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The "potential" face of absorptive capacity. An empirical investigation for an area of 3 European countries *

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Abstract

This paper draws on the multi-dimensional characterization of absorptive capacity (AC) to empirically investigate the antecedents and the effects of its "potential" dimension (PAC): i.e., the firm's capacity of acquiring and assimilating external knowledge, as distinguished from its "realized" transformation and exploitation (RAC). Based on a sample of about 10,500 firms for an area of 3 EU countries (Italy, Germany and Spain) we find that the firm's reliance on external knowledge in general increases its PAC, and that this effect is magnified by the internal shocks the firm faces. However, both these effects find relevant exceptions when different kinds of external sources are considered, at different kinds of distance from the absorbing firm. Unexpectedly, social integration mechanisms in the firm makes PAC less, rather than more, inductive of innovation outcomes. On the contrary, the human capital of the firm has a positive moderating role on the PAC effects. A possible trade-off in the exploitation of the externally assimilated knowledge is suggested.

JEL Classification: O31;O33;
Key-words: absorptive capacity; external knowledge; innovation.

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1 Introduction

Since the seminal work by Cohen and Levinthal (1989), the "complementarity" between internal and external knowledge has been found to be crucial for firms' innovation by several empirical studies (e.g. Cassiman and Veugelers, 2006; Lichtenthaler, 2009). At the same time, their seminal idea of *absorptive capacity* (AC), defined as the "firm's ability to identify, assimilate, and exploit knowledge from the environment" (Cohen and Levinthal, 1989, p.569), has evolved in its theoretical stance. From a quite "black-boxed" by-product of the firm's R&D (i.e. its second "face"), to an "open-box" of issues pertaining to different organizational theories, which have enriched its meaning (for a critical review, see Volberda et al. (2010)). Among these, Zahra and George (2002) inaugurated a research stream, which places AC in the arena of the firm's dynamic capabilities (Teece and Pisano, 1994) and looks at it as a multidimensional capability of organizational learning and innovating.

The present paper sets in this research stream. We start from the distinction Zahra and George (2002) introduce between *Potential Absorptive Capacity* (PAC) – amounting to the firm's capacities of "acquiring" and "assimilating" newly relevant external knowledge – and *Realized Absorptive Capacity* (RAC) – constituted by the capacities of "transforming" and "exploiting" it, and thus obtaining an innovation.

We then investigate PAC antecedents and effects. First of all, drawing on international business studies (e.g. Phene and Almeida, 2008), we argue that the multinational ownership of the firm should be considered as an important factor determining the firm exposition to external knowledge. Second, we suggest that experience of external knowledge interaction is an important PAC antecedent, depending on the kind of external source: as established by innovation diffusion and R&D spillover studies (e.g. Boschma, 2005; Breschi et al., 2003). Third, following the literature on organizational learning and managerial cognition (e.g. Lenox and King, 2004), we claim that those internal "shocks" which trigger the firm's search for problem-solving activities outside its boundaries (Zahra and George, 2002, p.193) have a moderating role on PAC, which is dependent on the specific source of external knowledge too. Finally, we turn to the factors which moderate the innovation impact or efficiency of the PAC transformation into RAC (Zahra and George, 2002, p.194). We test the standard hypothesis that the socialization of external knowledge, which stems from pervasive interactions among organization members, should be a positive efficiency factor. We contrast it with the effect that the firm's human capital can have on the same transformation (Vinding, 2006).

We formulate these arguments into hypotheses and test them using a sample of about 10,500 firms located in 3 EU countries (Italy, Germany

and Spain). For these firms we have detailed information about innovation activities from the 4^{th} Community Innovation Survey (CIS), during the period 2002-2004. Although cross-sectional, compared to recent empirical studies using the same source, our dataset is wider (Escribano et al., 2009), for example, is longitudinal, but for one country only) and more updated (Grimpe and Sofka, 2009), for example, refers to 13 EU countries, but for the previous CIS-3 wave).

Our contribution to the debate on the issue is twofold. On the one hand, we try to fill some of the "research gaps" which can be found in the literature (on which see Volberda et al. (2010)): in particular, we address the different PAC impact of different external knowledge sources. On the other hand, we attempt at drawing some policy and managerial implications from a number of hypotheses which have been up to know mainly confined to theoretical organization studies.

The remainder of the paper is organized as follows. Section 2 introduces the theoretical framework and translates it into hypotheses. Section 3 describes the dataset, the relevant variables and the econometric strategy. Section 4 reports the results of the empirical analysis. Section 5 concludes.

2 Theoretical background

Innovation requires firms to undertake a complex process of new knowledge generation, in which internal efforts – such as, for example, R&D investments – are complemented by external sourcing – such as, for example, R&D cooperation agreements (Cassiman and Veugelers, 2002, 2006).

