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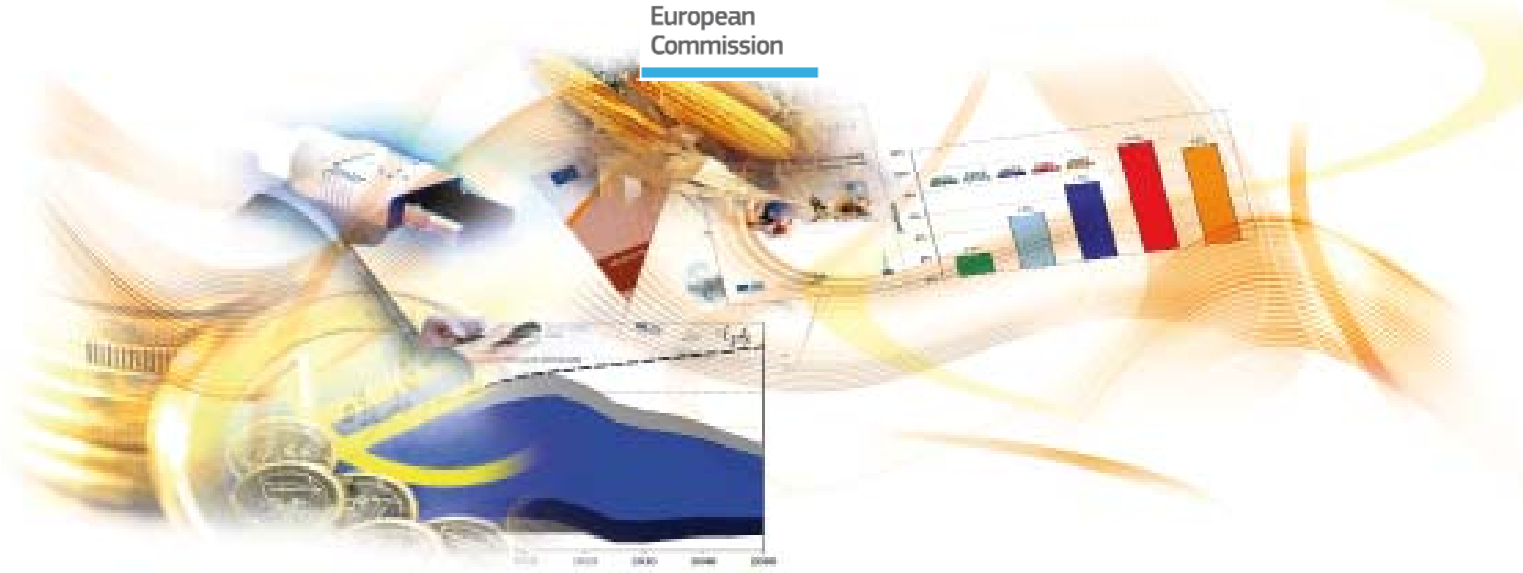

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Absorptive capacity, innovation cooperation and human-capital. Evidence from 3 European countries

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Abstract

The paper aims at extending the analysis of the firm's absorptive capacity (AC) by taking stock of its manifold nature. Innovation cooperation is recognised as one of its antecedents, along with R&D, but with different possible outcomes, depending on the kind of partner. Human capital is claimed to be as important as other organisational mechanisms for the AC impact on innovation. The empirical application, carried out on about 10,500 firms located in 3 EU countries (i.e. Germany, Italy and Spain), confirms the role of these factors. Interacting with research organisations, for example, increases the firm's AC providing it occurs within the national boundaries. The transformation of AC into actual innovation is favoured by the human capital of the firm, while it is actually hampered by socialisation mechanisms of an organisational nature.

Keywords: Absorptive capacity – Innovation cooperation – Human capital.

JEL codes: 033, 032, J24

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1 Introduction

Innovation is a complex process of knowledge exploration and exploitation (Dosi, 1988). Firms need to combine the results of their internal efforts with those of other firms and research organisations in innovation systems (Edquist, 2000). This requires them to have the capacity to grasp external knowledge for the sake of innovation. In a seminal paper, Cohen and Levinthal (1989) referred to it as "absorptive capacity" (AC).

In the last twenty years, the idea of AC has attracted a lot of empirical research. It has also evolved in its theoretical stance. From a "black-boxed" by-product of the firm's R&D (i.e. its second "face"), AC has become an "open-box" of issues belonging to different theoretical strands (for a critical review, see Volberda *et al.*, 2010).

Following this debate, AC has been shown to be the result of a manifold learning process involving antecedents and competences of different kinds (Jansen *et al.*, 2005; Xia and Roper, 2008; Fosfuri and Tribó, 2008). Some interpretative mechanisms have been identified.[1] However, their actual measurement and empirical testing still require further investigation (Volberda *et al.*, 2010).

More recently, the attention for AC has crossed that for the governance of the innovation process – mainly, the "open-innovation" mode (Chesbrough *et al.*, 2006) – and for the role of cooperation in it – for example, technology transfer and R&D agreements (for example, Belderbos *et al.*, 2004; Hagedoorn and Van Kranenburg, 2003). This cross-fertilisation has brought to the front new elements of analysis[2] which need to be considered in a wider conceptual framework.

The present paper is set in this research stream. Its first aim is to increase the current understanding of the factors that enhance the firms' AC. In particular, we add new insights on the role of innovation cooperation and of the (manifold) proximity between the absorbing firm and the knowledge source. The paper also addresses the impact that AC has on the firms' innovation performance. An original focus is placed on the role that human capital has for this impact compared with that of more standard organisational mechanisms.

[1] For example, the distinction between "potential" and "realised" AC (Zahra and George, 2002), or that between "internal" and "external" AC routines (Lewin *et al.*, 2011).

[2] For example, the presence of barriers to innovation cooperation and the policy role in attenuating them (for example, Bruneel *et al.*, 2010).

We empirically investigate these issues by referring to a sample of about 10,500 firms located in 3 EU countries (Italy, Germany and Spain). We use the Community Innovation Survey (CIS), which covers the period between 2002 and 2004. Although cross-sectional, our dataset is wider in terms of countries covered and more updated than the ones used in recent similar studies (for example, Escribano *et al.*, 2009; Grimpe and Sofka, 2009).

The remainder of the paper is organised as follows: Section 2 develops our theoretical arguments about the antecedents and effects of AC on innovation. Section 3 describes the dataset, the relevant variables and the econometric strategy. Section 4 comments on the results of the empirical analysis. Section 5 concludes and draws some implications for policy and practitioners.

2 Theoretical Background

The complementarity between internal and external knowledge is by far an established result in innovation studies (for example, Cassiman and Veugelers, 2002, 2006).

The extent to which this complementarity works and turns into innovation instead depends on numerous factors. The nature of the underlying knowledge-interaction (Todtling *et al.,* 2009; Frenz and Ietto-Gillies, 2009; Kang and Kang, 2009) and the firms' capacity to search and manage external knowledge sources (Chesbrough *et al.*, 2006; Laursen and Salter, 2006; Van de Vrande *et al.*, 2009) are among the most important.

A special role is played by what Cohen and Levinthal (1989), more than 20 years ago, called *Absorptive Capacity* (AC): that is, the "firm's ability to identify, assimilate, and exploit knowledge from the environment" (Cohen and Levinthal, 1989, p. 569). Since then, a lot of work has been done in order to understand the factors which AC depends on (in brief, its antecedents) and those which are responsible for its innovation impact (among the recent contributions, see Murovec and Prodan, 2009; Lim, 2009; Volberda *et al.*, 2010; Lewin *et al.* 2011). Among these factors, the role of innovation cooperation and human capital, respectively, has been surprisingly under-investigated and deserves further scrutiny.

2.1. AC antecedents: the role of innovation cooperation

According to Cohen and Levinthal (1989) AC is mainly the "second face" of the firm's R&D. Investing in R&D, not only does the firm enlarge its knowledge base. It also reduces the cognitive distance with respect to other firms (for example, competitors, customers and suppliers) and research organisations (for

example, universities and private/public laboratories) of the innovation system. The external knowledge provided by them thus becomes more understandable and usable. This holds the more true when the firm engages in systematic R&D efforts in-house, through dedicated organisational divisions. Continuous investments in R&D, and the learning experience that the firm acquires internally through them, thus represent the "usual suspect" in the search for the AC antecedents.

