internationally comparable results for innovation activities of European countries, and the above-mentioned ACAP proxies are commonly introduced as measurements.

Absorptive Capacity in the Context of Open Innovation

Open innovation (OI) is defined as “the use of purposive inflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” [Chesbrough, 2003, p. XXIV]. OI is a paradigm that assumes that firms can and should “use external ideas as well as internal ones, and internal and external paths to market, as they look to advance their technology” [Chesbrough et al., 2006, p. 2]. OI means not only sourcing and integrating external knowledge (inbound OI or “outside-in”), but also letting its own ideas be used by other companies (outbound OI or “inside-out”) [Lichtenthaler, 2008, 2011] as well as the outside-in and inside-out processes combined (“coupled process”); that is, working in alliance with complementary knowledge [Gassmann, Enkel, 2004]. Outbound process (inside –out) can result in non-pecuniary benefits (revealing) as well as pecuniary ones (sales of knowledge). Inbound OI (outside-in process) also

has indirect benefits (sourcing, collaborating) as well as pecuniary benefits (acquiring) [Dahlander, Gann, 2010]. Open innovation has a significant impact on capabilities and resources, and requires internal dynamic capabilities (including *absorptive capacity*) – the ability to integrate, built and reconfigure internal and external competencies, especially in the environment irrespective of the appropriability regime [Teece et al., 1997].

In this part of the paper, the focus will be on selected influential proposals of new classifications of organisational capacity in the context of open innovation (OI). Works of U. Lichtenthaler and E. Lichtenthaler [2009], P.L. Robertson, G.L. Casai and D. Jacobson [2012], as well as the proposal of A. Spithoven, B. Clarysse and M. Knockaert [2011], which emphasises the role of “knowledge centres” in building *absorptive capacity* needed for inbound open innovation activities of firms from traditional sectors will be discussed.

At this point it should be noted, that the above-cited work of Lichtenthaler [2009], as well as his other thirteen papers, have been retracted due to doubtful statistical analysis. Nevertheless, the theoretical proposal of the paper is of interest, and is therefore described below.

Proposal of U. Lichtenthaler and E. Lichtenthaler

Lichtenthaler and Lichtenthaler [2009], building on Gassmann and Enkel’s [2004] three open innovation processes, proposed three linked capabilities – absorptive for inflow, multiplicative for outflow, and relational for coupled processes. Jointly, these organizational capacities form the foundation for a dynamic capability to manage open innovation [Lichtenthaler, Lichtenthaler, 2009].

TABLE 4. Organisational capacity and open innovation

Level	Knowledge exploration	Knowledge retention	Knowledge exploitation
Intra-firm	<i>Inventive capacity</i>	<i>Transformative capacity</i>	<i>Innovative capacity</i>
Inter-firm	<i>Absorptive capacity</i>	<i>Connective capacity</i>	<i>Desorptive capacity</i>

Source: Lichtenthaler, U., Lichtenthaler, E. [2009].

The first criteria (the first horizontal line in table 4) characterizes the main goals of OI activities – identification (exploration), saving (retention), and commercialization (exploitation) of knowledge, while the second (the first column in table 4) refers to the level at which OI activity happens inside or outside a firm. When combined, they create six different types of OI capacity necessary for firms to implement related OI activities [Lichtenthaler, Lichtenthaler, 2009].

Inventive capacity enables firms to produce creative knowledge internally, symbolising how well a firm can handle internal R&D. This capacity determines a firm’s basic capability, as it influences R&D collaboration and in-sourcing as well as the closed innovation.

In the case of knowledge retention, *transformative capacity* defines a firm's capability to maintain knowledge internally as well as its active management, by conveying resources to keep knowledge "alive" and avoid pasting over time. After identifying an opportunity to use preserved knowledge, it should be revitalized, adopted, and blended with additional knowledge [Garud, Nayyar, 1994; Smith et al., 2005].

Absorptive capacity allows firms to integrate external knowledge. A firm with strong *absorptive capacity* should open up its boundaries to explore and assimilate external ideas and, eventually, compensate for its own low "inventive capacity". OI modes, such as cooperation, in-sourcing or venture investment, are related to this capacity.