This complementarity has been found to depend on different factors.[1] A special role among them has been recognized to what Cohen and Levinthal (1989), more than 20 years ago, called the firm's "capacity" to "absorb" external knowledge for the sake of innovation: in brief, *Absorptive Capacity* (AC). In turn, AC has been found to have a "multidimensional" nature, that is: different constitutive capacities (e.g. Zahra and George, 2002; Todorova and Durisin, 2007), temporal dimensions (e.g. Van den Bosch et al., 1999) and specifications with respect to both the kind of absorbing firm and of external provider (e.g. Lane et al., 2001; Lim, 2009). This result has challenging implications. On the one hand, it enables the researcher to disaggregate

[1] In particular, the kind of knowledge-interactions firms establish with their external partners (e.g. Tödtling et al., 2009; Frenz and Ietto-Gillies, 2009; Kang and Kang, 2009) and the intra- and inter-organizational aspects which affect the firms' capacity of managing external knowledge (e.g. Chesbrough et al., 2006; Laursen and Salter, 2006; Van de Vrande et al., 2009).

the AC analysis and have a deeper understanding of its antecedents and outcomes. On the other hand, it risks to make the concept "reified" (Lane et al., 2006), depriving its analysis of useful managerial and policy implications.

In dealing with this sort of trade-off, in the following we start from the most established "multi-conceptualization" of AC – which distinguishes it into Potential Absorptive Capacity (PAC) and Realized Absorptive Capacity (RAC) (Zahra and George, 2002) – and try to add some missing aspects to its operationalization.

2.1 PAC and RAC: a resume

According to Zahra and George (2002), *Potential Absorptive Capacity* (PAC) refers to the initial *momentum* of the firms' sourcing of external knowledge for innovation. First of all, it encompasses the firm's capacity to search for the location of the relevant knowledge. As the empirical evidence suggests, this search does not occur in a vacuum and is, at least initially, a local process (Nelson and Winter, 1977; Rosenkopf and Almeida, 2003). In neo-Schumpeterian terms, innovation search takes place within those sector- and geographic-specific systems of innovation in which firms are located (Freeman, 2008). In this kind of "environment", the sourcing firm has to identify which are the relevant providers and eventually which is(are) the most suitable one(s). In both respects, previously generated knowledge, typically through in-house R&D, provides the firm with a sort of "background", with which the recognition of external partners is easier than from scratch (e.g. Shane, 2000). Furthermore, the same task is enabled by its prior experience of *learning processes*. Both in general, that acquired through its innovation history, and in particular, that accumulated through prior interactions with external knowledge sources. All in all, these are the antecedents of a capacity that Zahra and George (2002) call *acquisition capacity*, which is the first PAC dimension.

Once the relevant partner has been chosen, the innovative firm needs to understand to which extent the relevant external knowledge is also useful to its innovation project. In order to do that, the firm has to classify, organize and compare the inner contents of the external knowledge. Indeed, this task requires to the firm what Zahra and George (2002) call *assimilation capacity*, that is the second PAC dimension, whose antecedents are also in the firm's experiential learning (Fosfuri and Tribó, 2008, p.175). This "assimilated knowledge" is the knowledge which the firm could "potentially" turn into an innovation, that is the outcome of a *Potential Absorptive Capacity* (PAC). As we said, its antecedents can be found in the firm's previous experience of external learning. However, the organizational setting in which the

firm operates should be considered too. Developing the capacity to absorb external knowledge could be urged, for example, by a change in the firm's strategy, following which it might end up competing in an unfamiliar market. More in general, the development of PAC could be magnified by the pressure of other kinds of organizational changes (such as, for example, the introduction of new information systems), which might make the previously assimilated knowledge "obsolete" (Zahra and George, 2002). Accordingly, these changes could be considered "Internal Activation Triggers" (IAT) for PAC (Fosfuri and Tribó, 2008, p.175).

In Zahra and George (2002), the second *momentum* of the firm's absorptive process is called *Realized Absorptive Capacity* (RAC). First of all, the firm has to combine and integrate the assimilated knowledge with that generated (and available) internally. In order to do that, the firm should establish operative connections and labour mobility between its internal organization units (such as, for example, multi-functional groups) and those of the partner(s) (such as join-ventures and partnerships). In general, firms need to rely on what Fosfuri and Tribó (2008) call "Social Integration Mechanisms" (SIM), through which the newly acquired knowledge gets embedded in the organization. A task that Zahra and George (2002) consider dependent on the first RAC dimension, called *transformation capacity*. Second, the firm is required to obtain from this (innovation) "viable knowledge" an economically viable new product (or process). In order to do that, it has to use its "complementary assets" (Teece, 1986) and capabilities other than R&D ones. As is well-known in Schumpeterian economics, this is a further transformation, whose outcome impinges on the second RAC capacity, that is the firm's *exploitation capacity*. All in all, the outcome of these two RAC dimensions is what the firm actually realizes of its potential. Accordingly, the more "efficient" is this transformation, the higher is the firm's innovation outcome.

In a synthetic way (schematized in Figure 1), that is how the dynamic capabilities view of AC suggested by Zahra and George (2002) works. As Lane et al. (2006) argue, this conceptualization is not free from limitations.[2] However, it has the advantage to provide a schematic representation of the complex construct of (external and internal) capabilities and (meta)routines AC consists of (for a more comprehensive analysis of it, see Lewin et al. (2011)). Indeed, in its illustration, the main antecedents and outcomes of the *PAC-RAC* construct have emerged. On this basis, a number of hypotheses can be put forward and tested. A task to which previous empirical works

[2]The process could admit different specifications and amendments. Furthermore, its sequence could not be linear, and rather depends on the co-evolution of the firm's absorptive capacity and its knowledge environment (Van den Bosch et al., 1999; Lim, 2009).

have been dedicated and to which our own tries to bring some new interpretative elements (e.g. Fosfuri and Tribó, 2008; Jansen et al., 2005).