The firm's capacity to absorb external knowledge depends also and above all on their experience of learning across organisational boundaries (Raisch *et al.*, 2009). Although its role is apparently trivial to claim, external-learning experience is quite hard to measure and can be at most proxied. In the extant literature, one of the most used proxies is represented by the firm's patents portfolio and by its patents applications (Fosfuri and Tribó, 2008; Harison and Koski, 2010). In synthesis, a learning effect with respect to external knowledge would emerge when the patent application process requires the firm to be aware of, and eventually quote, other patents and/or other codified pieces of knowledge (for example, scientific publications).[3] Furthermore, the patent propensity of the firm can be considered a proxy of the intensity of its codified knowledge. This kind of internal knowledge has an important role for increasing the assimilation and retention of the externally generated one. For example, it reduces problems of information asymmetries and "causal ambiguity" between the user firm and the knowledge provider (Bierly III *et al.*, 2009; Garcia-Muiña *et al.*, 2009).

A more direct proxy of the firm's external learning experience is of course represented by its engagement in innovation cooperation. This is an aspect that the "open-innovation" debate (Dahlander and Gann, 2010) has recently made fundamental and that innovation surveys have accordingly become equipped to capture (the most relevant example is the EU Community Innovation Survey). However, in the AC-specific literature, the focus has mainly been placed on the firm's cooperation in aggregated terms, without distinguishing the role of that occurring with one rather than another partner (Fosfuri and Tribó, 2008).[4]

This is to us quite unfortunate. A consistent amount of studies on knowledge diffusion, R&D spillovers and R&D partnerships (for example, Boschma, 2005; Breschi *et al.*, 2003; Hagedoorn and Van Kranenburg, 2003) have shown that the impact of innovation cooperation crucially depends on the kind of firm's knowledge base and of external provider (for example, Carayannopoulos and Auster, 2010). This is mainly due to two reasons. Firstly, the typology of interacting partners affects the degree of diversity of their objectives and incentives in the cooperation. In particular, this diversity impacts on their different evaluation of innovation related matters, such as, for example, intellectual property rights. For example, business cooperation and cooperation with public research organisations have been found to have

[3] This is true providing the patenting effort is accomplished by the firm itself. In the case of Small and Medium size Enterprises (SME), which often resort to external patent attorneys, the same argument gets attenuated. Also for this reason, the size of the firm will have to be controlled by empirical analysis.

[4] In those cases in which the kind of partnership is considered, the research question is actually different from the one we are addressing in this paper (for example, Muscio, 2007; Hervas-Oliver *et al.*, 2012).

different mechanisms and innovation outcomes (Mora-Valentin *et al.*, 2004; Belderbos *et al.*, 2004). Furthermore, both business (for example, customers and suppliers vs. competitors) and institutional partners (for example, universities and research organisations) are different among themselves in their patterns of innovation cooperation (Arranz and Fdez de Arroyabe, 2008).

The second reason for focusing on different external knowledge sources is that they are generally placed at different distances (or "proximity") from the absorbing firm. The firm and its interacting partners can be placed at different distances on the territory (*geographical proximity*). They can be linked by inter-organisational arrangements of different nature in terms of control and authority (*organisational proximity*). They can master knowledge bases of different kinds (*cognitive proximity*) and be embedded within different sets of contexts and rules (*institutional proximity*). All these distances have been found to have an important role for the firm's knowledge assimilation process (see Boschma (2005) for a critical review).

We propose to look at the impact that innovation cooperation has on the firm's AC – as a whole – by distinguishing the firm's interactions according to the kind of external source. In so doing, we implicitly admit that, by interacting with a certain source *x* (e.g., a competitor), a generic firm *i* can increase the knowledge it absorbs, not only from *x*, but also from another source *y* (e.g., a customer) with which *x* interacts. For example, the firm might increase the absorption of knowledge available at one of its customers by interacting with one of its competitors, in the non-rare event that they "share" the same customer. Although the different "centrality" (in the network theory language) that firms have in these knowledge networks might affect the "total" external knowledge they absorb through their individual (direct and indirect) interactions, our approach appears in general motivated. Of course, the case would be different if the investigated firms were completely isolated nodes and the network extremely fragmented. However, even in these exceptional cases, our approach could be motivated by the firm's search for knowledge sources which could have widespread learning effects: in other words, by the search for what have been called "knowledge-brokers" (Pawlowski and Robey, 2004) and "knowledge-innovation hubs" (Youtie and Shapira, 2008).

Drawing on management and organisation studies (see Todorova and Durisin, 2007), in our analysis of the AC antecedents, we should also consider the "moderating" role of specific business events, which could induce the firm to intensify the search for external knowledge. For example, this is the case of the introduction of new information and marketing systems, or the adoption of a new management form. If the firm does not have previous experience of these systems, it could actually be forced to tap into more experienced external providers for their implementation. For this reason, in previous studies (for example, Fosfuri and Tribó, 2008), these events have been considered as "activation triggers" of the AC antecedents, which make their functioning more intensive.

Consistent with our previous argument, and different from what the literature finds in aggregate terms (see, for example, Fosfuri and Tribó, 2008), we argue that this can not be taken for granted either. On the contrary, we expect it to be also conditional on the kind of external knowledge source. For example, if the absorbing firm and the external provider are rivals in a certain innovation project and/or competitors in some markets, organisational shocks might lead the former to refrain from interacting with the latter for dealing with them. As we will actually see, rivalry phenomena like the so-called "Non-Invented-Here" syndrome (NHS) (for example, Katz and Allen, 1982) might interfere with the role of the AC "activation-triggers".

2.2. AC impact: the role of human capital

In innovation studies, AC is generally considered a fully direct innovation driver. In empirical analyses, it is often plugged into innovation regressions through a simple additive R&D proxy (de Jong and Freel, 2010).

However, following a more comprehensive AC interpretation, this is not entirely accurate. On the one hand, the knowledge which has been absorbed from the external environment – and that, as we also claimed, can have a relationship with the firm's R&D – can be expected to have a direct contribution to the firm's innovation. On the other hand, however, the innovation impact of the external knowledge mainly passes through its combination, transformation and integration with that generated (and available) internally (Fosfuri and Tribó, 2008). Firms thus need a larger set of capabilities for turning external knowledge into actual innovation.

These capabilities are generally more widespread across the firm's organisation than those for searching the external environment and assimilating external knowledge. While the activities of the R&D division are pivotal for these latter ones, the former require an intensive degree of "coupling" between R&D and other organisational divisions (for example, Nonaka and Von Krogh, 2009). The firm needs to have the capacity to establish operative connections and foster labour mobility between its internal organisation units (for example, through multi-functional groups) and between these and those of the partner(s) (for example, through joint ventures, partnerships and other kinds of inter-organisational mechanisms) (Knoben and Oerlemans, 2012).

The pervasiveness of these competences makes them difficult to be measured. One way to overcome this empirical problem is to look for the presence of organisational mechanisms which, within the firm, facilitate the integration of the externally acquired knowledge and its dissemination. In technical terms, these mechanisms could be expected to positively moderate the impact that the firm's AC has on its direct innovation outcome.

In the AC literature, these integration mechanisms have been mainly analysed through a perspective of organisational knowledge creation (for example, Nonaka and Von Krogh, 2009). In synthesis, the transformation of (external) assimilated knowledge into (internal) exploited knowledge, and finally into innovation, has been related to the firm's capacity to filter it through its proper organisational codes and to assimilate it into its organisational routines (Henderson and Clark, 1990; Zahra and George, 2002).

This perspective points to the role of such organisational capabilities as "connectedness and socialisation tactics" (Jansen *et al.*, 2005, p. 999), and of such organisational mechanisms as cross-functional interfaces and formal communication flows across divisions. In management studies, these have been called "Social Integration Mechanisms" (*SIM*), or sometimes simply integration mechanisms (*IM*) (Hirunyawipada *et al.*, 2010; Jansen *et al.*, 2009).

In the analysis of the impact of AC on innovation, the firm's human capital and the training investments through which it is built up have been instead less investigated. In those few studies which explicitly recognise to it a role (for example, Minbaeva *et al.*, 2003; Vinding, 2006; Lopez-Garcia and Montero, 2011), human capital is rather generally treated as an additional proxy of AC, which works along with R&D as a "radar" to let external knowledge reach the firm. On the contrary, the role of human capital for its actual integration and assimilation in the firm has not been addressed.

This is for us unfortunate and represents another aspect which deserves attention in our empirical investigation.