Transformative capacity (internal knowledge retention) describes "a firm's ability to internally maintain knowledge over time" [Lichtenthaler, Lichtenthaler, 2009, p. 1320] and if needed, reactivate, internalize, and synthesize it with additional knowledge.

Connective capacity (external knowledge retention) "focuses on externally maintaining knowledge which does not assume immediate inward knowledge transfer. Instead, firms ensure privileged access to external knowledge without directly acquiring it" [Lichtenthaler, Lichtenthaler, 2011, p. 82].

Innovative capacity, first introduced by Suarez-Villa [1990], to measure "the level of invention and the potential for innovation in nation, geographical area or economic activity" [Suarez-Villa, 1990, p. 291], here refers to the ability of firms to commercialize their internal or external knowledge in order to design new products or provide new services. This capacity describes the extent to which firms can digest internal or external ideas towards making actual profit. *Innovative capacity* is crucial in closed innovation, but is also related to certain OI modes such as customer involvement or in-sourcing.

And lastly, *descriptive capacity* is the ability to make a profit outside the firm and certain OI modes such as licensing-out or spinning-off (venturing). Firms can make extra profit by selling or licensing their unused intellectual property (IP) or spinning off technologies that are believed to diverge from their main business areas [Kirschbaum, 2005]. To accumulate strong *descriptive capacity* in outbound open innovation, a firm can benefit from market knowledge developed in its other innovation undertakings, under the condition, that it maintain a large R&D portfolio connected to a wide variety of technology markets.

Consequently, internal technology development and outbound technology transfer are likely to complement each other [Hu et al., 2015].

In further research by Mo Ahn et al. [2013], the authors used the Korean Innovation Survey (KIS) 2008 data to empirically test the six OI capacities (*inventive, absorptive, transformative, connective, innovative* and *descriptive*) and their influence on financial performance. The results of structural equation modelling (SEM) showed that a firm's OI capacities are significantly linked with a firm's financial performance (both positively and negatively); are highly correlated with one another and are differently configured within diverse types of firms based on size, being a member of a capital group, the industry's technological level, and the firm's location.

Proposal of P.L. Robertson, G.L. Casai and D. Jacobson

Robertson, Casai and Jacobson [Robertson et al., 2012] discuss the above-mentioned Lichtenthalers' proposal and present their own conceptualisation of *absorptive capacity* in the context of introducing incremental process innovation in an open innovation mode. The authors argue, that although the Lichtenthalers' explanation of the role of ACAP in open innovation was a step forward, their model did not specify what capabilities a firm desires in order to achieve required outcomes. To remedy this, they propose three categories of innovative capacities that can help firms achieve open incremental innovation: *accessive capacity*; *adaptive capacity* and *integrative capacity*.

Accessive capacity, which is similar to ACAP, "comprises all knowledge generating and gathering activities, both internal and external that are relevant to the given problem (...). It concentrates not just on how internal knowledge can affect a firm's ability to collect external knowledge, but on how the two classes of knowledge can be used together, in complementary or supplementary roles, to achieve incremental process innovation" [Robertson et al., 2012, p. 826].

Adaptive capacity involves "converting knowledge generated for one purpose to another", as "new knowledge does not necessarily arrive in a ready-to-use form, when innovation is open" [Robertson et al., 2012, p. 827]. *Integrative capacity*, including human resource changes (like personnel training), is the "ability to apply knowledge to particular situations and may demand physical and organisational alterations to an existing setup" [Robertson et al., 2012, p. 827].

Knowledge may be created within the organisation (internally, by its managers and employees) or outside the organisation (and come from suppliers, customers, consultants or other sources). Although all actors may play a role in the entire range of innovative capacities, according to Robertson et. al., the relative strength of each of them may vary from case to case.

It should be underlined that, like the Lichtenthaler model, [2009], all three capacities do not function automatically. They have to be directed by *innovative management capacity*, which organises the knowledge that has been created and gathered. And Robertson, et. al., emphasize that this "master" capacity must include capabilities for operationalisation and "effective knowledge application" [Robertson et al., 2012, p. 829].