2.2 Hypotheses

The first set of hypotheses concerns the antecedents of PAC, as distinguished from the RAC antecedents (on their possible trade-off, see Zahra and George (2002)). As we said, PAC is set at work by the firm on the external knowledge sources it is exposed to, being part of sector- and geographic- specific systems of innovation.

In Fosfuri and Tribó (2008), this twofold innovative location is treated as the determinant of the firms' external knowledge base, to which the PAC-RAC construct then applies (we will illustrate that in Section 3.2). While sticking to this approach, we also encapsulate in it the firm's location in an organizational environment, which makes the firm more *exposed* to (international) knowledge sources, namely in a Multinational Corporation (MNC). Indeed, as has been largely recognized by international business studies (e.g. Minbaeva et al., 2003; Phene and Almeida, 2008), a MNC structure makes available to the firm the knowledge of other subsidiaries and (eventually) of the parent company, both in the same and in other countries, whose absorption requires qualified interactions, on which we will focus in the following. Accordingly, we state the following introductory lemma:

Lemma: *Participation to MNCs is a significant determinant of the firm exposition to external knowledge, along with the participation to sector- and geographic-specific systems of innovation.*

The first hypothesis about the PAC antecedents is the most expected one: the very famous "second face" of R&D (Cohen and Levinthal, 1989). By investing in R&D, not only does the firm enlarge its knowledge base. But it also shrinks the cognitive distance from other firms and external organizations. This holds particularly true when the firm engages in continuous R&D efforts in-house, through dedicated organizational divisions – in brief, intramural R&D efforts. On the other hand, extramural R&D, while increasing the firm's experience of external learning, might create to it problems of "knowledge leakage" and innovation appropriability, so that its expected PAC impact is ambiguous.

HP1: *Intramural R&D efforts have a positive impact on the level of PAC.*

The second hypothesis refers to the firm's *learning experience*. First of all, that acquired by engaging in innovation, through which the firm gradually stores the relative competences in organizational routines and meta-routines (Cohen and Bacdayan, 1994; Becker and Zirpoli, 2008). In particular, the

degree to which these competencies can be retrieved by the firm is the higher – also in front of external sources – the more its innovative projects are based on codified knowledge: for example, databases, user manuals and, above all, patents. This is not to say that knowledge codification necessarily leads to higher innovativeness (on this debated issue see, for example, Jensen et al. (2007). Rather, the codification process itself can be retained to increase the assimilation and retention of new external knowledge. For example, by reducing "causal ambiguity" and overcoming information asymmetries (Garcia-Muiña et al., 2009). In the specific case of patenting, this learning effect applies to external knowledge insofar the application process requires the firm to be aware of, and eventually quote, other patents and/or other codified pieces of knowledge. These arguments are at the basis of our second hypothesis (as we will see, similar, but not identical to that by Fosfuri and Tribó (2008) (p. 177, HP2)).

HP2: *Patenting has a positive impact on the level of PAC.*

Learning experience of *external* knowledge as such is of course very important for PAC too. A positive impact on PAC of the firm's interaction with external knowledge sources would appear guaranteed (as the HP1 by Fosfuri and Tribó (2008) (p. 177)). However, empirical evidence suggests us to be cautious with that (e.g. Bierly III et al., 2009), pointing to its dependence on the kind of firm's knowledge base and of the external provider (e.g. Carayannopoulos and Auster, 2010; Tortoriello and Krackhardt, 2010). As the literature on knowledge diffusion and R&D spillovers has extensively shown (e.g. Boschma, 2005; Breschi et al., 2003), different external knowledge sources are placed at different distances (or "proximity") from the absorbing firm. Both in geographical terms – i.e. on the territory – and in organizational terms – i.e. with respect to the firm's boundaries – if not even in "economic-production" terms – i.e. along the value chains which eventually connect them (e.g. Franco et al., 2011). All these distances have been found to matter for the firm's assimilation process, to the point of inhibiting it, when the two knowledge sources are too dissonant.

HP3: *Interaction with external knowledge sources has an impact on the level of PAC, which depends on the kind of source.*

As we said in Section 2.1, possible organizational changes can be claimed to increase the firm's resort to external knowledge sources and thus positively "moderate" the PAC impact of the previous antecedents (what Fosfuri and Tribó (2008) call "Internal Activation Triggers" (p.177)). However, this can not be taken for granted either, and rather seems to us also conditional, in particular on the kind of knowledge source. For example, if the absorbing firm and the external provider are rival in a certain innovation project and/or competitors

on some markets, organizational shocks might lead the former to refrain from interacting with the latter for their solution. As we will see, the so-called "Non-Invented-Here" syndrome (NHS)[3] might interfere with this hypothesis, which we thus state as follows:

HP4: *Internal activation triggers moderate the PAC effects of external knowledge interaction, in a way which depends on the kind of source.*

The last set of hypotheses focus on the degree to which PAC gets transformed into RAC, and thus into an actual innovation outcome. The standard view is that such a transformation depends on the firm's capacity of making external knowledge circulate across its information filters and through its organizational codes (Henderson and Clark, 1990), and finally assimilate it in its organizational routines (Zahra and George, 2002; Fosfuri and Tribó, 2008). The role of such organizational capabilities as "connectedness and socialization tactics" (Jansen et al., 2005, p. 999) should thus lead us to conclude that the presence of "Social Integration Mechanisms" (SIM) within the firm – in the form of organizational devices which create linkages among organization members (e.g., a cross-divisional quality circle) – favor the level of RAC, exactly as in Fosfuri and Tribó (2008) (p.178).