The integration of external knowledge within the firm is a complex process, of both organisational and individual nature. Not only does it require the existence of organisational devices (such as, for example, a cross-divisional quality circle), which create links between organisation members for the sake of knowledge-sharing (as, for example, in Zahra and George, 2002). It also requires a qualified kind of interaction among them. The value of the transmitted knowledge needs to be critically evaluated on an individual basis, understood and finally socialised, rather than simply "dispersed". For this reason, the workers' skills and their relational capabilities need to be reinforced, for example, through the adoption of specific training programmes and practices of Human-Resources-Management (HRM).

In principle, both social and human-capital based *IM* could be expected to moderate the AC impact on innovation. However, this is not a necessary outcome. On the contrary, it depends on the specific organisational structure of the firm and the kind of socialisation process it sticks to, deliberately or not. The integration of external knowledge in the firm could turn out to be of two kinds: "wide", when the firm mainly relies on the first kind of organisational integration mechanisms or "deep", when knowledge integration mainly works through individually based integration mechanisms of the second kind. Although

the complementary presence and use of both – i.e. wide and deep integration of external knowledge – could be expected, their role should be investigated separately.

3 Empirical Application

3.1. Dataset

The antecedents and the impact of AC are investigated with respect to a sample of about 10,500 manufacturing firms based in 3 European countries: Germany, Italy and Spain.

The relative dataset has been built up by using data from the 4th Community Innovation Survey (CIS). Although the CIS4 uses a harmonised questionnaire across 16 countries in order to test the arguments of the paper on a relatively more homogeneous set of countries – especially in terms of number of surveyed innovative firms – the application is limited to the aforementioned 3 countries.

The distribution of firms by country, sector and size is reported in Table A1 (in the Appendix). Given our interest in the 3 countries as a whole, the evident biases in the distributions by individual countries are not a relevant problem.

The majority of CIS4 variables refer to the period between 2002 and 2004. Although some of them capture particular aspects in the last year of the reference period, or both in the first and the last year, the resulting dataset is a cross-sectional one. This issue will be considered in interpreting our results.

3.2. Econometric strategy

Consistent with our previous theoretical arguments, the econometric strategy that we follow has two steps.

3.2.1 AC antecedents

The first step consists of the estimation of the AC antecedents. Relying on the previous section, we run a set of OLS regressions of the following kind of model:

$$AC = \alpha + \beta_1 RD + \beta_2 PROPAT + \beta_3 COP + \beta_4 AT \times COP + \beta_5 CONT + \varepsilon \qquad (1)$$

In Eq. (1), the dependent variable, *AC*, is an indicator of the firm's capacity to scan, detect, and assimilate the relevant external knowledge.[5] Standard R&D-related proxies, such as the firm's R&D intensity, are thus not suitable for this scope. A more appropriate solution is suggested by Fosfuri and Tribó (2008), who look at the importance (on 4-point Likert scales) firms attribute to the information acquired from external knowledge sources for the sake of innovation (see Question 6.1 of the harmonised CIS4 questionnaire). In their argument, this evaluation should reflect two different aspects of the surveyed firms: the extent to which the relative external knowledge is present in their environment and the extent to which it is intelligible (i.e. absorbable) to them. Following this logic, AC can be proxied by that part of the external knowledge importance which is not explained by its availability. In analytical terms, this is given by the following expression:

$$AC = EXTKNOW - \hat{EXTKNOW} \qquad (2)$$

In our empirical application, *EXTKNOW* is obtained through a normalised factor analysis of the answers firms provided about the innovation importance of their sources of external knowledge.[6] $\hat{EXTKNOW}$ is instead the estimated value of *EXTKNOW* regressed against a set of country-specific, sector-specific and organisation-specific dummies. These dummies account for the firm's belonging to a certain national system of innovation, a specific sectoral system and, eventually, to a multinational corporation (MNC), respectively.[7] This last estimation is thus simply instrumental and serves to extract out of *EXTKNOW* that part which can be explained by the environment in which the firm is located.

In order to obtain the fitted values of $\hat{EXTKNOW}$, we first regress *EXTKNOW* against the relevant dummies with an OLS model. However, given the particular distribution of *EXTKNOW*, which shows a (relatively low) concentration around 0, and given the sort of censoring we introduced by normalising it in-between 0 and 1, as a robustness check a Tobit estimation is also applied.

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5 Zahra and George (2002), and the literature which followed them, call this capacity *Potential* AC, and distinguish it from the Realised AC, which is the capacity to transform the externally-acquired knowledge into actual innovation.

6 Given that factor analysis is mainly suitable for continuous variables or ordinal ones but with large scales, the narrow-scale categorical variables to which we have applied it have been corrected for by using a polychoric correlation matrix (Bartholomew *et al.*, 2002). We then used the principal factor method to extract a factor (Cronbach alpha = 0.779), which has been then normalised to vary between 0 and 1. The Kaiser-Meyer-Olkin measure of sampling adequacy is 0.8360, confirming that our variables have enough in common to run a factor analysis.

7 The reference to MNC represents an extension of Fosfuri and Tribó (2008), who just consider geographical and sectoral dummies. If they are part of MNC, firms can have privileged access to the knowledge generated by other subsidiaries and (if different from it) by the parent company, both in the same and in other countries (for example, Minbaeva *et al.*, 2003; Phene and Almeida, 2008).

As far as the regressors of Eq. (1) are concerned, we first consider as *AC* antecedents, the firm's engagement in R&D and its patenting activities. As the CIS does not provide suitable continuous and stock-kind of variables for that, we are forced to rely on a vector of dummies (*RD*). Firstly, we consider whether the firm makes continuous investments in R&D (*RDCONT*) and whether it acquires extramural R&D services (*RDEXT*).[8] Secondly, we detect whether the firm has applied for a patent (*PROPAT*) (see Table A2 for a detailed description).

The explanatory role of innovation cooperation (vector *COP* in Eq. (1)), our core AC antecedent, is also captured though dummy variables, but in a hierarchical manner.[9] First of all, we use a dummy for the presence of general cooperation (*INNOCOOP*), and then a set of variables for specific cooperation agreements, by distinguishing the type of partner. More precisely, we employ dummies for the cooperation with: (i) national and foreign firms (*COOPFIRMNAT* and *COOPFIRMFOR*), in turn divided – each one with both a national (*NAT*) and a foreign (*FOR*) termination – into firms belonging to the same group (*COOPGP*), suppliers (*COOPSUP*), customers (*COOPCUS*), and competitors (*COOPCOM*); (ii) national and international research organisations (*COOPORGNAT* and *COOPORGFOR*), in turn divided – each one with both a national (*NAT*) and a foreign (*FOR*) termination – into private laboratories and institutes (*COOPINS*), universities (*COOPUNI*), and governments and public research institutes (*COOPPUB*) (see Table A2 for details).

As for the "*activation triggers*" (*AT*) of AC, they are expected to moderate the impact that *COP* has on it, and are thus plugged into Eq. (1) through an interaction term. Following Fosfuri and Tribó (2008), we consider, still with a dummy (*AT*), those internal events which have entailed, simultaneously: the introduction of a new or improved knowledge management system, a new or improved marketing method, and a major change in the work organisation (see Question 10.1 of the CIS4 questionnaire and Table A2). Although "softer" changes (involving only one, or two, out of the three events above) have been considered in unreported regressions (with unchanged results), we decided to stick to the specification with "macro-events". Their trigging role is expected to be more intensive. Thus, we expect that this wide organisational changes, which modify how information and work is organised inside (i.e., through information and work management) and outside (i.e., though marketing) the firm's boundaries, make the firm more reliant on external knowledge for their effective implementation.

[8] To be sure, we do not use the continuous variables for R&D expenditures available in the CIS4 dataset, as these refer to the last year of the period (i.e. 2004) and might create endogeneity problems, when the dependent variables (for example, AC) refer to the entire period (i.e. 2002-2004). Furthermore, we include *RDCONT*, instead of another dummy for the general engagement in R&D, given that the latter might also capture trivial investments, which are not capable of stimulating the creation/accumulation of AC.

[9] This is a more qualified kind of information than that used for the construction of *EXTKNOW*, as it refers to the firm's "active participation with other enterprises or non-commercial institutions on innovation activities [...] exclud[ing] pure contracting out of work with no active co-operation" (Question 6.2 of the CIS4). For the same reason, extramural R&D (*RDEXT*) has not been inserted here.