All three types of capabilities – *accessive*, *adaptive* and *integrative* – meet the criteria of *first-order dynamic capabilities*. *Innovative management capacity* qualifies as a *higher-order capacity* [Collins, 1994; Winter, 2003], as it coordinates all three remaining capabilities.

But aggregating ACAP by opening up the firm's business model can also have some drawbacks, because to gain knowledge a firm has to simultaneously share knowledge [Kale et. al., 2000]. To justify this process and relate this notion to ACAP, the concept of *protective capacity* (PCAP), was introduced [Andersen, 2012]. PCAP is defined as a firm's "capacity to sustain, or to decrease the speed of depreciation of knowledge-based resources" [Andersen, 2012, p. 440]. Openness of the firm is positively connected with

the level of ACAP [Jansen, et al., 2005] and, according to Anderson [2012], is negatively related to PCAP. Thus, as author argues, an increased level of ACAP is likely to reduce the level of PCAP and vice-versa.

Proposal of A. Spithoven, B. Clarysse and M. Knockaert

Although A. Spithoven, B. Clarysse and M. Knockaert [2010] did not in fact propose, new types of *absorptive capacity* in the open innovation (OI) context, they drew attention to the connection of OI and *absorptive capacity* in SMEs and firms in traditional industries. These authors argue that small- or medium-sized firms, despite the often limited in-house *absorptive capacity*, do actively engage in inbound open innovation activities, but the mode in which they execute these activities may differ from larger companies or firms in high-tech sectors. These researchers focused on the function of “collective research centres” in building *absorptive capacity* at the inter-organisational level. They hypothesised, that in the case of SME or firms from traditional sectors, the number and qualification of personnel may not be sufficient to properly engage in open innovation activities. This is especially dangerous for those firms which have to compete with companies with a higher level of *absorptive capacity* that coordinates external knowledge flows more efficiently, stimulating innovative performance that leads to competitive advantage. It is expected that SME or firms from traditional industries will look for third-parties – technology intermediaries – to facilitate their building *absorptive capacity*. However, these “knowledge centres” have to dispose of their own *absorptive capacity* to fulfil their purposes.

In order to investigate the way *absorptive capacity* impacts inbound open innovation activities within traditional sectors, the authors examined the activity of “collective research centres” in Belgium, which were founded after the Second World War to “encourage scientific and technological research in specific sectors of the economy to improve productivity, quality and production” [Spithoven et al., 2010, p. 13] and are grouped in the Union of Collective Research Centres. They operate in traditional industries characterised by a low technology content measured by their R&D investments [Spithoven et al., 2010]. Based on the research conducted within these centres, the authors define three inter-related activities that increase the innovative capacity of their clients and thus fall in the definition of *absorptive capacity*.

These are (1) performing as a “knowledge intelligence unit” by the (upstream) identification and monitoring of related technology and knowledge; (2) operating as a “knowledge agency” on the need of the member firm to challenge encountered problems and apply technologies, therefore executing assimilation and transformation capabilities; and (3) acting as a “knowledge repository” designed for information dissemination which boosts the assimilation capability of the member.

The main finding of the works of Spithoven et al., is that *absorptive capacity* embraces both R&D activities and R&D-linked activities. In around half of the centres, the R&D-related activities were more significant than the R&D activities. This highlights the limitations

of measuring *absorptive capacity* if only R&D activities are taken into account. Another important issue is the role of “collective research centres” as knowledge intelligence units, knowledge agents and knowledge repositories, thus drawing attention to *inter-organisational absorptive capacity* and suggesting *absorptive capacity* should be analysed at a network, rather than firm, level.

Of three proposals, the one demonstrated by the Lichtenthalers’ is the most complex, whereas the one by Robertson, et al., tries to narrow Lichtenthalers’ concept by applying a managerial perspective. The third proposal of Spithoven, et al., has particular relevance for SME’s (especially from traditional industries), as it promotes cooperation in general with an emphasis on building collective *absorptive capacity* at the inter-organisational level.