HP5: *SIMs positively moderate the impact of PAC on innovation performance, and thus the level of RAC.*

Along with this organizational view of the PAC-RAC transformation, we here consider also another perspective, which makes it dependent on "individual" capabilities. In particular, those which emanate from the education and skills of the workers and managers of the firm, their motivation and experience, as proxied by the firm's practices of Human-Resources-Management (HRM) (e.g. Vinding, 2006; Minbaeva et al., 2003; Volberda et al., 2010). The basic idea is that the actual assimilation of external knowledge passes through its embodiment in the competences of the workers and that their human capital is also conducive of its circulation and exploitation.

HP6: *Human capital positively moderates the impact of PAC on innovation performance, and thus the level of RAC.*

[3]In brief, the fact that the employees of a firm resist external knowledge when it conflicts with its organizational routines and culture, or even more when it is seen to remedy to the problems entailed by the latter (Katz and Allen, 1982).

3 Empirical application

3.1 Data

The previous hypotheses are tested with respect to a sample of about 10,500 manufacturing firms, based in an area of 3 European countries, that is Germany, Italy and Spain. The relative dataset has been built up by using anonymised data from the 4^{th} Community Innovation Survey (CIS), which uses an harmonized questionnaire across 16 countries.[4] However, the focus on this portion of the CIS dataset (hereafter EU3) has been motivated by the attempt of testing the 6 hypotheses of the paper on a relative more homogeneous set of countries, from both an economic and an innovation point of view. The distribution of firms by country, sector and size is as in Table 5. Given our interest for the identified European area as a whole, the evident biases in the distributions are not a relevant problem.

In addition to firms' general characteristics, the CIS4 includes detailed information on several dimensions of the innovation process, such as: (i) product and process innovations; (ii) innovative inputs and expenditures; (iii) public funding; (iv) sources of information; (v) cooperation agreements; (vi) effects of innovation; (vii) hampering factors; (viii) intellectual propriety rights; (ix) organizational and marketing innovation; (x) effects of organizational innovation. In particular, the CIS is extremely detailed on the kind of partnerships one firm has established through cooperation agreements for innovation (sub v). The majority of these variables refer to the period 2002-2004. 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.[5]

[4] As far as the anonymisation of the data is concerned, Eurostat micro-aggregates the data. The resulting database consists of the same number of units as kept in the original database. Artificial units are created by replacing original values by the mean (for quantitative variables) or mode value (for qualitative variables) within clusters of three observations formed of individuals of "maximum similarity" (i.e. with the nearest value). The variables in the original dataset are micro-aggregated independently of each other (i.e. clusters are established separately for each specific variable).

[5] In order to have the complete range of variables, for all the observations in our dataset, we have decided to drop those ones with unexpected missing values and those related to firms that had not to fill the entire questionnaire: i.e., those companies that in the period 2002-2004 did not introduce any product or process innovations and did not carry out any innovation activities.

3.2 Variables

3.2.1 Dependent variables

The key dependent variable of the empirical application is PAC. For its construction we follow the multi-step procedure suggested by Fosfuri and Tribó (2008). At first, we look at the importance EU3 firms attribute to a number of sources of external knowledge for their innovation and run a factor analysis to extract a variable, $EXTKNOW$, which accounts for the relevance of external knowledge as a whole.

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[6] 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 normalized to vary between 0 and 1.[7]

Following the Lemma of Section 2.2, we then retain $EXTKNOW$ as explained, at first, by the firm's location in specific sector and national systems of innovation, along with the eventual belonging to a MNC, which we tentatively proxy with simple dummies (respectively, $COUNTRIES$, $SECTORS$, and MNC). Accordingly, we run the following estimation:

$$EXTKNOW = a + bCOUNTRIES + cSECTORS + dMNC + \epsilon \quad (1)$$

where a is the constant and ϵ the error term.

Finally, we define PAC as the residual (of course, only in econometric terms) explanation of $EXTKNOW$. That is, as what explains the importance of external knowledge sources, once pure reasons of knowledge availability have been accounted for. Indeed, what is left should be explained by the firm's capacity of acquiring and assimilating the external knowledge to which it is exposed:

$$PAC = EXTKNOW - [\hat{a} + \hat{b}COUNTRIES + \hat{c}SECTORS + \hat{d}MNC] \quad (2)$$

[6] Firms had to indicate, on a 4-point Likert scale, the extent to which each of the following knowledge sources has been relevant for their innovation activities: (i) sources within the enterprise or the enterprise group; (ii) suppliers; (iii) clients; (iv) competitors; (v) universities; (vi) consultants, commercial labs or private R&D institutes; (vii) government or public research institutes; (viii) professional conferences, trade fairs, meetings; (ix) scientific journals, trade/scientific publications; (x) professional and industry associations.