Finally, in Eq. (1) *CONT* is a vector of controls and ε is a standard error term. Among the controls, particularly important for our investigation is the size of the firms, which we capture with the two dummies *SMALL* and *MEDIUM*. Knowing whether firms export their goods to foreign markets (the dummy *EXPORT*) is equally important, given the worldwide knowledge links they would have for that.

3.2.2 AC impact

The second part of our empirical analysis consists of the estimates of the following econometric model:

$$y = a + b_1 AC + b_2 AC \times IM + b_3 CONT + \varepsilon \qquad (3)$$

In Eq. (3), *y* is a variable which captures the firm's innovation performance, *AC* is our proxy for its absorptive capacity (see Section 3.2.1), and *IM* is the vector of what we called (see Section 2) integration-mechanisms variables (*CONT* and ε have the same meaning as in Eq. (1)).

Given our interest in the actual innovative exploitation of external knowledge by the firm, we first refer *y* to the economic output of innovation: that is, the percentage of turnover which is due to the introduction of product innovations, both new to the market and to the firm (*TURNINNO*). Given its skewedness, in order not to miss all of the observations with nil values, we follow Laursen and Salter (2006) and employ a logarithmic transformation of it, that is: *lnTURNINNO=ln*(1+*TURNINNO*). Furthermore, as *lnTURNINNO* takes value 0 with a positive probability, but is roughly continuously distributed over positive values, we refer to a "corner solution model" (Wooldridge, 2002) and estimate Eq. (3) with a Tobit.[10]

Further elements of analysis are then obtained by using for *y* a dummy capturing whether or not a firm introduced a successful product innovation (*INNOPROD*), irrespectively from the turnover it gains from it. Given its binary nature, a probit estimation procedure is used.[11]

Finally, in order to account for the existence of a possible sample selection bias, we implement a series of Heckman selection models, using *lnTURNINNO* as a dependent variable. To this purpose, we use *INNOPROD* as an exclusion restriction. This dummy, which captures the introduction of a product innovation, is supposed to directly affect the "selection" (i.e., whether the economic exploitation of the innova-

[10] Running standard OLS for the entire sample, or for the subsample for which *lnTURNINNO*>0 would lead to inconsistent estimations of the coefficients. Tobit models instead imply the existence of a latent variable y*, in addition to the observed y, such that y=y* if y*≥0 and y=0 when y*<0. However, in a corner solution model the latent variable is rather an artificial device and the interest of the estimates goes to E(y|x,y>0) and E(y|x) (Wooldridge, 2002).

[11] In both the versions of the second step of the analysis, it should be noted that the "residual" way we obtained our measurement of AC (as in Equation 2) might create a problem of multicollinearity. Accordingly, proper multicollinearity tests are run.

tions is greater than 0, but not the actual amount of the economic outcome due to the introduction of product innovations.

As far as *IM* is concerned, as we said, we expect that the relevant "integration" mechanisms moderate the impact that AC has on *y*, and we thus plug it into Eq. (3) as an interaction term. We build up two dummies, which could account for the presence in the firm of "integration" mechanisms (*IM*) of organisational nature (Table A2). With the dummy *IM1* we look at whether firms consider internal information flows (within their boundaries or within their business groups) relevant for their innovation. If so, we assume that such information flows should have been enabled by the existence of proper organisational mechanisms (for example, cross-functional interfaces).

With the dummy *IM2* we refer to those firms which, in addition to *IM1*, also have a (medium or high) flexible production system in place. Flexible organisational forms in fact require high levels of information sharing, mainly for compensating the attenuation (or even the lack) of formal command (Constant *et al.*, 1994; Volberda, 1996). The working of flexible production systems should thus rely also on the firm's capacity to disseminate external knowledge throughout its organisation.

Two further dummies are built up in order to proxy the presence of integration mechanisms, which work through human resources (Table A2). *IM3* identifies those firms which either report training programmes as an innovation enabler, or do not report the lack of qualified workers as an innovation obstacle. In both cases, these can be thought as firms in which human capital has been built up - in occasion of, or before the innovation - but still to support innovation activities. These can also consider firms in which the internal transmission of externally acquired knowledge passes through skilful employees, who diminish the risk that its diffusion remains blocked by understanding problems. *IM4* is just a softer version of *IM3*, for which the alternative to the presence of training programmes is that of little problems, rather than no problems at all, for the lack of qualified workers (Table A2).[12]

[12] It should be noted that, although related to it, these are only distant proxies of the firm's human capital. A more careful insertion of human capital in the analysis of AC antecedents and effects, as in Vinding (2006), would require more qualified information than that available in the CIS4. However, the fact that the kind of training and qualified work the CIS refers to is related to innovation does not prevent us from considering it beneficial for the sake of AC. On the contrary, an important part of this training is presumably devoted to foster the capacity of recognising previously unexplored connections, which internal and external knowledge very often present (Hagardon, 2002).

4 Results

4.1. AC Antecedents

The role of the AC antecedents is tested through hierarchical regressions in an incremental way. In Table 1, Model 1 considers the main AC antecedents and controls in isolation, with no interactions. Firm's innovative cooperation is also considered, but in "aggregate terms", without distinguishing its specifications.

The different sources of innovation cooperation are disentangled in Model 2 – by simply distinguishing firms from research organisations (national and foreign) – and in Model 3 – by disaggregating each of them in further typologies. Finally, Model 4 addresses the interaction between the AC antecedents and the activation triggers that we considered (*AT*).

Given the high number of inserted covariates and interaction terms in the last two models, the risk of multicollinearity in their estimation is high. However, a VIF test guarantees that this is not a significant issue in our application.[13]

Insert Table 1 here

The "second face" of R&D, which Cohen and Levinthal (1989) identified in their seminal work, appears visible in our application too. The R&D variables are significantly positive across all the models. More precisely, our results extend the findings by Cohen and Levinthal (1989) and suggest that AC benefits from the two kinds of formal R&D engagements we have considered: the R&D carried out on a continuous basis, possibly in formal R&D divisions (*RDCONT*), and the contracted-out R&D (*RDEXT*). Although apparently inconsistent with the literature on the risks of R&D outsourcing in terms of knowledge-leakage (for example, Howells, 1999), this last result is consistent with Fosfuri and Tribó (2008) and with their interpretation. While it does not entail an "active participation" to innovation activities, extramural R&D in general increases the firm's capacity to acquire and assimilate external knowledge.

The firm's propensity to patent (*PROPAT*) also finds robust support across all the model specifications. As we expected, those learning efforts firms usually do in order to apply for a patent seem to have a side effect on their learning capacity of external knowledge.

As far as innovation cooperation is concerned, our hypothesis that its role for AC depends on the kind of knowledge source (external partner) is not rejected. On the one hand, the firm's involvement in innovation cooperation unambiguously increases its AC: *INNOCOOP* turns out significant and positive in the most ag-

gregated model (Model 1). On the other hand, once the various external knowledge sources are considered, in the other models, mixed results are obtained. First of all, the geographical distance from the external source with which the firm cooperates matters. Both in the cooperation with firms and with research organisations, the AC impact is significant and positive only with respect to the national ones (i.e. *COOPFIRMNAT* and *COOPORGNAT* in Model 2). Cooperating in innovation across different countries could actually create linguistic and cultural barriers to the understanding of the knowledge which is produced and/or spread through it. This is a result which makes the pendulum swing towards the binding (rather than unbinding) role of geographical distance for leveraging external knowledge (for example, Tallman and Phene, 2007).

The hampering effect that geographically-distant cooperation has on AC appears however conditional on the cognitive and institutional distance between the partners (Boschma, 2005; Nooteboom, 2000). In general, the firms that we observe interacting can be claimed to face similar techno-economic problems as their business kind of partners, that is, suppliers, customers and competitors. Sharing the same market-oriented knowledge base makes innovation cooperation with them able to build on their AC, both in the case of national and foreign interactions (*COOPSUPNAT* and *COOPSUPFOR*, *COOPCUSNAT* and *COOPCUSFOR*, *COOPCOMNAT* and *COOPCOMFOR* in Models 3 and 4). Conversely, research organisations have different incentives, objectives and behavioural rules than the firms which leverage knowledge from them (Boschma, 2005). Cooperating in innovation with research organisations thus continues to require a national setting to increase the firm's general AC (i.e., *COOPINSNAT*, *COOPPUBNAT* and *COOPUNINAT*, in Model 3 and 4).

