Industry and Innovation
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ciai20

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Published online: 20 Aug 2014.

To cite this article: Chiara Franco, Alberto Marzucchi & Sandro Montresor (2014) Absorptive Capacity, Proximity in Cooperation and Integration Mechanisms. Empirical Evidence from CIS Data, Industry and Innovation, 21:4, 332-357, DOI: 10.1080/13662716.2014.942083

To link to this article: http://dx.doi.org/10.1080/13662716.2014.942083

Industry and Innovation, 2014
Vol. 21, No. 4, 332–357, http://dx.doi.org/10.1080/13662716.2014.942083

Research Paper

Absorptive Capacity, Proximity in Cooperation and Integration Mechanisms. Empirical Evidence from CIS Data

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ABSTRACT The paper extends available findings on the antecedents and impact of the firm's absorptive capacity. Innovation cooperation is recognized as a driver of its potential side (PAC). Considering different forms of proximity, we expect to find a higher impact for interactions occurring between close partners. Human capital (HC) is expected to be as important as other organizational mechanisms for the innovation impact of PAC. An empirical application with Community Innovation Survey data confirms these arguments only partially. The firm's cooperation with geographically closer partners (i.e., in the same country) increases its PAC, but it is cooperation with institutionally distant ones (e.g., research organizations) that augments it. Among the integration mechanisms of external knowledge, those increasing the firm's HC are the only ones that positively moderate the innovation impact of PAC.

KEY WORDS: Absorptive capacity, innovation cooperation, human capital

JEL Classification: O33, O32, J24

1. Introduction

In the past 20 years, the idea of absorptive capacity (AC) developed by Cohen and Levinthal (1989)—as the "firm's ability to identify, assimilate, and exploit knowledge from the environment" (569)—has attracted a great deal of attention. From a "black-boxed" by-product of the firm's R&D (its famous "second face"), AC has become an "open-box" of issues pertaining to different disciplines.

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Recent contributions have depicted AC as the result of a manifold learning process involving antecedents and competences of different kinds (Jansen, Van den Bosch, and Volberda 2005; Xia and Roper 2008; Fosfuri and Tribó 2008; Bogers and Lhuillery 2011). Zahra and George (2002), in particular, have drawn a seminal distinction between the firm's *potential absorptive capacity* (PAC) and its *realized absorptive capacity* (RAC) which has brought new AC mechanisms to the fore.

These mechanisms have been investigated by different research streams, such as strategic management, organization theory and, with a special standpoint, international business. As Volberda, Foss, and Lyles (2010) note in their literature review,[1] international business is in fact the field in which the concept appeared for the first time (Kedia and Bhagat 1988), even before Cohen and Levinthal (1989). Indeed, in the analysis of international technology transfer, the problem of absorbing external knowledge is made evident by two crucial issues on which a number of their reviewed papers have focused (e.g., Lyles and Salk 1996; Lane and Lubatkin 1998; Koza and Lewin 1999; Shenkar and Li 1999; Lane, Salk, and Lyles 2001; Minbaeva et al. 2003): the distance (or, alternatively, the proximity) between the knowledge source and the absorbing firm, which in the international case is macroscopic and the organizational mechanisms through which the recipient firm integrates, assimilates and exploits the absorbed external knowledge—mechanisms which international business studies evidence in the governance of multinational corporations (MNC).

In spite of their higher visibility in the international realm, these two issues have a general relevance to the analysis of AC which, however, the extant literature has largely failed to recognize. First, a firm's AC is affected not only by geographical proximity to the knowledge source but also by other kinds of proximity, which influence the processes of knowledge-exchange. Innovation studies, especially with a regional/urban focus, have widely shown this to be the case (Boschma 2005; Knoben and Oerlemans 2006). Second, organization, production and industrial relations studies have shown that irrespective of the complexity of the multinational organization, the transformation of external knowledge into actual innovation is helped by a nested set of integration mechanisms (IM), among which the training of the firm's workforce is essential (Vinding 2006; Tortoriello 2014).

The limited recognition of these two aspects in the AC literature represents the first research gap that the present study intends to fill by putting forward a number of hypotheses. A second gap addressed by the paper is the scarcity of systematic empirical applications in the AC literature, which mainly consists of in-depth field studies on specific sectors and/or technologies. In order to give these a wider external validity, we test our hypotheses by using the largest innovation data-set at the firm-level in Europe, i.e., the Community Innovation Survey (CIS). In particular, by considering the features of the available data, we carry out our analysis by pooling the CIS data-sets for Germany, Italy and Spain. Our study is not a cross-country comparison; rather, it aims to identify empirical regularities which hold true across the countries and sectors of the general sample.

The paper is organized as follows. Section 2 reviews the literature and puts forward our research hypotheses. Section 3 describes the data-set, the variables and the econometric

[1] Previous systematic surveys of the AC literature are scanty and include Lane, Koka, and Pathak (2006) and Zahra and George (2002).

strategy. Section 4 comments on the results. Section 5 concludes and draws some policy and strategic implications.

2. Theoretical Background

Among the various approaches to the analysis of AC (Volberda, Foss, and Lyles 2010), the present paper focuses on the "reconceptualization" provided by Zahra and George (2002) through their distinction between PAC and RAC. This distinction has yielded deeper understanding of the process through which the firm acquires and assimilates "external knowledge," and transforms the relative "assimilated knowledge" into innovation (on this research stream see Floyd and Lane 2000; Jansen, Van den Bosch, and Volberda 2005; Todorova and Durisin 2007; Lichtenthaler 2009). Following the recent re-examination of the distinction by Fosfuri and Tribó (2008), this process can be represented as in Figure 1(a) (adapted from them), which schematically reports the different antecedents and moderating factors of the two AC capacities.[2]

Of the various components of this conceptual construct, two deserve further theoretical scrutiny and empirical evidence. The analysis of their AC role has in fact been somewhat "marginalized" in international business studies to a stream of research developing its own autonomous retrospective exercises (e.g., Minbaeva et al. 2014). The first component is *innovation cooperation* and the *proximity* of the interacting partners. The second one is the set of IM on which the firm relies to transform the assimilated knowledge into innovation; in particular, those connected to the firm's human capital (HC). Figure 1(b) schematically represents the way in which we propose to re-address these two elements.

2.1 PAC and Innovation Cooperation: The Role of Proximity

AC is usually considered to be a determinant of a successful innovation *outcome* of cooperation (e.g., Cassiman and Veugelers 2002). Nevertheless, innovation cooperation is in general a PAC *antecedent*, irrespective of the cooperation's success. Searching for a partner in innovation, exchanging ideas with the candidates on the opportunity to cooperate and entering into a relationship of innovation cooperation can be deemed to have, per se, an impact on the firm's PAC. By enhancing exposure to and participation in a community of practice, innovation cooperation can boost the firm's capacity to develop routines for external knowledge search, as well as its capacity to recognize and adopt new technological developments (e.g., Cockburn and Henderson 1998; Fosfuri and Tribó 2008; Zahra and George 2002).

[2] PAC has been found to depend on four main within-the-firm antecedents: that is, its (i) R&D, as a cognitive facilitator of external knowledge; (ii) patents, as inventive efforts requiring acknowledgment of previous codified knowledge; (iii) human capital, as a "mosaic of individual capabilities" that combine into the organization's AC and (iv) the internal shocks that trigger the search for external knowledge (e.g., the adoption of new information systems). Two additional PAC antecedents are instead located outside the firm's boundaries: that is, contracted-out R&D and cooperation with external agents for the sake of innovation (e.g., R&D agreements). As for RAC, the "efficiency" with which PAC translates into it has been related to the presence of integration mechanisms in the organization (e.g., cross-functional interfaces) that moderate the innovation impact of PAC. See Figure 1.