The analysis of three proposals for linking ACAP and OI concepts suggests that there is still much to be researched and understood. Table 5 is a step in this direction. It compares the concept of *absorptive capacity* and the “outside-in” process of open innovation from several criteria perspectives.

TABLE 5. Similarities and differences between absorptive capacity and outside-in dimension of open innovation

Criterion	Absorptive capacity	Outside-in dimension of open innovation
<i>Similarities</i>		
Strategic aim	Strengthening firms’ competitive advantage	Strengthening firms’ competitive advantage
Relation between internal and external knowledge	Complementarity	Complementarity
<i>Differences</i>		
Role in the firm	Dynamic capability – process to create new resources	Knowledge sourcing strategy
Complexity of the concept	More complex	Less complex
Intra-firm level of analysis	Major focus of the concept	Covered by the concept
Inter-firm level of analysis	Covered by the concept	Major focus of the concept
Impact on innovation performance	Impact mostly depends on the firm’s scope and quality of knowledge base	Impact mostly depends on knowledge base of external provider
Measurability	Input, output oriented and perceptive instruments	Scope and depth of cooperation

Source: own elaboration.

The major similarity of both concepts is undoubtedly their positive impact on a firm’s competitive advantage. Both concepts also positively influence innovation performance.

But *absorptive capacity*'s impact depends more on the firm's scope and quality of knowledge base, whereas in the case of outside-in open innovation it results from the knowledge base of external partners. In both of the concepts complementarity between internal and external knowledge is important, but *absorptive capacity* is more focused on the intra-firm context, whereas outside-in open innovation is concentrated on inter-firm relations. It is worth underlining that *absorptive capacity* has features of dynamic capability and, as such, enables new knowledge resources to be created, whereas outside – in open innovation is focused on exiting knowledge sourcing. As for measurability, in the case of *absorptive capacity* input, output and perceptive measurements are used, whereas in outside-in open innovation the breadth and depth of innovation cooperation is usually investigated. Definitely, both concepts need more empirical research to validate their practical relevance.

Conclusions

The purpose of this paper was to analyse the theoretical concepts related to the notion of *absorptive capacity*, its determinants, outcomes, measurement modes, and role in open innovation activities. The results highlight the importance of the capabilities of external knowledge absorption for innovation performance and competitive advantage. In contrast to the traditional view, which relates *absorptive capacity* to R&D activities, the more recent works underline differences between potential and actual ACAP and suggest its numerous, more accurate measures. The study stresses the importance of combining external sources of knowledge identification with a firm's internal efforts to absorb it by discussing the interrelations between *absorptive capacity* and open innovation. The attempt to highlight similarities and differences between both concepts therefore opens up new avenues of future research.

The article does not cover all aspects of *absorptive capacity* versus open innovation. For example, the complimentary effect of both concepts was not covered [Flor et al., 2013], as well as the relation with cognitive proximity [Boschma, 2005]. Some authors suggest that a firm's *absorptive capacity* moderates the relationship between remote collaboration and the innovative performance of firms, as investment in *absorptive capacity* simplifies knowledge transfer with partners who are located far-away [Berchicci et al., 2013; Enkel, Heil, 2014; Lewandowska, 2014]. Thus, cognitive proximity, which is enhanced by investments in *absorptive capacity*, may balance the lack of geographical proximity between partners.

The review of empirical studies of *absorptive capacity* underscores the need to develop measurement methods suitable for addressing the construct's complexity and allowing international comparisons to be made. Cooperation between academics and practitioners may support this process.

Future works should also consider the problem of determining the types of knowledge to be acquired (and consequently, the *absorptive capacities* required). One possible

direction would be to investigate the differences in *absorptive capacity* for domestic and foreign knowledge.

Summing up, this paper illustrates the complexity of problems related to firms' *absorptive capacity*.

Notes

¹ The abbreviations are used for each question in the CIS questionnaire in order to ease and unify the comparison of questions between different questionnaire versions.

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