This is an interesting result. In order to work as "innovation hubs" (Youtie and Shapira, 2008) and help the knowledge absorption capacities of the firms they interact with, research organisations need to share with them the same linguistic and cultural codes. On the contrary, the firm's interactions with other business actors, characterised by a relatively higher cognitive and institutional proximity, increase the firm's capacity to absorb external knowledge irrespectively from the nationality of the partners. In other words, even in the globalisation realm, national science-technology relationships are as important as worldwide business-to-business relations to increase the firm's experience of external learning.

All these results confirm the multidimensional nature of AC. In particular, they are consistent with Lim's (2009) findings about the multiple "faces" of absorptive capacity. Following Lim, AC would actually depend on the nature of the knowledge to be acquired: in particular, "domain-specific knowledge", vs. "solutions to specific technical problems" and "knowledge embedded in tools and processes". What we add to

[13] All the VIF values are lower than 10 in each of the employed models.

his interpretation is that these different faces also have different "tongues" (i.e., speak different languages and rely on different transmission channels).

A last remark deserves the role of what can be considered an organisational kind of distance, meant as the similarity of governance structure and business processes between two organisations. Although with some limitations, this proximity can be proxied by the firms' belonging to the same business group of the partner.

Cooperation within the group increases the firm's AC only when it works with national subsidiaries (*COOPGPNAT* in Models 3 and 4). On the contrary, the interaction with foreign ones significantly decreases it (*COOPGPFOR*, in Models 3 and 4). A tentative explanation of this result might be found in the so-called "Not-Invented-Here" (NIH) syndrome (Katz and Allen, 1982). In brief, the knowledge-brokering role of foreign units might be dampened (to be sure, even reversed) by the scepticism with which domestic ones look at them as rivals in developing superior innovations for their common business (for empirical evidence on such phenomena see, for example, Lehrer and Asakawa, 2003). As Wastyn and Hussinger (2011) suggest, while potentially at work with respect to any external source, this phenomenon is increased by the firms sharing the same organisational culture and codes, and thus perceiving themselves as stronger rivals, like when they are in the same business group.

The nature of the external knowledge-source appears crucial for AC also for the moderating role of the activation triggers (*AT*) that we have identified. On the one hand, they directly contribute to the accumulation of AC (Model 1). Indeed, the business events that we have identified with *AT* make firms cognitively more open to the external environment. However, their moderating effect on the other AC antecedents is heterogeneous.

As far as innovation cooperation is concerned, once interacted with any of the foreign knowledge sources, *AT* makes the significance of their AC impact vanish. It seems like the occurrence of organisational changes (of the kind we captured) requires knowledge-solutions which, in order to be absorbed, are "transmitted", if not even "produced" by national partners. This is a result which reinforces our previous finding in terms of geographical distance. The moderating effect of *AT* is instead mixed with respect to national partners in innovation cooperation. On the one hand, it is positive with respect to both national suppliers and customers (*COOPSUPNAT* and *COOPCUSNAT* in Model 4), whose "normal role" of AC antecedents is actually triggered by the considered business events. On the other hand, the interaction with *AT* turns the impact of innovation cooperation with the national competitors (*COOPCOMNAT*) from positive to negative (Model 4). The NIH syndrome might still play a role here, when we consider the higher organisa-

tional proximity firms have with their competitors than with their suppliers and customers.[14] The interaction with AT makes this argument relevant also with respect to national firms of the same group (*COOPGPNAT* in Model 4), which had a positive AC impact, and which now gets a (weakly) significant negative interacted impact.

The moderating role of *AT* is clear-cut when the relationship between AC and *RDEXT* or *PROPAT* is considered: in both cases, it is not significant. In the presence of those internal organisational processes and practices that we have considered as "activation triggers", resorting to external R&D services or engaging in patenting activities do not increase the firm's AC, as instead occurs when they are considered as simple regressors. In the interaction with such "softer" organisational changes as *AT*, these "harder" technological drivers apparently lose their AC triggering role.

As a robustness check, the previous analysis has been repeated using a different AC measurement, which controls for the nature of the underlying data distributions (see Section 3.2.1). The results appear extremely robust. By re-estimating all of the 4 models of Table 1 with the alternative measurement of AC obtained through a Tobit regression, the coefficients of the AC antecedents are very similar in both significance and sign (results are available from the authors on request).

4.2. AC Impact

The analysis of the innovation impact of the firms' AC is first carried out with respect to *TURNINNO*. More precisely, the results are obtained through the hierarchical regression of a Tobit model, which uses the transformation *lnTURNINNO* described in Section 3.2.2.

We refer to 6 specifications. Starting from the baseline (Model 1), we progressively add to AC, and to its antecedents and controls, the other covariates of interest. Among these, particularly important are the interactions with the integration mechanisms (*IM*) that we have described above (Section 3.2.2).

Due to the way AC was built up, some problems of collinearity may arise. However, we have conducted a test of multicollinearity and found that this is not an issue in our empirical application.

As expected, AC has a significant and positive impact on the firm's innovation in all the model specifications (Table 2).

[14] This result appears consistent with what Wastyn and Hussinger (2011) find with respect to Germany. "Competitors are the most similar out-group for companies as compared to suppliers, customers (and universities) [and as …] employees refuse to value rivals' knowledge, in particular, in order to avoid degradation of their own technological advances and the loss of group-identity […] a NIH syndrome is most likely to occur if firms source knowledge from competitors rather than from suppliers, customers (or universities)" (ibidem, p. 2).

Insert Table 2 here

However, as we claimed in the theoretical background, the innovation impact which passes through the firm's AC should consider also the way this capacity is exploited within the organisation. In some specifications (i.e. Model 2, 3, 6), the positive effect of AC is compensated by the negative one of its interactions with the *IM* variables. Hence, their role should be carefully controlled.

The expected moderating effect of *IM* is not confirmed when we look at the integration mechanisms of organisational nature, that is *IM1* and *IM2*. While they are both significant and positive as individual regressors (Model 2, 3 and 6), once they are interacted with the firm's capacity of bringing "home" external knowledge, the same mechanisms seem to impoverish its innovation outcome: *IM1*AC* and *IM2*AC* are significantly negative.

The countervailing effect of *IM*1 and *IM*2 on the *AC* transformation into innovation does not make it completely "inefficient'.[15] Still, such a result is apparently in contrast with both the theory and empirical evidence on the issue (for example, Fosfuri and Tribó, 2008). This point deserves further and closer scrutiny in future research. By now, one possible explanation could be that the process of knowledge "socialisation" which passes through the firm's organisational structure (for which Nonaka and Takeuchi (1995) is the standard reference), could have some drawbacks in terms of knowledge transformation. For example, it could imply a "dispersion" of assimilated external knowledge, which makes its synthesis with the internal one and with the existing competencies harder to occur. In other words, in the absence of further safeguards, the organisational socialisation of external knowledge may hamper what Galunic and Rodan (1998) have called a "synthesis-based recombination": a process, in which the existing competencies of the firm are combined to synthesise novel competencies. Unlike "knowledge distribution", "knowledge dispersion" in fact creates problems of knowledge movement and detection, and in general diminishes the likelihood of convenient "resource recombinations" (*ibidem*, pag. 1198, *Proposition 3*).[16]

[15] Following Wiersema and Bowen (2009), we calculated the "correct" marginal effect of *AC* and of its interactions with *IM1* and *IM2*. We considered the moderating dummy variables *IM* and *IM2* at their two possible values, 0 and 1, and all the other variables at their means. The marginal effect of the interactions terms are then calculated as the difference between the value at *IM1*(or *IM2*)=1 and *IM1*(or *IM2*)=0. In Models 2 and 3, the marginal effects of *AC* and of its *IM*-interactions on *lnTURNINNO* (i.e. $\partial E(y|x)/\partial x$, for which see Cameron and Trivedi (2009)) are, respectively: 1.35 (*AC*) and -1.34 (*IM1*AC*), in Model 2; 1.33 (*AC*) and -0.98 (*IM2*AC*), in Model 3. Hence, the "net" effect of *AC* on innovation performance is positive also in those cases in which the relevant integration mechanisms are in place (i.e. *IM*1 or *IM*2 are equal to 1).

[16] The difference is well explained by the following example: "A picture on a jigsaw puzzle is distributed when each person receives a photocopy of the picture. The same image would only be dispersed when each of the pieces is given to a different person" (Galunic and Rodan, 1998, p. 1198). On the micro-foundations of "knowledge

The sets of results changes substantially when we consider the other two integration mechanisms, *IM3* and *IM4*.