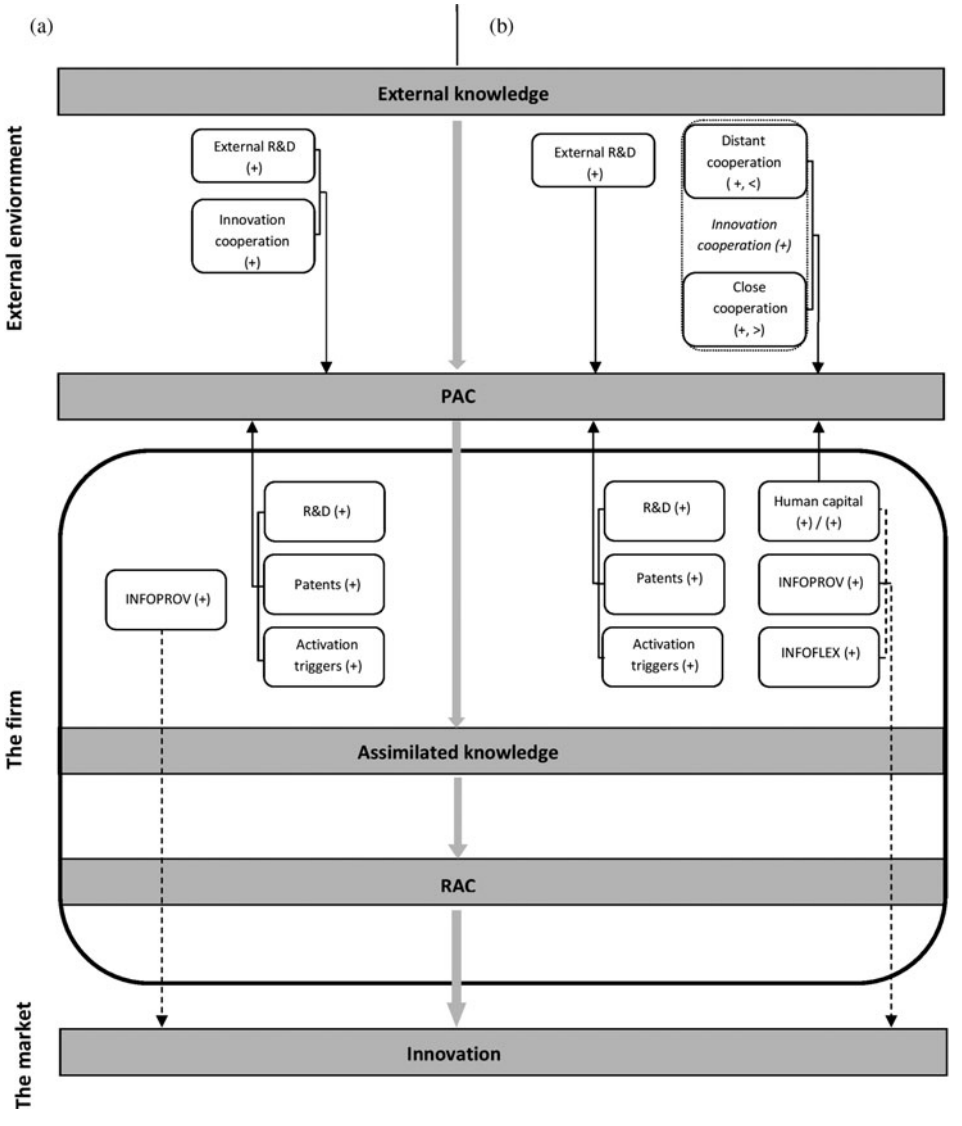

Figure 1. Solid lines denote direct effects; dashed lines denote PAC–innovation moderating effects. INFOPROV captures integration mechanisms based on information provision, while INFOFLEX denotes integration mechanisms based on information provision and flexibility in production (see Table A3 for a description of these variables). PAC antecedents are included also as controls in the innovation equation. (a) Standard model (adapted from Fosfuri and Tribó 2008) and (b) our model.

While apparently evident, the effect of innovation cooperation on PAC has been mainly examined in the specific literature on international joint venture (IJV). This shows how, by entering such a special cooperation agreement, firms develop the capacity to build different connections with different kinds of partners with which they could not connect before (e.g., distant firms and foreign universities) (e.g., Beamish and Berdrow 2003; Lin et al. 2012;

Fabrizio 2009). In this literature, the distance or *proximity* between the partners—in the specific case, their different nationalities—assumes a specific AC-enabling role. However, a role in building up the firm's PAC is also played by distances other than differences in the nationality of the partners. This appears evident if we consider the literature on knowledge diffusion, R&D spillovers and R&D partnerships (e.g., Breschi, Lissoni, and Malerba 2003; Hagedoorn and Van Kranenburg 2003), especially developed within innovation and regional/urban studies, on the basis of which we can construct our first set of hypotheses.

In general, one can easily argue that the closer (the more distant) is the partner with which the firm is cooperating, the higher (the lower) is the firm's capacity to directly assimilate and acquire the specific knowledge of this interacting partner. Nevertheless, "closer" is a rather general term because different forms of proximity should be considered (Boschma 2005; Knoben and Oerlemans 2006).

First, there is *geographical proximity*, simply defined as "the territorial, spatial, local or physical proximity" between the cooperating partners (Knoben and Oerlemans 2006, 73). Several contributions (Lane and Lubatkin 1998; Rosenkopf and Almeida 2003; Volberda, Foss, and Lyles 2010) lead us to argue that the search for and transfer of external knowledge is more PAC effective when firm's alliances and cooperation are "local." Geographical proximity enhances fundamental face-to-face interactions between the "student" firm and the "teacher" firm/organization, especially as far as tacit knowledge is concerned. Given that the diffusion of the latter occurs in an embodied way, distant cooperation would be in fact affected by higher transport and communication costs of the relative means. Furthermore, as urban and regional studies have largely shown following the Marshallian tradition, face-to-face interactions with physically close partners also increase mutual trust and make them socially embedded as well (Brusco 1982). This will attenuate the opportunistic behaviors that in the case of distant cooperation, relatively anonymous interacting partners may have an incentive to perpetuate. Our first hypothesis thus follows:

H1: Cooperating with geographically close partners increases the firm's PAC more than cooperating with geographically distant ones.

Besides geographical closeness, *institutional proximity* is another factor that affects the impact of cooperation on PAC. This form of proximity is broadly defined as the similarity of informal and formal rules, values, habits, incentives schemes and norms of conduct between the partners. It pertains not only to a country-level set of institutions but also to rules of conduct which are organization-specific (e.g., Boschma 2005; Ponds, Van Oort, and Frenken 2007). In particular, the overlapping of norms, values and operational priorities (e.g., relative to knowledge appropriation and diffusion) between the partners may trigger the capacity to understand and acquire external knowledge by equipping the parties with a compatible set of rules for the transfer. Conversely, distant interacting partners may have different sets of rules and incentives, the conflict between which may diminish the actual assimilation of external knowledge (Lyles and Salk 1996; Lane and Lubatkin 1998; Lane, Salk, and Lyles 2001). Accordingly, we can argue that:

H2: Cooperating with institutionally close partners increases the firm's PAC more than cooperating with institutionally distant ones.

Finally, an effect on PAC can be expected for the *cognitive proximity* between the partners, which is defined as "the similarities in the way actors perceive, interpret, understand and evaluate the world" (Knoben and Oerlemans 2006, 77). Cognitive proximity can be enhanced by the learning-by-interacting, sharing of technological problems and mutual understanding that occur, for instance, in user–producer interactions along the value chain (Lundvall 1992). Given the overlap between the parties' knowledge bases in these production relationships, we expect that a company will be more likely to learn from its partner (Lane and Lubatkin 1998; Lane, Salk, and Lyles 2001). Conversely, in cognitively distant cooperation, firms will less efficiently recognize and absorb external knowledge because it draws on principles and concepts that are different from their own (Rosenkopf and Almeida 2003). In other words, we expect that:

H3: Cooperating with cognitively close partners increases the firm's PAC more than cooperating with cognitively distant ones.

In regard to the network effects that the aforementioned forms of proximity are expected to enhance, they should increase not only the firm's capacity to assimilate the *specific* knowledge generated by its interacting partners but also the *general* knowledge deriving from actors other than those directly cooperating with it.