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

where $\hat{a}$, $\hat{b}$, $\hat{c}$, and $\hat{d}$ are the estimated coefficients of Equation 1.

Given the way it has been built up, PAC refers to the firm's (potential) capacity of absorbing external knowledge from whatever kind of source, without distinguishing the relative weight of that originating from one rather than another. In the light of that, disaggregating by source the analysis of the firm's external interactions, and of their PAC-impact – as we suggest in HP3 and HP4 – amounts to admitting that the firm's knowledge interaction with a certain source x (e.g. a competitor) might also increase its knowledge absorbed from another source y (e.g. a customer), in addition to x. Apparently, this is inconsistent with the standard "learning-by-interacting" logic, which would support either an aggregated kind of analysis – as in (Fosfuri and Tribó, 2008) – or a completely disaggregated one – i.e. of the role of knowledge interaction with x (y) for the absorption of x (y) generated knowledge. However, our "aggregated-disaggregated" approach is motivated by a system idea of the innovation process and by a network view of the underlying knowledge flows. In this approach, a certain firm can also "absorb" the knowledge of a certain source y by interacting with x, if x in turn has the possibility of interacting with y. In our previous example, the firm might increase the knowledge available at one of its customers by interacting with one of its competitors, in the non unfrequent 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, unless the investigated firms are completely isolated nodes and the network extremely fragmented. Still, even in these exceptional cases, our approach could be motivated by the search of specific knowledge interactions, which might have general learning effects: in other words, by the search for what can be assimilated to "knowledge-brokers" (Pawlowski and Robey, 2004; Hargadon, 1998) and "knowledge-innovation hubs" (Youtie and Shapira, 2008).

Whereas PAC is the dependent variable in the first set of regressions, aimed at testing the first 4 hypotheses, for the second set of 2 hypotheses we need a variable of innovation performance. As we are interested in the actual innovative exploitation of external knowledge, at first we use a commercial output of innovation: that is, the percentage of turnover due to the introduction of innovations, both new to the market and to the firm, $TURNINNO$.

Further elements of analysis are then obtained by using a variable of marketable, rather than commercial, output: that is, a dummy capturing whether a firm introduced or not a successful product innovation ($INNOPROD$).

3.2.2 Explanatory variables and controls

The variables we use to test for the PAC impact of R&D efforts (HP1) – those denoted by $RDENG$, $RDCONT$, and $RDEXT$ – and of patenting (HP2) – that is, $PROPAT$ – are quite standard dummies (see Table 6 for their definition).[8]

The impact on PAC of the firm's cooperation for innovation (HP3 and HP4) is tested by including, at first, a general dummy ($INNOCOOP$) and by further distinguishing the type of partner. More precisely, we employ dummies for cooperation with: (i) national and foreign firms ($COOPFIRMNAT$ and $COOPFIRMFOR$), in turn divided – each one with both a national (NAT) and foreign (FOR) termination – into firms belonging to the same group ($COOPGP$), suppliers ($COOPSUP$), customers ($COOPCUS$), and competitors ($COOPCOM$); (ii) national and international research organizations ($COOPORGNAT$ and $COOPORGFOR$), in turn divided – each one with both a national (NAT) and foreign (FOR) termination – into private labs and institutes ($COOPINS$), universities ($COOPUNI$), and governments and public research institutes ($COOPPUB$) (see Table 6 for details).

Some comments are required for the other covariates (for their definition, see Table 6). Those internal organizational modifications which are expected to trig the activation of PAC (that is, *International Activation Triggers* (IAT)) according to HP4, are proxied by an array of changes in work, knowledge and market management systems, for whose modification firms often turn to external providers.

As far as HP5 is concerned, the firm's capacity to circulate the newly acquired knowledge within the organization, as a result of its *Social Integration Mechanisms* (SIM), is captured with two dummy variables. The first, $SIM1$, refers to the effects that these SIM have on the relevance of internal information flows: should the latter be relevant for the firm, the former might be thought to be actually at work. The second, $SIM2$, tries to account for the circulation of information within the firm which is possibly related also to the internal mobility of the workforce, in turn assumed at work in the presence of flexible production processes.

Finally, the relevance of human capital in mediating the relationship between PAC and RAC (HP6) is addressed by building up two different dummy variables that try to capture the quality of workers' human capital. In the absence of more specific information, the best we can do is to elicit such a quality,

[8] As for R&D, unlike Fosfuri and Tribó (2008), we extract its "simple" contracting-out (i.e., extramural R&D ($RDEXT$)) from the group of variables which refer to wider innovation cooperation between the parties, defined in the following (i.e. the $COOP$ variables).

at two different, increasingly higher, levels ($HUMCAP2$ and $HUMCAP1$), by crossing information about the the firm's human capital shortages and training programs.

Among the controls we include two dimensions which are widely considered as important to explain both PAC antecedents and impacts. The first, $EXPORT$, controls for the fact that – as the literature about the linkage between export and innovation shows – exporting firms may benefit from higher worldwide knowledge linkages, being more innovative as well as experiencing a sort of learning by exporting-effect. The second dimension is the firm's size, captured by the two dummies $SMALL$ and $MEDIUM$. Even though the literature has not reached conclusive results about the relationship between size and innovation, the inclusion of these variable allows us to control for the effect of the firm's dimension on the accumulation of technological capabilities that enable the accumulation PAC and/or its transformation into higher innovation outcomes.