First of all, in general and as expected, they both increase the firm's innovation outcome *per se*. Furthermore, they seem to work efficiently in transforming AC into innovation. Finally, in the most comprehensive model (i.e., Model 6), the positive AC-moderating role of *IM*3 more than compensates the negative one of *IM1* (similar results, available on request, are obtained for the other combinations between *IM1*/*IM2* and *IM3*/*IM4*).

This last result is quite interesting. It suggests that the two kinds of mechanisms we addressed do not work along the same direction in moderating the impact of AC on innovation. On the contrary, for the investigated firms, the presence (and the effects) of innovation-related training programmes is necessary to prevent the AC innovation impact from being inefficient, in those cases in which organisational integration mechanisms dampen it.[17] More generally, the same result suggests that the role of human capital for AC (as captured by *IM*3 and *IM*4) deserves more attention. The accumulation of experience of the employees increases the tacit knowledge of the firm and, through it, its innovation outcomes also. This is a result that evolutionary theories of innovation have established since long (for example, Dosi, 1988). Through training and other human capital investments, employees can also have more fruitful knowledge exchanges. This can occur both between them and with other individuals outside the firm, with whom they can create "communities of practice", which facilitate the access to and the utilisation of external knowledge (for example, Mangematin and Nesta, 1999). In other words, the social integration of external knowledge also benefits from the creation of individual "knowledge brokers". These latter are essential for driving external knowledge within the firm's boundaries (Brown and Duguid, 1998, p. 103) and for the internal "know-how trading" which takes place in it afterwards (Carter, 1989).

In order to check the robustness of our results, we carried out the analysis of the AC effects by employing a probit estimation, which uses *INNOPROD* as a dependent variable (see Table 3). The coefficients of AC and the other regressors and interaction terms yield fully consistent outcomes.

Insert Table 3 here

dispersion" see, for example, Cowan and Jonard (2004), who use network theory to show the existence of a trade-off between efficiency and equity in knowledge diffusion.

[17] Following Wiersema and Bowen (2009), in Model 6, the marginal effects of *AC* and of its *IM1*- and *IM3*-interactions on *lnTURNINNO* (i.e. $\partial E(y|x)/\partial x$, for which see Cameron and Trivedi (2009)) are respectively: 1.32 (*AC*), -1.45 (*IM1***AC*), and 1.38 (*IM3***AC*). A negative impact would thus occur for those firms in which *IM*1 is equal to 1 and *IM*3 is equal to 0.

Furthermore, in order to control for the existence of a possible bias due to sample selection, we re-estimate Model 1-6 of Table 2 with a series of Heckman selection models. More precisely, in the selection equation, to the sets of the independent variables we add the variable *INNOPROD* as an exclusion restriction. The underlying argument is that *INNOPROD* is likely to affect the selection (i.e. *lnTURNINNO*>0), but not the amount of *lnTURNINNO*. The results (not reported here, but available upon request) show that selection-bias is not an issue in our empirical application. With the two-step method, Mill's ratios are always statistically insignificant. Similarly, with the maximum likelihood estimation, the hypothesis that the selection and outcome parts of the models are independent is never rejected.

Similarly to what we did for the AC antecedents, as a robustness check, we carried out the analysis of its innovation impact with a different measurement of *AC* (see Section 3.2.1). The results (available from the authors on request) appear largely robust and consistent with the ones reported above.

5 Conclusions

The paper develops the idea that, in the realm of firms, "absorptive capacity" (AC) is the result of a complex, multi-dimensional learning process. One thing is for the firm to look for and bring new external knowledge within its organisational boundaries. Another thing is to combine external knowledge with that available internally, and transform it into new products and/or processes. Different capabilities and experience are required. Furthermore, different factors play a role in moderating their effects on the AC, as well as the impact of the AC on innovation.

Although it places in a developed research stream, the paper contributes to it with some elements of originality and a set of implications for policy and practitioners.

Consistent with the original idea by Cohen and Levinthal (1989), for the firms of the European area we have investigated, AC actually appears to be the "second face" of R&D. Both continuous and contracted out R&D increase the firm's capacity to assimilate external knowledge. This result supports the current policy concern for an increase of the European firms' expenditure in R&D, at the intensive margin. On the other hand, it suggests the opportunity of increasing it also at the extensive margin. For example, policy makers could spur firms to resort to extramural R&D, when problems of minimum threshold prevent the intramural one from being efficient. This policy implication is thus particularly important for SMEs.

The experience of patenting activities increases AC too. This is due to, among the others, the external knowledge management that it entails, and the codification efforts it requires. Although a more accurate proxy would be needed to support it, this result suggests that, somehow paradoxically, policy interventions aimed at enforcing intellectual protection do not necessarily conflict with an "open innovation" mode.

The most relevant result of the paper concerns the AC-impact of a firm's experience in innovation cooperation. Interacting with an external partner has an impact of the firm's AC. However, this depends on the manifold kind of distance (or "proximity") which separates them. In particular, research organisations work as "innovation hubs" for the firm only if their interaction occurs in the same national setting. On the other hand, a business kind of interaction augments the firm's AC whatever the nationality of the partner is. More generally, the geographical distance intertwines with the cognitive and institutional ones, and points to different dimensions of the firms' AC. From a policy perspective, national innovation systems still maintain a role in the acquisition of external knowledge, and thus deserve proper system kind of policies. This is true even for firms which simultaneously source their knowledge within business-to-business global networks.

Finally, the organisational proximity between the interacting firms - proxied by their belonging to the same business group - in some cases appears to reverse the positive AC impact of global business interactions. This could be due to the "competition" effects it induces, of the kind of the notable "Not-Invented-Here" syndrome. At the business level, this poses to managers the delicate choice of not favouring distant innovation partnerships, even if this would be necessary to increase the firm's knowledge base. Similar management implications emerge from the results on those internal "Activation Triggers" (*AT*), which spur the search for external knowledge. Policy makers should retain these implications in devising initiatives of inter-firm networking, especially in the attempt to overcome R&D scale problems which are typical of the European area. In some cases, these initiatives might end up in a "zero-sum" game.

The analysis of the innovation impact of AC has also given us some interesting insights. Those "Integration Mechanisms" (*IM*), which previous studies have found important for the so-called socialization of external knowledge, did not appear at work in our empirical application. On the contrary, their side-effect in terms of "knowledge dispersion" within the firm has appeared to depress the innovation impact of AC. The AC effects in terms of innovation depend on other integration mechanisms, more related to the firm's human capital. Their role in facilitating the absorption of external knowledge thus deserves larger consideration. On the one hand, on-the-job training initiatives also have a "second face" in terms of absorptive capacity, as much as R&D. On the other hand, investing public resources to foster training (and education) finds an additional justification, which makes them twice as important for reaching targets of "smart" growth.

While these are the most substantial added values of the paper, when compared with previous works using a similar methodology (for example, Fosfuri and Tribó, 2008), other elements of originality have been introduced at the methodological level. The "residual" role of AC in explaining the importance that firms attribute to external knowledge has been better accounted for by considering their eventual belonging to MNCs. The role of external knowledge has been addressed more extensively by considering a number of different kinds of sources. The analysis of the AC impact has been carried out with more sophisticated econometric methods, reliable innovation proxies, and a wider array of moderating factors.

Of course, the paper is not free from limitations, to whose solution future research will be devoted. For example, further efforts are required for the definition of the "Activation Triggers", whose role has been at most elicited, as well as that of the "Integration Mechanisms". All of these variables, along with possibly others, have been defined on the basis of the available, CIS data. In this last respect, while the current application has somehow made previous ones more general in terms of geographical coverage, it remains a cross-sectional one. This requires us to be cautious and interpret the results as correlations among variables, rather than as causal relationships as such. The use of longitudinal data, possibly coming from the availability of more CIS waves, would remedy this limitation. Still, the articulated way in which we have captured AC in the paper, far beyond the simple use of an R&D proxy, provides us with at least conceptual arguments to disfavour a reading of reverse-causality of the significant correlations which we have obtained.