2.2 PAC and Innovation: Re-Addressing IM

The second aspect on which we refocus the attention is the set of IM on which the firm relies to transform its assimilated knowledge into actual innovation (Figure 1). Following Zahra and George (2002), we argue that this transformation also depends on the "efficiency" with which PAC is transformed into RAC. Although further factors affect the latter, the innovation impact of the former is at least informative of how efficient the "transformation ratio" has been, and thus from how much RAC the firm has been able to benefit. Again in accordance with Zahra and George (2002), and with subsequent applications, we retain the firm's IM as a factor *moderating* the innovation impact of PAC (Fosfuri and Tribó 2008, 178). We then propose two novel contributions to the investigation of IM. First, we extend the analysis of the managerial mechanisms of knowledge integration—as emerging from the debate on "organizational ambidexterity" (Mom, Van den Bosch, and Volberda 2007; Jansen et al. 2009)—with that of the flexible organizational arrangements emphasized by the studies on flexible production systems (Ono 1988; Schonberger 1982). Second, we combine "old" and new evidence on the IM functioning (e.g., Ebers and Maurer 2014) and point to training and human resource management (HRM) practices undertaken to increase the firm's HC as a further mechanism moderating the innovation impact of PAC, as illustrated in Figure 1(b).

As regards the first point, the extant AC literature has focused on quite dedicated (e.g., connectedness and socialization tactics) and specific (to certain sectors and/or companies) IM (Van den Bosch, Volberda, and de Boer 1999; Jansen, Van den Bosch, and Volberda 2005) which spread the externally absorbed knowledge within the organization, pushing it beyond its point of entry—e.g., a R&D lab—and overcome its "sticky" nature (von Hippel 1994; Szulanski 1996). These specific IM ease the organizational circulation of the externally acquired knowledge and enhance the firm's capacity to exploit it for innovation (Fosfuri and Tribó 2008). On considering a wider

spectrum of studies, and in particular the information-processing stream in the organizational design literature (Colombo, Foss, and Rossi-Lamastra 2013), we claim that the previous argument can be extended to more common forms of "information provision" within the firm. These are centrally devised policies and programs for internal information transfer (Lenox and King 2004), the evidence for which can be expected to be more pervasive.[3] We thus put forward the following hypothesis:

H4: Practices of information provision within the firm are a significant IM and positively moderate the innovation impact of PAC.

Whilst certainly important, central information provision may not be enough to integrate externally absorbed knowledge unless the recipient of such provision—that is, the firm's workforce—actively participates in its integration. This is another crucial insight emerging from studies on MNC, where HRM practices that incentivize workers to use the knowledge provided by the parent company are considered a factor that facilitates internal knowledge transfer (Minbaeva et al. 2003, 2014). Also in this respect, we claim that the underlying argument can be generalized. In particular, we expect that HRM motivating the workforce to use and diffuse newly acquired knowledge could be found in organizations inspired by a "flexible organizational logic," irrespectively of their international nature (MacDuffie 1995). In turn, this logic is likely to be common in firms that adopt flexible production systems in which the abatement of "buffers" of final and in-process inventories is such that workers are constantly required to identify and resolve problems "on-the-line" (Ono 1988; Schonberger 1982). Flexibility in production requires a variety of decentralized practices (e.g., employee involvement groups or quality circles), which can be expected to combine with centralized information provision and also ease the effective circulation of acquired knowledge. This would imply a positive moderation effect on the PAC–innovation relation, and thus leads to the following hypothesis:

H5: Flexibility in production combined with information provision within the firm is a significant IM and positively moderates the innovation impact of PAC.

Our second extension of the standard analysis of IM concerns the role of the firm's HC. Whilst supposedly important in building up the firm's PAC, the role of HC is possibly more evident in moderating the PAC–innovation relationship. Once again, this aspect has been mainly investigated in international business studies, which have shown that specific vocational programs are crucial for the capacity of the MNC subsidiary and/or the IJV participant to adopt and disseminate the new knowledge absorbed from foreign partners (Lyles and Salk 1996; Lane and Lubatkin 1998; Lane, Salk, and Lyles 2001). However, the role of HC in integrating externally absorbed knowledge can be claimed to be more general. With properly trained personnel, the value of the transmitted knowledge can be critically evaluated on an individual basis, understood and finally socialized, rather than being simply "dispersed." Accordingly, trained workers act as individual "guideposts" through which the stickiness that hampers the "central" diffusion

[3] These span from the simple use of information pamphlets and promotional brochures, through internal seminars on and demonstrations of the newly absorbed piece of knowledge, to liasons connecting different business units.

of newly acquired knowledge within the firm is overcome and the absorbed knowledge finds its way toward innovation (Lenox and King 2004). This is generally confirmed by several studies on the role of HC in increasing the firm's innovation potential and its economic performance (Huselid 1995; Delaney and Huselid 1996; Koch and McGrath 1996). More specifically, it is consistent with what more recent studies on the PAC–RAC distinction have found with regard to the role of training in fostering the firm's RAC by increasing relational embeddedness and relational empowerment (Ebers and Maurer 2014).

On the basis of the previous arguments, our final hypothesis states that:

H6: The presence of skilled personnel within the firm is a significant IM and positively moderates the innovation impact of its PAC.

3. Empirical Application

3.1 Data and Variables

We test our six hypotheses with respect to a sample of about 10,500 manufacturing firms from the 4th Community Innovation Survey (CIS4). Although the CIS4 is EU-wide, the application is limited to a more homogeneous subset of countries: Germany, Italy and Spain.[4] This subset still shows some differences. For example, Germany has more homogeneous shares of small and medium enterprises and large firms than Italy and Spain (Table A1). Differences are also noticeable with respect to some of our focal variables (Table A2). However, these dissimilarities do not harm our analysis; rather, they make it robust to cross-country differences. The majority of CIS4 variables refer to the period 2002–2004, or to the first and/or last year of this period, making the resulting data-set cross-sectional. This issue will have to be considered in interpreting our results.

As for the operationalization of the data-set, we define our first dependent variable as a proxy for the firm's PAC. Following Fosfuri and Tribó (2008), we build it in three steps. First, we run a factor analysis on the variables capturing the importance that the sample firms attribute to a number of external sources.[5] Using a polychoric correlation matrix, given the narrow-scale categorical variables at hand (Bartholomew et al. 2002), we then extract and normalize between 0 and 1, the factor EXTKNOW (Cronbach $\alpha = 0.779$).[6] This factor reflects two aspects of the firms surveyed: first, the extent to which the relative external knowledge is present in their environment; second, the extent to which it is intelligible to them. In order to "isolate" the first aspect, in the second step, we account for that part of

[4] There are two reasons for this choice. On the one hand, we concentrate on large countries, with information available for a significantly high number of innovative firms, leaving out for instance Belgium, Greece and Portugal. On the other hand, we focus on the countries relatively more homogeneous from an institutional point of view, excluding in particular EU late entrants (e.g., Czech Republic, Hungary, Bulgaria and Romania).

[5] Firms had to indicate, on a four-point Likert scale, the innovation relevance of: suppliers; customers; competitors; universities; consultants, commercial labs or private R&D institutes; government or public research institutes; professional conferences, trade fairs, meetings; scientific journals, trade/scientific publications and professional and industry associations.

[6] The Kaiser-Meyer-Olkin measure of sampling adequacy is 0.8360, confirming that our variables have enough in common to run a factor analysis.

EXTKNOW explained by the firm's location in specific sector and national systems of innovation (NSI), along with its belonging to an MNC,[7] which we proxy with simple dummies (COUNTRY, SECTOR and MNC, respectively). Accordingly, we run the following estimation:

$$\text{EXTKNOW}_i = \alpha + \beta_1 \text{COUNTRY}_i + \beta_2 \text{SECTOR}_i + \beta_3 \text{MNC}_i + \varepsilon_i. \quad (1)$$

In the third step, we define PAC as the residual (in econometric terms) explanation of EXTKNOW: that is, what explains the importance of external knowledge once pure reasons of knowledge availability have been accounted for:

$$\text{PAC} = \text{EXTKNOW}_i - [\hat{\alpha} + \hat{\beta}_1 \text{COUNTRY}_i + \hat{\beta}_2 \text{SECTOR}_i + \hat{\beta}_3 \text{MNC}_i]. \quad (2)$$

The second dependent variable that we need to investigate the PAC impact is related to the firm's innovation performance, INNO. Given our interest in the actual innovative exploitation of external knowledge by the firm, we first refer to the economic output of innovation: in particular, the share of turnover (from 0 to 1) due to the introduction of product innovations new to both the market and the firm (TURNINNO). Further elements of analysis are then obtained by using an alternative dependent variable: a dummy capturing whether a firm introduced new or significantly improved goods (INNOPROD).