3.3 Econometric strategy

The first part of our empirical application, dedicated to the PAC antecedents, starts by running a standard OLS regression of Equation 1 in order to get the measurement of PAC as defined in Section 3.2.1.

Given the particular distribution of $EXTKNOW$ in Equation 1, which shows a (relatively low) concentration around 0, and given the sort of censoring we introduced by normalizing it in-between 0 and 1, as a robustness check we differently calculate our PAC measurement by re-estimating Equation 1 with a Tobit model and considering the relative residuals as in Equation 2.

Once obtained PAC, we test our first 4 hypotheses (i.e. HP1-HP4) by running a set of OLS regressions for it on the correspondent determinants and controls (Section 3.2.2).

The second part of our empirical analysis, concerning the innovation impacts of PAC (HP5 and HP6), is complicated by the particular nature of the first dependent variable we use for it, that is $TURNINNO$. Given its skeweness, in order not to miss all of the observations with nil values of TURNINNO, we tackle this problem by following Laursen and Salter (2006) and employ a logarithmic transformation of it such as $lnTURNINNO = ln(1 + TURNINNO)$. Furthermore, as $lnTURNINNO$ takes value 0 with a positive probability, but is roughly continuously distributed over positive values, we estimate the PAC impact on it by using a "corner solution model" (Wooldridge, 2002) and estimate it with a Tobit.[9]

[9]Standard OLS on the entire sample, or OLS using the subsample of $lnTURNINNO >$

Table 1: Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1														
2	.124*	1													
3	.152*	.296*	1												
4	.169*	.266*	.670*	1											
5	.083*	.175*	.146*	.148*	1										
6	.134*	.205*	.267*	.297*	.211*	1									
7	.129*	.282*	.252*	.283*	.184*	.230*	1								
8	.071*	.131*	.093*	.108*	.122*	.120*	.104*	1							
9	.093*	.172*	.232*	.241*	.066*	.139*	.164*	.045*	1						
10	.092*	.213*	.143*	.172*	.072*	.104*	.131*	.077*	.694*	1					
11	.064*	.042*	.083*	.123*	.157*	.133*	.114*	.089*	.098*	.075*	1				
12	.038*	.028*	.083*	.122*	.109*	.114*	.079*	.057*	.078*	.062*	0.666*	1			
13	.049*	.141*	.272*	.277*	.084*	.212*	.160*	.036*	.081*	.091*	.048*	.053*	1		
14	.010	-.141*	-.210*	-.247*	-.150*	-.226*	-.165*	-.049*	-.051*	-.073*	-.121*	-.118*	-.295*	1	
15	-.016	.032*	.076*	.070*	-.02	-.003	0	-.024	0	.012	.018	.022	.160*	-.684*	1

* Correlation significant at 1% level.
Legend: 1: TURNINNO; 2: PAC; 3: RDENG; 4: RDCONT; 5: RDEXT; 6: PROPAT; 7: INNOCOOP; 8: IAT; 9: SIM1; 10: SIM2; 11: HUMCAP1; 12: HUMCAP2; 13: EXPORT; 14: SMALL; 15: MEDIUM

The PAC effects analysis is completed by considering $INNOPROD$ as a second dependent variable. Given its nature, a probit estimation procedure is used. In both the versions of the second step of the analysis, it should be noted that the "residual" way we obtained our measurement of PAC (as in Equation 2) might create a problem of multicollinearity with the other determinants in estimating their impact. Accordingly, proper multicollinearity tests will have to be run in presenting the relative results. [10]

4 Results

As preliminary evidence, Table 1 reports pairwise correlations among the relevant variables.

As expected, there are traces of positive correlations between PAC (numbered 2 in Table 1) and the antecedents of HP1 (4) and HP2 (6). The correlation with innovation cooperation, meant in aggregated terms ($INNOCOOP$, 7), is also positive, as well as that with IAT (8). On the other hand, as is

0 are supposed to lead to inconsistent estimations of the coefficients. Typically Tobit models imply the existence of a latent variable y^*, in addition to the observed y, such that $y = y^*$ if $y^* \geq 0$ 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).

[10] Finally, to account for the existence of a possible sample selection bias, in addition to the Tobit estimation we implement a series of Heckman selection models, using as exclusion restriction $INNOPROD$. This dummy, capturing the introduction of a product innovation, is supposed to affect the selection (i.e. whether the economic exploitation of the innovations is greater than 0) but not the outcome (i.e. the actual amount of turnover, $lnTURNINNO$ in our case, due to the introduction of product innovations).

also expected, $TURNINNO$ (1) is positively correlated both with PAC and with the two proxies of SIM (9 and 10) and $HUMCAP$ (11 and 12).

More reliable tests for the hypotheses identified in Section 2.2 on the PAC antecedents as well as on its impact on $lnTURNINNO$ and $INNOPROD$ are of course obtained by employing the econometric approach described in Section 3.3.

4.1 PAC antecedents

The first set of hypotheses (HP1-HP4) is tested through hierarchical regression, in an incremental way. In Table 2, Model 1 considers the main PAC antecedents and controls in isolation, with no interactions, and retains firms' innovative cooperation in "aggregate terms", without distinguishing its specifications. The different sources of innovation cooperation are instead considered in Model 2 – by simply distinguishing firms from research organizations (national and foreign) – and Model 3 – by further disaggregating each of them. Finally, Model 4 addresses the interaction of the PAC antecedents with IAT, in particular with all the sources of external knowledge (as detailed in Table 6).