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Tables

Table 1: AC antecedents

Dependent variable: AC

	I *Coeff./S.E.*	**II** *Coeff./S.E.*	**III** *Coeff./S.E.*	**IV** *Coeff./S.E.*
SMALL	-0.01331**	-0.01027*	-0.01249**	-0.01191**
	0.005	0.005	0.006	0.006
MEDIUM	-0.00305	-0.00034	-0.00311	-0.00295
	0.005	0.005	0.006	0.006
EXPORT	0.01326***	0.01359***	0.01083**	0.01072**
	0.004	0.004	0.004	0.004
RDCONT	0.05573***	0.05447***	0.05566***	0.05548***
	0.004	0.004	0.004	0.004
RDEXT	0.03963***	0.03768***	0.04042***	0.03953***
	0.004	0.004	0.004	0.005
PROPAT	0.03543***	0.03329***	0.03399***	0.03651***
	0.004	0.004	0.005	0.005
AT	0.05676***	0.05285***	0.06186***	0.06939***
	0.007	0.006	0.007	0.01
INNOCOOP	0.07435***			
	0.005			
COOPFIRMNAT		0.04542***		
		0.006		
COOPORGNAT		0.07943***		
		0.006		
COOPFIRMFOR		0.00165		
		0.007		
COOPORGFOR		0.01256		
		0.011		
COOPGPNAT			0.02217**	0.03002***
			0.01	0.01
COOPGPFOR			-0.06606***	-0.06745***
			0.011	0.012
COOPSUPNAT			0.01817**	0.01420*
			0.008	0.008
COOPSUPFOR			0.02624**	0.02436**
			0.011	0.012
COOPCUSNAT			0.03770***	0.03086***
			0.009	0.01
COOPCUSFOR			0.02408**	0.02961**
			0.012	0.012
COOPCOMNAT			0.02684***	0.04160***

			0.01	0.011
COOPCOMFOR			0.02618*	0.02814*
			0.014	0.015
COOPINSNAT			0.02417***	0.02368**
			0.009	0.009
COOPINSFOR			0.00613	0.01159
			0.017	0.018
COOPUNINAT			0.06465***	0.06643***
			0.008	0.009
COOPUNIFOR			0.01474	0.01308
			0.019	0.021
COOPPUBNAT			0.07217***	0.06596***
			0.013	0.015
COOPPUBFOR			-0.04762	-0.00702
			0.031	0.036
COOPFIRMNAT*AT				
COOPORGNAT*AT				
COOPFIRMFOR*AT				
COOPORGFOR*AT				
RDEXT*AT				0.00943
				0.014
PROPAT*AT				-0.02257
				0.015
COOPGPNAT*AT				-0.05979**
				0.027
COOPGPFOR*AT				0.01279
				0.033
COOPSUPNAT*AT				0.04092*
				0.022
COOPSUPFOR*AT				-0.01171
				0.027
COOPCUSNAT*AT				0.06355**
				0.026
COOPCUSFOR*AT				-0.05178
				0.032
COOPCOMNAT*AT				-0.10066***
				0.028
COOPCOMFOR*AT				-0.02925
				0.036
COOPINSNAT*AT				0.00622
				0.025
COOPINSFOR*AT				-0.02989

				0.045
COOPUNINAT*AT				-0.01064
				0.023
COOPUNIFOR*AT				0.00822
				0.048
COOPPUBNAT*AT				0.04042
				0.03
COOPPUBFOR*AT				-0.08536
				0.06
Const.	-0.07647***	-0.07730***	-0.07423***	-0.07505***
	0.006	0.006	0.007	0.007
R^2	0.144	0.158	0.151	0.154
F	226.484	192.375	93.577	58.022
N	10490	10490	9815	9815

***, **, * denote a significance level of 1%, 5% and 10% respectively

Table 2: AC effects

Dependent variable: lnTURNINNO

	I *Coeff./S.E.*	**II** *Coeff./S.E.*	**III** *Coeff./S.E.*	**IV** *Coeff./S.E.*	**V** *Coeff/S.E.*	**VI** *Coeff./S.E.*
SMALL	0.34348***	0.34119***	0.34863***	0.38724***	0.36852***	0.38504***
	0.065	0.065	0.065	0.065	0.066	0.065
MEDIUM	0.12069*	0.11733*	0.12506**	0.14823**	0.13873**	0.14455**
	0.063	0.063	0.063	0.063	0.063	0.063
EXPORT	0.26014***	0.23276***	0.25482***	0.25911***	0.25869***	0.23249***
	0.064	0.064	0.064	0.064	0.064	0.064
RDCONT	1.05556***	0.96653***	1.03084***	1.02963***	1.03778***	0.94221***
	0.055	0.055	0.055	0.054	0.055	0.055
RDEXT	0.26944***	0.25392***	0.26267***	0.23547***	0.25949***	0.21987***
	0.055	0.055	0.055	0.055	0.055	0.055
PROPAT	0.79835***	0.78695***	0.80151***	0.76528***	0.78432***	0.75490***
	0.052	0.052	0.052	0.052	0.052	0.052
AT	0.45189***	0.44339***	0.43008***	0.39747***	0.43594***	0.38734***
	0.073	0.072	0.072	0.074	0.073	0.073
AC	1.98179***	2.90750***	2.32613***	0.79065***	1.00207***	1.76487***
	0.135	0.186	0.163	0.237	0.313	0.266
INNOCOOP	0.36502***	0.35141***	0.35036***	0.33112***	0.35310***	0.31962***
	0.055	0.055	0.055	0.055	0.055	0.055
IM1		0.45614***				0.43569***
		0.05				-0.05
AC*IM1		-2.06953***				-2.22291***
		0.249				-0.248
IM2			0.33967***			
			0.054			
AC*IM2			-1.47234***			
			0.267			
IM3				0.36049***		0.36605***
				0.054		0.054
AC*IM3				1.79646***		1.84131***
				0.277		0.277
IM4					0.24578***	
					0.066	
IM*IM4					1.22597***	
					0.34	
Const.	-0.11979	-0.23456***	-0.16759*	-0.33771***	-0.31479***	-0.44590***
	0.086	0.087	0.086	0.093	0.102	0.094
Pseudo R^2	0.05	0.054	0.052	0.053	0.051	0.057
F	251.062	217.349	212.617	220.459	211.143	197.656
N	10490	10490	10459	10490	10490	10490

***, **, * denote a significance level of 1%, 5% and 10% respectively

Table 3: AC effects

Dependent variable: INNOPROD

	I	II	III	IV	V	VI
	Coeff./S.E.	*Coeff./S.E.*	*Coeff./S.E.*	*Coeff./S.E.*	*Coeff./S.E.*	*Coeff./S.E.*
SMALL	0.01542	0.01471	0.017	0.03212	0.02331	0.03141
	0.042	0.042	0.042	0.043	0.042	0.043
MEDIUM	-0.01283	-0.01381	-0.01123	-0.00329	-0.00801	-0.00447
	0.042	0.042	0.042	0.043	0.042	0.043
EXPORT	0.27187***	0.26080***	0.27245***	0.27171***	0.27117***	0.26121***
	0.032	0.032	0.032	0.032	0.032	0.032
RDCONT	0.55727***	0.51537***	0.55466***	0.54835***	0.55020***	0.50793***
	0.029	0.03	0.029	0.029	0.029	0.03
RDEXT	0.16141***	0.15440***	0.16075***	0.14572***	0.15680***	0.13912***
	0.032	0.032	0.032	0.032	0.032	0.032
PROPAT	0.51628***	0.51338***	0.52602***	0.50239***	0.51085***	0.50002***
	0.035	0.035	0.035	0.035	0.035	0.035
AT	0.26164***	0.26293***	0.24763***	0.23859***	0.25623***	0.23965***
	0.055	0.055	0.055	0.056	0.056	0.056
AC	1.05900***	1.34422***	1.14006***	0.46443***	0.52267***	0.79010***
	0.075	0.098	0.088	0.119	0.155	0.135
INNOCOOP	0.21838***	0.20809***	0.20998***	0.20390***	0.21346***	0.19461***
	0.035	0.035	0.035	0.035	0.035	0.036
IM1		0.23030***				0.21921***
		0.028				0.028
AC*IM1		-0.74383***				-0.80859***
		0.145				0.147
IM2			0.11087***			
			0.031			
AC*IM2			-0.43118***			
			0.164			
IM3				0.15014***		0.14917***
				0.028		0.028
AC*IM3				0.97078***		0.95491***
				0.15		0.15
IM4					0.10731***	
					-0.033	
AC*IM4					0.69125***	
					-0.174	
Const.	-0.48553***	-0.55371***	-0.50610***	-0.57241***	-0.56733***	-0.63574***
	0.049	0.05	0.049	0.052	0.055	0.053
Pseudo R^2	0.153	0.161	0.156	0.158	0.155	0.165
Wald $\chi 2$	1789.66	1923.12	1841.86	1775.48	1787.85	1923.78
N	10151	10151	10120	10151	10151	10151