Turning to our independent variables, the "standard" ones that the literature has identified as PAC antecedents (Figure 1) are proxied as reported in Table A3 by crossing the extant literature with data availability.[8] As for our focal regressors in H1, 2 and 3, the firm's innovation cooperation is at first captured with a dummy, INNOCOOP. Cooperation in the presence (absence) of *geographical* proximity is proxied with a dummy for the focal firm doing it within (across), COOPNAT (COOPFOR), its national boundaries. Note that COOPNAT (COOPFOR) also accounts for cooperation in the presence (absence) of country-specific formal and informal norms, that is, of a *macro-institutional* kind of proximity.

Considering the distinctive set of incentives and behavioral rules, the firm's cooperation with close or distant *micro-institutional* partners is proxied by its collaborations with, respectively, other firms in the business realm, COOPFIRM, and with research organizations in the world of science, COOPORG. Finally, given the entailed sharing of technological problems, *cognitive* proximity in cooperation is assumed higher (lower) for interactions with partners along (outside) the firm's value chain—that is, suppliers and customers—COOPCHAIN (rather than partners other than suppliers and customers, COOPNOCHAIN).

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[7] The reference to MNC is an extension of Fosfuri and Tribó (2008), who consider only geographical and sectoral dummies, and tries to incorporate the results of international business studies (e.g., Minbaeva et al. 2003; Phene and Almeida 2008).

[8] It should be noticed that we do not use the continuous variables for R&D expenditures available in the CIS4 data-set. Indeed, unlike the dummies for the engagement in continuous R&D, which refer to the entire period (2002–2004), the continuous variables for the same phenomenon refer only to the year 2004, and are thus more exposed to the risk of reverse causality with respect to the dependent variables such as PAC and INNOPROD, which also refer to the 3-year period (2002–2004). Furthermore, we include RDCONT, instead of another dummy for general engagement in R&D, given that this latter might capture also trivial investments not able to stimulate the creation/accumulation of AC.

As for the variables in H4, 5 and 6, we proceed as follows. With the dummy INFOPROV, we elicit the presence of information provision practices by considering whether, as a possible reason for their adoption, the firm considers internal information flows (within its boundaries or within its business group) to be of high importance for innovation. Capturing the evidence of organizational flexibility in the firm, INFOFLEX adds to the previous specification the recognition by the company of high levels of flexibility in production and/or service provision. Finally, in the absence of more accurate information, the firm's HC is proxied with a dummy combining two different aspects. In particular, it takes value 1 if the firm either reports training programs as an innovation enabler or does not consider the lack of skilled workers to be an innovation obstacle.[9]

The list of regressors is closed by a suitable array of controls and by a list of sector and country dummies. These filter out the possible interference of institutional specificities which might be nested in the analysis of the PAC antecedents and impact. The specification of these variables and the descriptive statistics for the whole sample are provided in Table A3. Table A4 reports pair-wise correlations coefficients.

3.2 Econometric Strategy

We start by estimating Equation (1) with an ordinary least squares (OLS) model.[10] The PAC antecedents are then investigated by running a set of OLS regressions of the following model:

$$\text{PAC}_i = \alpha + \beta_1 \text{INNOCOOP}_i + \beta_2 \text{CTRL}_i + \varepsilon_i, \tag{3}$$

where the relevant variables and controls (CTRL) are defined in Table A3.

In order to test H1, 2 and 3, we integrate the estimate of Equation (3) based on INNOCOOP (Model I) first with an alternative model for geographical (and macro-institutional) proximity in cooperation (Model II), which replaces INNOCOOP with COOPNAT and COOPFOR. Micro-institutional proximity in cooperation is first captured, in Model III, by using COOPFIRM and COOPORG instead of INNOCOOP, and then integrated, in Model IV, with the geographical (and macro-institutional) one by using four combined regressors (see Table A3): COOPFIRMNAT, COOPORGNAT, COOPFIRMFOR and COOPORGFOR. Model V assesses the role of cognitive proximity by substituting INNOCOOP for COOPCHAIN and COOPNOCHAIN. Finally, Model VI integrates cognitive and geographical (and macro-institutional) proximity by estimating Equation (3) with four combined variables (see Table A3): COOPCHAINNAT, COOPNOCHAINNAT, COOPCHAINFOR and COOPNOCHAINFOR.

[9] The same variable is used as PAC antecedent. As a robustness check we also employed an alternative measure of HC. This is a dummy variable taking value 1 if there is: (1) presence of training programs or (2) no or *low* problems due to a lack of skilled workers. The original variable is operationalized by considering only the absence of a skilled personnel shortage, while this alternative HC includes also low problems related to the lack of skilled workers. The results, not reported in the paper but available upon request, are extremely robust.

[10] Given the particular distribution of EXTKNOW—which shows a (relatively low) concentration around 0—and the sort of censoring that we introduce by normalizing it in-between 0 and 1, as a robustness check, Equation (1) is also estimated with a Tobit model. On re-estimating all of our models (Tables 1–3) with the alternative measurement of PAC, obtained through a Tobit regression, the coefficients of the PAC antecedents and PAC impacts are very similar in both significance and sign (the results are available from the authors on request).

For the second part of our empirical analysis, we estimate the following econometric model[11]:

$$\mathrm{INNO}_i = \alpha + \beta_1 \mathrm{PAC}_i + \beta_2 \mathrm{IM}_i + \beta_3 \mathrm{PAC}_i \times \mathrm{IM}_i + \beta_4 \mathrm{CTRL}_i + \varepsilon_i, \quad (4)$$

where the relevant variables and controls (CTRL) are defined in Table A3.

In the first set of estimates of Equation (4), we capture innovation performance (INNO) with TURNINNO. We follow Laursen and Salter (2006) and account for its skewness by employing a logarithmic transformation of it, that is: lnTURNINNO = ln(1 + TURNINNO*100). Furthermore, because 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 estimated Equation (4) with a Tobit. When INNOPROD is used as dependent variable instead, given its binary nature, Equation (4) is estimated with a Probit procedure.

In order to test for H4, 5 and 6, we integrate the baseline model (Model I) —with no interaction terms—and first re-estimate Equation (4) by plugging into it the additive and PAC-moderating role of INFOPROV (Model II), INFOFLEX (Model III) and HC (Model IV), respectively. The combined role of INFOPROV (INFOFLEX) and HC is then considered in Model V (Model VI).[12]

4. Results

4.1 PAC Antecedents

As Table 1 shows, nearly all the PAC "standard" determinants that we employ as controls prove to be significant and with the expected signs in all the relevant models. A notable exception is represented by the firm's HC, which negatively correlates with PAC and is a result hard to interpret. However, the specific nature of both the dependent variable—i.e., the firm's capacity to bring new external knowledge within its boundaries, rather than transforming it into innovation—and of the proxy that we used—training programs directed to innovation, rather than to external interactions—could account for a result which is reversed when we look at the PAC effect on innovation (Tables 2 and 3).[13]

Turning to our hypotheses, we observe that the role of INNOCOOP as PAC antecedent (Model I) is strengthened by the fact that, in the following five models, innovation cooperation increases it at whatever distance the partner is located.[14] However, as our hypotheses suggest, the proximity of the partners plays a role in the extent to which this happens. First of all, geographical proximity increases the PAC effect of innovation cooperation. In Model II, the coefficient of COOPNAT is higher than that of COOPFOR,

[11] It should be noted that the "residual" way in which we obtained our measurement of PAC might create a problem of multicollinearity. Accordingly, a Variance Inflation Factor (VIF) test is employed. The VIF values excludes multicollinearity issues.