Table 2: PAC antecedents

	1	2	3	4
	Coeff./(se)	Coeff./(se)	Coeff./(se)	Coeff./(se)
SMALL	-0.01153**	-0.00852	-0.01054*	-0.00996*
	(0.005)	(0.005)	(0.006)	(0.006)
MEDIUM	-0.00218	0.00047	-0.00206	-0.00202
	(0.005)	(0.005)	(0.006)	(0.006)
EXPORT	0.00931**	0.00977**	0.00701	0.00683
	(0.004)	(0.004)	(0.004)	(0.004)
RDENG	0.07212***	0.07048***	0.06961***	0.06944***
	(0.005)	(0.005)	(0.005)	(0.005)
RDCONT	0.01902***	0.01875***	0.02006***	0.01982***
	(0.005)	(0.005)	(0.005)	(0.005)
RDEXT	0.04021***	0.03942***	0.04272***	0.04703***
	(0.005)	(0.005)	(0.005)	(0.005)
PROPAT	0.03053***	0.02856***	0.02951***	0.03127***
	(0.004)	(0.004)	(0.005)	(0.005)
IAT	0.05183***	0.04806***	0.05661***	0.07329***
	(0.007)	(0.006)	(0.007)	(0.009)
INNOCOOP	0.08015***			
	(0.004)			
COOPFIRMNAT		0.04568***		
		(0.006)		
COOPORGNAT		0.08377***		
		(0.006)		
COOPFIRMFOR		0.00370		

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	1	2	3	4
		(0.007)		
COOPORGFOR		0.01064		
		(0.011)		
COOPGPNAT			0.02766***	0.03523***
			(0.010)	(0.010)
COOPGPFOR			-0.06014***	-0.06134***
			(0.011)	(0.012)
COOPSUPNAT			0.01742**	0.01279
			(0.008)	(0.008)
COOPSUPFOR			0.02794***	0.02702**
			(0.011)	(0.012)
COOPCUSNAT			0.03291***	0.02591***
			(0.009)	(0.010)
COOPCUSFOR			0.02708**	0.03230**
			(0.012)	(0.013)
COOPCOMNAT			0.02941***	0.04609***
			(0.010)	(0.011)
COOPCOMFOR			0.02145	0.02251
			(0.014)	(0.016)
COOPINSNAT			0.02434***	0.02430***
			(0.009)	(0.009)
COOPINSFOR			0.00494	0.00943
			(0.017)	(0.019)
COOPUNINAT			0.07209***	0.07306***
			(0.008)	(0.009)
COOPUNIFOR			0.02036	0.01938
			(0.019)	(0.021)
COOPPUBNAT			0.07064***	0.06569***
			(0.014)	(0.015)
COOPPUBFOR			-0.06815**	-0.03205
			(0.031)	(0.037)
RDEXT*IAT				-0.03391**
				(0.015)
PROPAT*IAT				-0.01486
				(0.015)
COOPGPNAT*IAT				-0.05060*
				(0.027)
COOPGPFOR*IAT				0.00678
				(0.032)
COOPSUPNAT*IAT				0.04463**
				(0.022)
COOPSUPFOR*IAT				-0.01464
				(0.027)
COOPCUSNAT*IAT				0.06491**
				(0.027)
COOPCUSFOR*IAT				-0.05340
				(0.033)
COOPCOMNAT*IAT				-0.11036***
				(0.029)
COOPCOMFOR*IAT				-0.02825
				(0.036)
COOPINSNAT*IAT				0.00633
				(0.025)
COOPINSFOR*IAT				-0.02589

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	1	2	3	4
				(0.046)
COOPUNINAT*IAT				-0.00420
				(0.024)
COOPUNIFOR*IAT				0.00819
				(0.047)
COOPPUBNAT*IAT				0.03452
				(0.030)
COOPPUBFOR*IAT				-0.06909
				(0.059)
Const	-0.09952***	-0.09961***	-0.09582***	-0.09714***
	(0.007)	(0.007)	(0.007)	(0.007)
R^2	0.159	0.172	0.166	0.169
F	223.02***	190.91***	96.64***	61.07***
N	10490	10490	9815	9815

To start with, the famous "second face" of R&D, Cohen and Levinthal (1989) identified in their seminal work, appears visible in our application too. HP1 finds support in all of the four model specifications. To be sure, somehow extending the findings by Cohen and Levinthal (1989), our results seem to suggest that PAC benefits from any kind of formal R&D engagement by the firm: not necessarily from that carried out in stable R&D departments ($RDCONT$), but also from that which is done on an occasional basis ($RDENG$) and which is contracted out ($RDEXT$), the latter involving some kind of external-interaction experience (Fosfuri and Tribó, 2008).

Also HP2 finds robust support across all the model specifications of Table 2. As we said, in the lack of patent data for constructing a stock-kind proxy of learning experience, what we can conclude is simply that 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. Considering that filing a patent application usually requires firms to master, and eventually quote, the knowledge of other related patents, possibly obtained by other firms and inventors, this is no surprising and indeed aligned with similar results of previous evidence (e.g. Fosfuri and Tribó, 2008).