***, **, * denote a significance level of 1%, 5% and 10% respectively

Appendix

Table A1: Sample statistics

	Germany		*Italy*		*Spain*		*Total*	
Size	*Number*	*%*	*Number*	*%*	*Number*	*%*	*Number*	*%*
Small (0-49)*	765	33.51	1287	47.30	3019	55.03	5071	48.22
Medium (50-249)	763	33.42	954	35.06	1778	32.41	3495	33.24
Large (> 250)	755	33.07	480	17.64	689	12.56	1924	18.30
Total	*2283*	*100*	*2721*	*100*	*5486*	*100*	*10490*	*100*
NACE sector **	*Number*	*%*	*Number*	*%*	*Number*	*%*	*Number*	*%*
DA	145	6.35	226	8.31	649	11.83	1020	9.72
DB	105	4.60	215	7.90	302	5.50	622	5.93
DC	21	0.92	0	0.00	81	1.48	102	0.97
20_21	135	5.91	100	3.68	249	4.54	484	4.61
22	123	5.39	134	4.92	196	3.57	453	4.32
DF_DG	202	8.85	203	7.46	670	12.21	1075	10.25
DH	143	6.26	149	5.48	316	5.76	608	5.80
DI	91	3.99	179	6.58	353	6.43	623	5.94
27	91	3.99	131	4.81	164	2.99	386	3.68
28	286	12.53	399	14.66	534	9.73	1219	11.62
DK	277	12.13	331	12.16	661	12.05	1269	12.10
DL	422	18.48	362	13.30	614	11.19	1398	13.33
DM	140	6.13	163	5.99	340	6.20	643	6.13
DN	102	4.47	129	4.74	357	6.51	588	5.61
Total	*2283*	*100*	*2721*	*100*	*5486*	*100*	*10490*	*100*

* In Italy small firms are in-between 10 and 49 employees

** We excluded from our sample Italian firms belonging to the NACE rev 1.1 19 (i.e. DC) 20 (belonging to 20_21) and 23 (belonging to DF_DG), as for these sectors the anonymization process carried out by the Italian National Statistical Institute resulted in the aggregation of the medium and large firms into a unique dimensional class. We also excluded NACE 1.1 rev. 30 (belonging to DL) as it resulted in the aggregation of small, medium and large firms into a unique dimensional class.

Table A2: Variables description

Variable	Description	Obs	Mean	SD
AC	See section 3.1.1	10490	0.000	0.197
TURNINNO	% Turnover (2004) due to product innovations new to the market or firm (rescaled [0, 1])	10490	0.196	0.287
INNOPROD (D)	Introduced a product innovation	10151	0.575	0.494
RDCONT (D)	Engagement in continuous R&D	10490	0.481	0.500
RDEXT (D)	Acquisition of extramural R&D	10490	0.343	0.475
PROPAT (D)	Filed (at least one) patent application	10490	0.265	0.441
INNOCOOP (D)	Engagement in innovation cooperation agreements	10490	0.269	0.444
COOPFIRMNAT (D)	Coop. with national firms	10490	0.173	0.378
COOPFIRMFOR (D)	Coop. with foreign firms	10490	0.091	0.287
COOPORGNAT (D)	Coop. with national research organisations	10490	0.151	0.358
COOPORGFOR (D)	Coop. with foreign research organisations	10490	0.034	0.181
COOPGPNAT (D)	Coop. with national firms of the same group	10040	0.057	0.232
COOPGPFOR (D)	Coop. with foreign firms of the same group	10037	0.043	0.204
COOPSUPNAT (D)	Coop. with national suppliers	10076	0.105	0.307
COOPSUPFOR (D)	Coop. with foreign suppliers	10072	0.042	0.200
COOPCUSNAT (D)	Coop. with national customers	10108	0.080	0.271
COOPCUSFOR (D)	Coop. with foreign customers	10111	0.045	0.208
COOPCOMNAT (D)	Coop. with national competitors and firms in the same sectors	9947	0.044	0.205
COOPCOMFOR (D)	Coop. with foreign competitors and firms in the same sector	9950	0.023	0.150
COOPINSNAT (D)	Coop. with national, private research insitutes, commercial labs or consultants	9923	0.079	0.269
COOPINSFOR (D)	Coop. with foreign private research insitutes, commercial labs or consultants	9923	0.018	0.133
COOPUNINAT (D)	Coop. with national universities or higher education institutions	10187	0.116	0.320
COOPUNIFOR (D)	Coop. with foreign universities or higher education institutions	10171	0.022	0.146
COOPPUBNAT (D)	Coop. with national governments and public research institutes	10020	0.043	0.204
COOPPUBFOR (D)	Coop. with foreign governments and public research institutes	10005	0.008	0.089
AT (D)	Introduction of: 1) new or improved knowledge management system AND 2) major changes in work organisation AND 3) imrpoved marketing method	10490	0.079	0.270
IM1 (D)	Information from within the firm or the enterprise group highly relevant for the firm's innovation	10490	0.484	0.500
IM2 (D)	As IM1 AND high or medium production flexibility	10459	0.310	0.462
IM3 (D)	1) Presence of training programmes OR 2) No problems due to lack of qualified workers	10490	0.635	0.481
IM4 (D)	1) Presence of training programmes OR 2) No or low problems due to lack of qualified workers	10490	0.797	0.402
SMALL (D)	Less than 50 employees	10490	0.483	0.500
MEDIUM (D)	More than 49 and less than 250 employees	10490	0.333	0.471
EXPORT (D)	Export to foreign markets	10490	0.726	0.446

*: Defined on the period 2002-2004, unless differently specified
(D): dummy variable

Table A3: Correlations among main variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1													
2	0.1252*	1												
3	0.2665*	0.1675*	1											
4	0.246*	0.1132*	0.3115*	1										
5	0.2066*	0.1342*	0.2973*	0.2436*	1									
6	0.2833*	0.1286*	0.2831*	0.41*	0.2302*	1								
7	0.1312*	0.0708*	0.1071*	0.0869*	0.1204*	0.1044*	1							
8	0.1665*	0.0932*	0.2412*	0.1474*	0.1392*	0.164*	0.0445*	1						
9	0.209*	0.0927*	0.1722*	0.1161*	0.104*	0.1309*	0.077*	0.694*	1					
10	0.0415*	0.0637*	0.1225*	0.11*	0.1335*	0.114*	0.0888*	0.0701*	0.0734*	1				
11	0.0271*	0.0373*	0.1214*	0.0769*	0.1135*	0.0791*	0.0567*	0.0671*	0.0612*	0.6658*	1			
12	-0.1408*	0.0092	-0.2476*	-0.196*	-0.2272*	-0.165*	-0.0492*	-0.0921*	-0.0744*	-0.1218*	-0.1183*	1		
13	0.0314*	-0.0151	0.0713	0.0285*	-0.0027	0.0004	-0.0239	0.0183	0.0137	0.0188	0.0221	-0.6838	1	
14	0.1413*	0.049*	0.2774*	0.1792*	0.2117*	0.1595*	0.0354*	0.1285*	0.0915*	0.0474*	0.0521*	-0.295*	0.1603*	1

*: Significant at the 1% level

Legend: 1: AC, 2: TURNINNO, 3: RDCONT, 4: RDEXT, 5: PROPAT, 6: INNOCOOP, 7: AT, 8: IM1, 9: IM2, 10: IM3, 11: IM4, 12: SMALL, 13: MEDIUM, 14: EXPORT

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Abstract
The paper aims at extending the analysis of the firm's absorptive capacity (AC) by taking stock of its manifold nature. Innovation cooperation is recognised as one of its antecedents, along with R&D, but with different possible outcomes, depending on the kind of partner. Human capital is claimed to be as important as other organisational mechanisms for the AC impact on innovation. The empirical application, carried out on about 10,500 firms located in 3 EU countries (i.e. Germany, Italy and Spain), confirms the role of these factors. Interacting with research organisations, for example, increases the firm's AC providing it occurs within the national boundaries. The transformation of AC into actual innovation is favoured by the human capital of the firm, while it is actually hampered by socialisation mechanisms of an organisational nature.

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