[12] Given that INFOFLEX is "nested" in INFOPROV, their simultaneous consideration, with and without that of HC, would lead to uninterpretable results and are thus not considered.

[13] Following the "attention-based view" of the firm (Ocasio 1997), we could argue that the training efforts of the firm may clash with, and in our case even crowd-out, those directed to absorb external knowledge.

[14] The only exception is cooperation with foreign partners located outside the value chain (COOPNOCHAINFOR).

Table 1. PAC antecedents

	Dependent variable: PAC					
	I	II	III	IV	V	VI
RDCONT	0.06812*** (0.004)	0.06730*** (0.004)	0.06647*** (0.004)	0.06682*** (0.004)	0.06722*** (0.004)	0.06687*** (0.004)
RDEXT	0.04384*** (0.004)	0.04407*** (0.004)	0.04148*** (0.004)	0.04128*** (0.004)	0.04324*** (0.004)	0.04266*** (0.004)
PROPAT	0.04244*** (0.005)	0.04419*** (0.005)	0.04231*** (0.005)	0.04345*** (0.005)	0.04300*** (0.005)	0.04300*** (0.005)
IAT	0.05459*** (0.007)	0.05833*** (0.007)	0.05636*** (0.007)	0.05703*** (0.007)	0.05762*** (0.007)	0.05752*** (0.007)
HC	−0.00921** (0.004)	−0.00906** (0.004)	−0.00931** (0.004)	−0.00968** (0.004)	−0.00981** (0.004)	−0.00968** (0.004)
INNOCOOP	0.08052*** (0.005)					
COOPNAT		0.06940*** (0.006)				
COOPFOR		0.03762*** (0.007)				
COOPFIRM			0.03982*** (0.006)			
COOPORG			0.08529*** (0.006)			
COOPFIRMNAT				0.04229*** (0.006)		
COOPORGNAT				0.07670*** (0.007)		
COOPFIRMFOR				0.01499* (0.008)		
COOPORGFOR				0.02152* (0.012)		
COOPCHAIN					0.05703*** (0.006)	
COOPNOCHAIN					0.05740*** (0.006)	
COOPCHAINNAT						0.04008*** (0.007)
COOPNOCHAINNAT						0.06585*** (0.006)
COOPCHAINFOR						0.04212*** (0.009)
COOPNOCHAINFOR						−0.00564 (0.009)

(*Continued*)

Table 1. (*Continued*)

	Dependent variable: PAC					
	I	II	III	IV	V	VI
SMALL	−0.01237** (0.006)	−0.01370** (0.006)	−0.01230** (0.006)	−0.01205** (0.006)	−0.01299** (0.006)	−0.01289** (0.006)
MEDIUM	−0.00435 (0.005)	−0.00644 (0.006)	−0.00495 (0.006)	−0.00447 (0.006)	−0.00566 (0.006)	−0.00516 (0.006)
EXPORT	0.01994*** (0.004)	0.01797*** (0.004)	0.01849*** (0.004)	0.01756*** (0.004)	0.01794*** (0.004)	0.01706*** (0.004)
Cons.	−0.03303*** (0.011)	−0.02850*** (0.011)	−0.02866*** (0.011)	−0.02775** (0.011)	−0.02875*** (0.011)	−0.02663** (0.011)
R^2	0.162	0.162	0.174	0.167	0.167	0.164
F	85.23***	79.66***	89.99***	76.80***	84.85***	74.82***
N	10,490	10,074	10,171	9,907	10,163	9,944

***, ** and * denote a significance level of 1 per cent, 5 per cent and 10 per cent respectively; robust standard errors in brackets; all models include country and sector dummies; sector and country dummies are jointly significant at the 1-per cent level.

Table 2. PAC effects

	Dependent variable: lnTURNINNO					
	I	II	III	IV	V	VI
RDCONT	0.90446*** (0.054)	0.83177*** (0.053)	0.90253*** (0.058)	0.87519*** (0.054)	0.80431*** (0.054)	0.87463*** (0.058)
RDEXT	0.21463*** (0.051)	0.20651*** (0.05)	0.21087*** (0.059)	0.17778*** (0.051)	0.16964*** (0.051)	0.17417*** (0.059)
PROPAT	0.67834*** (0.051)	0.66438*** (0.05)	0.68490*** (0.056)	0.65788*** (0.051)	0.64491*** (0.05)	0.66412*** (0.057)
IAT	0.49170*** (0.072)	0.48529*** (0.071)	0.47416*** (0.067)	0.43362*** (0.072)	0.42678*** (0.071)	0.42162*** (0.068)
PAC	2.18587*** (0.145)	3.11407*** (0.187)	2.29238*** (0.141)	1.01762*** (0.247)	1.96493*** (0.271)	1.16138*** (0.217)
INNOCOOP	0.30636*** (0.054)	0.30182*** (0.054)	0.29740*** (0.056)	0.27761*** (0.053)	0.27412*** (0.053)	0.26954*** (0.056)
INFOPROV		0.41173*** (0.053)			0.39456*** (0.054)	
INFOPROV*PAC		−2.08710*** (0.241)			−2.19548*** (0.242)	
INFOFLEX			0.23875*** (0.075)			0.20927*** (0.075)
INFOFLEX*PAC			−1.02231*** (0.323)			−1.20726*** (0.321)
HC				0.36302*** (0.053)	0.36113*** (0.052)	0.35218*** (0.053)
HC*PAC				1.75965*** (0.251)	1.81681*** (0.255)	1.75675*** (0.27)
SMALL	0.25845*** (0.06)	0.27433*** (0.059)	0.26824*** (0.078)	0.27711*** (0.059)	0.29266*** (0.059)	0.28602*** (0.078)
MEDIUM	0.10424* (0.059)	0.11054* (0.058)	0.11551* (0.068)	0.11437* (0.058)	0.12029** (0.058)	0.12505* (0.067)
EXPORT	0.17491** (0.069)	0.15740** (0.069)	0.17597*** (0.067)	0.16156** (0.069)	0.14463** (0.069)	0.16286** (0.067)
Cons.	−0.0787 (0.145)	−0.23574 (0.148)	−0.10548 (0.175)	−0.28198* (0.15)	−0.42984*** (0.153)	−0.29552* (0.175)
Pseudo R^2	0.057	0.061	0.058	0.06	0.064	0.061
Wald χ^2	3,020.71***	3,131.23***	2,928.22***	3,500.82***	3,652.66***	3,325.99***
N	10,490	10,490	10,459	10,490	10,490	10,459

***, ** and * denote a significance level of 1 per cent, 5 per cent and 10 per cent respectively; all models include country and sector dummies; Bootstrapped SE (200 repetitions) in brackets; sector and country dummies are jointly significant at the 1-per cent level.

Table 3. PAC effects

	Dependent variable: INNOPROD					
	I	II	III	IV	V	VI
RDCONT	0.47190*** (0.032)	0.43949*** (0.032)	0.47631*** (0.027)	0.45884*** (0.031)	0.42802*** (0.032)	0.46384*** (0.028)
RDEXT	0.13039*** (0.032)	0.12741*** (0.033)	0.13155*** (0.03)	0.11171*** (0.033)	0.10914*** (0.033)	0.11310*** (0.03)
PROPAT	0.48498*** (0.039)	0.48041*** (0.039)	0.49426*** (0.037)	0.47313*** (0.039)	0.46911*** (0.039)	0.48206*** (0.038)
IAT	0.27813*** (0.053)	0.27925*** (0.053)	0.26899*** (0.058)	0.24910*** (0.055)	0.25047*** (0.054)	0.24264*** (0.059)
PAC	1.19723*** (0.083)	1.47030*** (0.107)	1.21064*** (0.079)	0.60598*** (0.126)	0.90937*** (0.143)	0.64264*** (0.133)
INNOCOOP	0.17835*** (0.037)	0.17389*** (0.037)	0.17394*** (0.035)	0.16337*** (0.037)	0.15971*** (0.038)	0.15971*** (0.036)
INFOPROV		0.20038*** (0.028)			0.18902*** (0.028)	
INFOPROV*PAC		−0.71778*** (0.135)			−0.77126*** (0.136)	
INFOFLEX			0.03339 (0.041)			0.01659 (0.041)
INFOFLEX*PAC			−0.16873 (0.222)			−0.26864 (0.223)
HC				0.18052*** (0.029)	0.17662*** (0.029)	0.17499*** (0.031)
HC*PAC				0.97370*** (0.145)	0.96694*** (0.144)	0.96183*** (0.168)
SMALL	−0.05298 (0.045)	−0.04645 (0.045)	−0.05069 (0.04)	−0.04234 (0.045)	−0.03613 (0.045)	−0.04071 (0.04)
MEDIUM	−0.03669 (0.042)	−0.03489 (0.042)	−0.03326 (0.042)	−0.02979 (0.042)	−0.02828 (0.042)	−0.02689 (0.043)
EXPORT	0.21592*** (0.034)	0.20933*** (0.034)	0.21733*** (0.035)	0.21014*** (0.034)	0.20410*** (0.034)	0.21173*** (0.034)
Cons.	−0.61485*** (0.078)	−0.69658*** (0.08)	−0.62343*** (0.077)	−0.71912*** (0.081)	−0.79404*** (0.083)	−0.72078*** (0.077)
Pseudo R^2	0.168	0.174	0.17	0.174	0.179	0.175
Wald χ^2	2,401.83***	2,534.00***	2,117.34***	2,391.27***	2,576.27***	2,248.31***
N	10,151	10,151	10,120	10,151	10,151	10,120

***, ** and * denote a significance level of 1 per cent, 5 per cent and 10 per cent respectively; all models include country and sector dummies; Bootstrapped SE (200 repetitions) in brackets; sector and country dummies are jointly significant at the 1-per cent level.

providing a first item of evidence in favor of H1.[15] Furthermore, in regard to the macro-institutional proximity that COOPNAT entails, Model II also appears to confirm the NSI argument (Lundvall 1992).

Model III shows that COOPORG triggers PAC more than COOPFIRM and thus contradicts our H2. While possibly more difficult to coordinate than business-to-business cooperation, industry-research cooperation adds more to the firm's capacity to acquire external knowledge. The link with the world of science possibly enriches not only the content of external knowledge—that is, the "knowing what" of the outer environment—but also the procedures adopted to search for it—that is, the "knowing how." We should take another aspect into account. Cooperation between firms and research organizations is arguably characterized by a "denser" knowledge exchange than are interactions among firms. Indeed, the latter involve commercially valuable knowledge, or they occur between partners operating in the same markets. They may thus be hindered by imbalances of power, appropriability issues and free-riding problems (e.g., Cassiman and Veugelers 2002; Veugelers and Cassiman 2005).

In Model IV, cooperating with the same "micro-institutional" kind of partner within the national borders triggers the effect on PAC more than cooperating across them does, which gives further support to H1: the coefficients of COOPORGNAT and COOPFIRMNAT are higher than those of COOPORGFOR and COOPFIRMFOR, respectively. However, COOPORGNAT and COOPORGFOR have a higher PAC effect than COOPFIRMNAT and COOPFIRMFOR, respectively. While supporting the NSI, these results strengthen our argument concerning the effect on PAC of industry-research cooperation. The challenge posed by the institutional distance between firms and research partners helps the firm to develop stronger external search routines. Furthermore, research organizations may provide the firm with a link to the world of science, whose learning effects more than off-set possible coordination problems (Youtie and Shapira 2008).

Model V shows that cognitive proximity per se does not perform a PAC enhancing role: although positively significant, the coefficients of COOPCHAIN and COOPNOCHAIN are in fact not significantly different. User–producer interactions along the same value chain do not significantly increase the impact of cooperation on PAC: H3 is not supported. However, Model VI shows that cognitive proximity matters when combined with the geographical and institutional proximity determined by the nationality of the partner. First, when the lack of cognitive proximity is exacerbated by institutional and geographical distance, as happens with foreign partners outside the focal firm's value chain, innovation cooperation does not help its PAC (COOPNOCHAINFOR is nonsignificant). Second, cognitive proximity mitigates the aforementioned hindering role of crossing national borders, making COOPCHAINFOR and COOPCHAINNAT not significantly different. Finally, when cooperation occurs with higher institutional and geographical proximity at the country level, cognitive dissimilarity may create external knowledge search skills which impact on PAC more than do those acquired by interacting with cognitively closer but foreign partners: COOPNOCHAINNAT has a larger impact than COOPCHAINFOR.[16]

[15] A formal *F*-test confirms that the two coefficients are different at 1-per cent level of significance. Statistically tested differences also hold in the following comparisons of coefficients, unless differently stated.

[16] *F*-test confirms that the estimated coefficients are actually different at 5-per cent level of significance.

All in all, we conclude that geographical and macro-institutional proximity due to cooperation within national borders increases the positive effect of cooperation. By contrast, it is the micro-institutional distance between research organizations and business actors that increases the PAC impact of INNOCOOP. Cognitive proximity mitigates the hindering effect of cooperating across national borders. Nevertheless, in a context of geographical and macro-institutional proximity, cognitive diversity helps increase the positive effect of cooperation on PAC.

4.2 PAC and Innovation

When lnTURNINNO is used as dependent variable, Table 2 shows that in the baseline model (Model I), PAC has a significant and positive effect on the firm's innovation performance. The same holds for the same firm-level controls that we used to investigate its antecedents, which were expected to have a direct innovation effect as well.[17]

Turning to the other models, a series of likelihood ratio tests reveals that the inclusion of each and every interaction term that we use to test our hypotheses significantly (at the 1-per cent level) add to the predictive capacity of the econometric models.[18] To start with, Model II shows that INFOPROV increases firm's innovation per se, but negatively moderates the innovation impact of PAC and induces us to reject H4. A significantly negative moderation effect also emerges for INFOFLEX, although INFOFLEX has per se a positive direct effect as well. Although also H5 is rejected, we should however point out that, in its absolute value, the coefficient of the interaction term INFOFLEX*PAC in Model III is significantly lower than that of INFOPROV*PAC in Model II.[19] While not "saving" our hypothesis, this suggests that flexibility in production somehow attenuates the negative moderating effect of information provision. In spite of this qualification, however, the negative coefficients of the interactions between INFOPROV and INFOFLEX, on the one hand, and PAC on the other, are quite challenging and require consideration. One possible interpretation could be that the process of knowledge "socialization," which passes through the firm's organizational structure and organizational practices (e.g., Nonaka and Takeuchi 1995) as proxied by INFOPROV and INFOFLEX, may have drawbacks in terms of knowledge transformation: that is, the process could cause a "dispersion" of the external knowledge that the PAC allows the firm to absorb. In the absence of further safeguards, the organizational assimilation, combination and transformation of this absorbed 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 synthesize 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" (Galunic and Rodan 1998, 1198, *Proposition 3*).

[17] This is particularly the case of RDCONT, RDEXT, PROPAT, IAT and INNOCOOP.

[18] Given the nonlinear nature of the Tobit model, we could not analyze the increase in the R^2. Therefore, we employ the STATA command "nestreg" to compare models with and without PAC interactions.

[19] The difference between the two coefficients is significant when estimating the two models with the Stata's "suest" procedure, followed by a test of equality of parameters. The hypothesis of difference among the two coefficients is supported at the 1-per cent level of significance.

To conclude the analysis of INFOPROV and INFOFLEX, let us notice that their negative moderating effects only impoverish the transformation of PAC into innovation, but they do not make it completely "inefficient." The overall PAC impact, given its positive direct effect on innovation, does not vanish completely, even with the drawbacks of information provision and flexibility practices.[20]

In Model IV, not only does the firm's HC increase its innovation outcome, as expected, it also works efficiently in transforming PAC into innovation. The interaction between PAC and HC is significantly positive and supports our H6.

This is a final interesting result of our application. It is especially so when combined with the fact that, in both Models V and VI, the coefficients for HC are such that they more than compensate for the deterioration of the PAC innovation impact exerted, in the relative interactions, by INFOPROV and INFOFLEX, respectively.[21]

Taking into account the negative evidence that we obtained for HC as a PAC antecedent, and the positive evidence for its PAC moderation function, its role in the firm's AC requires careful consideration. The experience accumulated by the employees increases the firm's knowledge and, through it, its innovation outcomes. However, it does not help the firm in bringing new external knowledge within its boundaries because its PAC appears to be a process in need of organizational resources which training practices may even crowd-out. Rather, the firm's HC serves to complete the internal absorption of external knowledge—that is, to realize its potential.

To conclude the analysis of the innovation impact on PAC, we have carried out three robustness checks. First, we have checked for the presence of a selection bias by re-estimating Models I–IV with a series of Heckman selection models.[22] In the selection equation, estimated for all the available observations, the dependent variable is a dummy for the introduction of either a new good or service. The outcome equation is restricted to the firms that have introduced a new good or service and uses lnTURNINNO as dependent variable. Maximum likelihood estimations, with the same set of covariates in both the selection and outcome equations, reveal that the hypothesis that the selection and outcome parts of the models are independent is never rejected (results are available upon request) and make our Tobit estimations robust.

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[20] Following Wiersema and Bowen (2009), we calculate the "correct" marginal effect of PAC and of its interactions with INFOPROV and INFOFLEX. We consider the moderating dummy variables INFOPROV and INFOFLEX at their two possible values 0 and 1, and all the other variables at their means. The marginal effects of the interaction terms are then calculated as the differences between the value at INFOPROV (or INFOFLEX) = 1 and INFOPROV (or INFOFLEX) = 0. In Models II and III, the marginal effects of PAC and of its INFOPROV(INFOFLEX)-interactions on lnTURNINNO (i.e., $\partial E(y|x)/\partial x$, for which see Cameron and Trivedi 2009) are, respectively: 1.50 (PAC) and −1.36 (INFOPROV*PAC), in Model II; 1.53 (PAC) and −0.67 (INFOFLEX*PAC), in Model III. Hence, the overall "net" effect of PAC on innovation performance is positive also in those cases in which the relevant integration mechanisms are in place (i.e., INFOPROV or INFOFLEX are equal to 1).

[21] Still according to Wiersema and Bowen (2009), in Model V (Model VI), the marginal effects of PAC and of its interaction with INFOPROV and HC (INFOFLEX and HC) on lnTURNINNO (i.e., $\partial E(y|x)/\partial x$, for which see Cameron and Trivedi 2009) are, respectively: 1.46 (PAC), −1.45 (INFOPROV*PAC) and 1.38 (HC*PAC), in Model V; 1.50 (PAC), −0.82 (INFOFLEX*PAC) and 1.33 (HC*PAC), in Model VI.

[22] This is done because, given the structure of the CIS questionnaire, TURNINNO is in principle observable only for innovative firms (i.e., those that introduced a new or improved good or service).

As a second robustness check, we have re-estimated Equation (4) by using, with a Probit, INNOPROD as a dependent variable. The results, reported in Table 3, further confirm the robustness of those based on lnTURNINNO.[23]

As a third robustness check, drawing on Laursen and Salter (2014), we have adopted a seemingly unrelated estimations approach to take into account that the firm's PAC enhancing strategies are closely related to those for the transformation of PAC into innovation. Put briefly, when computing the standard errors, this approach estimates the simultaneous covariance of the coefficients emerging from the baseline model employed for the PAC-antecedents analysis and each specification employed in the PAC-impact models (Models I–IV, Tables 2 and 3). The results, available upon request, are still extremely robust.[24]

5. Conclusions

The paper has analyzed the antecedents of the firm's PAC and its impact on the firm's innovation. As an original contribution to the extant literature, we have addressed two crucial aspects whose analysis has been somewhat marginalized in international business studies. On the one hand, we have re-examined the role of innovation cooperation in triggering the firm's capacity to scan and assimilate external knowledge, putting a novel focus on the manifold proximity between the firm and its partners. On the other hand, we have re-analyzed the moderating effect that the firm's IM exert on the transformation of PAC into innovation, putting a novel emphasis on the role of HC.

The empirical application that we have carried out on a large sample of firms in three European countries has confirmed the basic results of the standard (P)AC literature. But it has also yielded some unexpected results. In particular, the firm's HC does not emerge as a PAC driver, and may even crowd out other organizational antecedents of the firm's PAC.

Original results have emerged with respect to the PAC antecedent role of cooperation by disentangling the manifold proximity between cooperating partners. The geographical and macro-institutional proximity characterizing the interactions between national partners increases the PAC effect of cooperation. By contrast, the micro-institutional proximity of cooperating partners, which share similar incentives and behavioral schemes, reduces it. Whilst this micro-institutional diversity may generate coordination problems, it may also stimulate positive learning-by-interactive effects. The PAC benefits accruing to firms from cooperating with the world of science is the case that we find in this latter respect.

The policy and strategic implications of these results are of extreme importance. NSI still appear to have a role in the innovation realm because they represent a cooperation-enhancing environment. However, support for innovation cooperation and the open innovation mode should carefully retain the nature of the relevant partners: in particular, the role of "innovation-hubs" played by research organizations is crucial for the firm's PAC.

Also the analysis of the innovation impact of PAC has yielded interesting new insights. Those IM which previous studies have found to be important for the so-called "socialization"

[23] Although INFOFLEX and INFOFLEX*PAC are now not significant, given that the coefficient of INFOPROV*PAC is always significantly negative, we can still say that flexibility practices attenuate the negative moderating effect of information provision.

[24] In the presence of nonlinear models for the analysis of the PAC innovation impact (i.e., Tobit and Probit) we cannot implement a seemingly unrelated regression approach. We instead adopt the "suest" procedure in Stata.

of external knowledge have not appeared to operate in our empirical application. On the contrary, their side-effect in terms of "knowledge dispersion" within the firm has been found even to depress the innovation impact of PAC. The effects of PAC in terms of innovation instead depend on other IM more closely related to the firm's HC, which thus requires attention as support for the firm's AC. On the one hand, on-the-job training initiatives also have a "second face" in terms of moderating the innovation impact of AC. On the other hand, the investment of public resources to foster training receives an additional justification and becomes twice as important for fostering innovation and growth.

While these are the most substantial added values of the paper, when compared with previous works using a similar methodology (e.g., Fosfuri and Tribó 2008), we have introduced further elements of originality at the methodological level: for instance, through a more refined and articulated method to obtain a measure of PAC. On the other hand, the paper is not free from limitations, to whose solution future research will be devoted. In particular, using the available CIS data, our application is a cross-sectional one and requires caution in interpreting the results as correlations, rather than as causal relationships. The use of longitudinal data, possibly coming from the availability of more CIS waves, would remedy this limitation, enabling us fully to consider the problem of endogeneity of some variables like cooperation.

Acknowledgements

Previous versions of this work have been presented at the 18th AISSEC Scientific Conference, Macerata (Italy); 8th ENEF Meeting, Strasbourg (France); 2011 Concord Conference, Seville (Spain); 2011 EAEPE Conference, Vienna (Austria); 2011 International Workshop on "Clusters in Global Value Chains/Production Networks: What is the role of innovation systems?", San Sebastian (Spain). We are really grateful to the participants of these events for their stimulating questions and comments. We thank Pablo D'Este, Massimiliano Mazzanti, Francesco Rentocchini, Giovanni Cerulli, Sean Kask and three anonymous referees for their valuable suggestions. Usual caveats apply.

The views expressed are purely those of the authors and may not in any circumstance be regarded as stating an official position of the European Commission.

Funding

All three authors gratefully acknowledge the financial support by the Autonomous Province of Trento, as the sponsor of the OPENLOC research project under the call for proposals Major Projects 2006.

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Appendix

Table A1. Sample statistics by country

	Germany		Italy		Spain		Total	
Size	Number	%	Number	%	Number	%	Number	%
Small (0–49)[a]	765	33.51	1,287	47.30	3,019	55.03	5,071	48.22
Medium (50–249)	763	33.42	954	35.06	1,778	32.41	3,495	33.24
Large (>250)	755	33.07	480	17.64	689	12.56	1,924	18.30
Total	2,283	100	2,721	100	5,486	100	10,490	100
NACE sector[b]	Number	%	Number	%	Number	%	Number	%
DA	145	6.35	226	8.31	649	11.83	1,020	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	1,075	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	1,219	11.62
DK	277	12.13	331	12.16	661	12.05	1,269	12.10
DL	422	18.48	362	13.30	614	11.19	1,398	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	2,283	100	2,721	100	5,486	100	10,490	100

[a] In Italy, small firms are in-between 10 and 49 employees.

[b] 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), because 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 single size class. We also excluded NACE rev 1.1 30 (belonging to DL) because it resulted in the aggregation of small, medium and large firms into a single size class.

Table A2. Descriptive statistics of main variables by country

	PAC	SMALL	MEDIUM	EXPORT	RDCONT	RDEXT	IAT	INNOCOOP	PROPAT	HC	INFOPROV	INFOFLEX	TURNINNO	INNOPROD
Italy														
N	2,721	2,721	2,721	2,721	2,721	2,721	2,721	2,721	2,721	2,721	2,721	2,690	2,721	2,721
Mean	8.51E-11	0.4730	0.3506	0.7273	0.4634	0.2870	0.0882	0.1713	0.2609	0.5303	0.3705	0.0952	0.1743	0.5413
SD	0.1700	0.4994	0.4772	0.4454	0.4988	0.4525	0.2836	0.3768	0.4392	0.4992	0.4830	0.2935	0.2611	0.4984
Min	−0.3514	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	0.6309	1	1	1	1	1	1	1	1	1	1	1	1	1
Spain														
N	5,486	5,486	5,486	5,486	5,486	5,486	5,486	5,486	5,486	5,486	5,486	5,486	5,486	5,486
Mean	−4.88E-10	0.5503	0.3241	0.7419	0.4954	0.3711	0.0767	0.3035	0.2062	0.5769	0.5368	0.1571	0.2126	0.6023
SD	0.2034	0.4975	0.4681	0.4376	0.5000	0.4832	0.2662	0.4598	0.4046	0.4941	0.4987	0.3640	0.3177	0.4895
Min	−0.3903	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	0.7120	1	1	1	1	1	1	1	1	1	1	1	1	1
Germany														
N	2,283	2,283	2,283	2,283	2,283	2,283	2,283	2,283	2,283	2,283	2,283	2,283	2,283	1,944
Mean	−6.88E-10	0.3351	0.3342	0.6864	0.4656	0.3425	0.0745	0.3040	0.4122	0.9006	0.4915	0.1323	0.1826	0.5468
SD	0.2111	0.4721	0.4718	0.4641	0.4989	0.4747	0.2626	0.4601	0.4923	0.2993	0.5000	0.3389	0.2306	0.4979
Min	−0.4168	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	0.6202	1	1	1	1	1	1	1	1	1	1	1	1	1

Table A3. Variables description

Variable	Description	Obs	Mean	SD
PAC	See Section 3.1	10,490	0.0000	0.197
TURNINNO	Share (from 0 to 1) of turnover (2004) due to product innovations new to the market or firm	10,490	0.1962	0.2869
INNOPROD (D)	Introduced a new or significantly improved good	10,151	0.5753	0.4943
RDCONT (D)	Engagement in continuous R&D	10,490	0.4806	0.4996
RDEXT (D)	Acquisition of extramural R&D	10,490	0.3431	0.4748
PROPAT (D)	Filed (at least one) patent application	10,490	0.2652	0.4415
INNOCOOP (D)	Engagement in innovation cooperation agreements	10,490	0.2693	0.4436
COOPFIRMNAT (D)	Coop. with national firms	10,256	0.1769	0.3816
COOPORGNAT (D)	Coop. with national research organizations	10,243	0.1542	0.3611
COOPFIRMFOR (D)	Coop. with foreign firms	10,081	0.0944	0.2924
COOPORGFOR (D)	Coop. with foreign research organizations	9,951	0.0356	0.1852
COOPNAT (D)	Coop. with national firms and national research organization	10,362	0.2305	0.4211
COOPFOR (D)	Coop. with foreign firms and foreign research organization	10,101	0.1040	0.3052
COOPFIRM (D)	Coop. with national and foreign firms	10,299	0.2018	0.4013
COOPORG (D)	Coop. with national and foreign research organization	10,261	0.1599	0.3666
COOPCHAIN (D)	Coop. with firms that are suppliers and customers	10,214	0.1586	0.3653
COOPNOCHAIN (D)	Coop. with firms other than suppliers and customers and research organizations	10,338	0.2059	0.4044
COOPCHAINNAT (D)	Coop. with national firms that are suppliers and customers	10,192	0.1396	0.3466
COOPNOCHAINNAT (D)	Coop. with national firms other than suppliers and customers and national research organizations	10,302	0.1882	0.3909
COOPCHAINFOR (D)	Coop. with foreign suppliers and customers	10,069	0.0700	0.2552
COOPNOCHAINFOR (D)	Coop. with foreign firms other than suppliers and customers and foreign research organizations	10,043	0.0746	0.2627
IAT (D)	Introduction of: (1) new or improved knowledge management system AND (2) major changes in work organization AND (3) improved marketing method	10,490	0.0792	0.2701
INFOPROV (D)	Information from within the firm or the enterprise group highly relevant for the firm's innovation	10,490	0.4838	0.4998
INFOFLEX (D)	Information from within the firm or the enterprise group highly relevant for the firm's innovation AND HIGH production flexibility	10,459	0.1358	0.3426
HC (D)	(1) Presence of training programs OR (2) No problems due to lack of qualified workers	10,490	0.6353	0.4814
SMALL (D)	Less than 50 employees	10,490	0.4834	0.4997
MEDIUM (D)	More than 49 and less than 250 employees	10,490	0.3332	0.4714
EXPORT (D)	Export to foreign markets	10,490	0.7260	0.4460

Note: Defined on the period 2002–2004, unless differently specified; (D), dummy variable.

Table A4. Pair-wise correlations among relevant variables

	PAC	INNOPROD	SMALL	MEDIUM	EXPORT	RCONT	RDEXT	IAT	INNOCOOP	PROPAT	HC	INFOPROV	INFOFLEX	TURNINNO
PAC	1													
INNOPROD	0.2717*	1												
SMALL	−0.1408*	−0.1322*	1											
MEDIUM	0.0314*	0.0384*	−0.6838*	1										
EXPORT	0.1413*	0.2117*	−0.295*	0.1603*	1									
RDCONT	0.2665*	0.3373*	−0.2476*	0.0713*	0.2774*	1								
RDEXT	0.246*	0.2163*	−0.196*	0.0285*	0.1792*	0.3115*	1							
IAT	0.1312*	0.1054*	−0.0492*	−0.0239	0.0354*	0.1071*	0.0869*	1						
INNOCOOP	0.2833*	0.2169*	−0.165*	0.0004	0.1595*	0.2831*	0.41*	0.1044*	1					
PROPAT	0.2066*	0.2693*	−0.2272*	−0.0027	0.2117*	0.2973*	0.2436*	0.1204*	0.2302*	1				
HC	0.0415*	0.1062*	−0.1218*	0.0188	0.0474*	0.1225*	0.11*	0.0888*	0.114*	0.1335*	1			
INFOPROV	0.1665*	0.1912*	−0.0921*	0.0183	0.1285*	0.2412*	0.1474*	0.0445*	0.164*	0.1392*	0.0701*	1		
INFOFLEX	0.1366*	0.0627*	−0.0362*	0.0027	0.046*	0.0821*	0.0657*	0.0662*	0.0716*	0.0416*	0.059*	0.4107*	1	
TURNINNO	0.1252*	0.4662*	0.0092	−0.0151	0.049*	0.1675*	0.1132*	0.0708*	0.1286*	0.1342*	0.0637*	0.0932*	0.0598*	1

*Significant at the 1-per cent level.