As we said, the most interesting hypothesis of the paper is HP3, which makes the PAC impact of external cooperation for innovation dependent on the kind of source. Such an hypothesis is confirmed by the heterogeneity of the relative results. On the one hand, being involved in innovation cooperation unambiguously increases the firm's PAC: $INNOCOOP$ turns out significant and positive – as in Fosfuri and Tribó (2008) – in the most aggregated model (Model 1). On the other hand, once the various external knowledge sources are considered, in the other models, different results are obtained. First of all, the geographical distance of the firm from the external source it cooperates with seems to matter in nurturing the general PAC of the former. Both in the cooperation with firms and with research organizations, the PAC impact is significant and positive only with respect to the

national ones (i.e. $COOPFIRMNAT$ and $COOPORGNAT$ in Model 2). As expected, a cross-country kind of distance from a partner in innovation cooperation might create language and cultural barriers to the understanding of the knowledge which is produced and/or spread by it.

The hampering role that long-distance cooperations have on PAC appears in turn conditional on the "functional" distance between the partners. The firm's interaction with business kind of actors, such as suppliers and customers, which are directly functional to its economic activity, is found to increase PAC both in the case of national and foreign interactions ($COOPSUPNAT$ and $COOPSUPFOR$, $COOPCUSNAT$ and $COOPCUSFOR$, in Models 3 and 4). Conversely, interacting with actors which are less functionally related to the firm's economic activity, such as private and public research institutes and universities, continues to require a national setting to increase the firm's general PAC (i.e. $COOPINSNAT$, $COOPPUBNAT$ and $COOPUNINAT$, in Model 3 and 4).

This is an interesting result. On the one hand, it suggests that, in order to work as actual "innovation-hubs" (Youtie and Shapira, 2008) and help the knowledge absorption capacities of the firm they interact with, research organizations need to share with them the same linguistic and cultural codes. On the other hand, interactions along the value chain seem to increase the firm's capacity to absorb external knowledge irrespectively from the nationality of the business partners. In other words, global value chains appear as important as national ones to increase the firm's experience of learning about the external environment.[11] All in all, these results confirm Lim (2009)'s findings about the multiple "faces" of absorptive capacity, depending on the nature of the relevant knowledge, that is: "domain-specific knowledge", requiring a "disciplinary absorptive capacity", "solutions to specific technical problems" and "knowledge embedded in tools and processes", requiring a "domain specific" and "encoded" absorptive capacity, respectively. Furthermore, it seems like these different faces also have different tongs.

In the test for HP3, a last remark deserves the role of organizational distance in cooperating for innovation, as proxied by the firms' belonging to the same business group of the partner. Within-group cooperation increases the firm's PAC only when it works with national subsidiaries ($COOPGPNAT$ in Models 3 and 4), while foreign ones significantly decrease it ($COOPGPFOR$, in Models 3 and 4). A tentative explanation of this result might be found in

[11] Quite interestingly, this global view does not hold true with respect to horizontal business relationships, as the firm's cooperation with the competitors significantly increases PAC only when they are national. On the other hand, interacting with foreign public research institutes (i.e. $COOPPUBFOR$ in Model 3), rather than foreign universities or private labs, even reduces the firm's PAC.

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 skepticism with which domestic ones look at them as rivals in developing superior innovations for their common business.[12] 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 organizational culture and codes, and thus perceiving themselves stronger rivals, as it occurs in the same business group.

The kind of external knowledge source appears crucial also in the test for HP4, which is thus supported too. At the outset, let us observe that, as in Fosfuri and Tribó (2008), IAT turns out significant and positive as an individual regressor, that is in Model 1. Internal activation triggers do directly contribute to the accumulation of PAC. Unlike in Fosfuri and Tribó (2008), IAT also works in moderating the effects of some of the other PAC antecedents, although in an heterogeneous way.[13] As far as innovation cooperation is concerned, once interacted with any of the foreign knowledge sources, IAT renders their PAC impact insignificant. It seems like the occurrence of organizational changes (of the kind captured by IAT) requires knowledge-solutions which, in order to be absorbed, are at least "transmitted", if not even "produced" by national partners.[14] Organizational shocks rather moderate the role that interacting with national partners has in nurturing the firm's PAC, but still with differences. In particular, the IAT moderation is positive for innovative cooperation with both suppliers and customers ($COOPSUPNAT$ and $COOPCUSNAT$ in Model 4), but negative with the competitors ($COOPCOMNAT$ in Model 4).

The NIH syndrome might still play a role in that, insofar internal problems spur the search for external solutions. Indeed, our result appears consistent with what Wastyn and Hussinger (2011) find with respect to the German part of the Community Innovation Survey (CIS), based on the Mannheim Innovation Panel (MIP): as "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

[12] The empirical literature on the problems entailed by the absorption of foreign business incubators (Lehrer and Asakawa, 2003), among which the case of Xerox at Palo Alto in the '80s is the most famous example, can be of some help in illustrating this point.

[13] Accordingly, whether IAT actually has a net final effect on PAC can't be concluded in general. In those models where significantly negative moderating factors are present, the relative coefficients should be controlled case by case: an exercise which is out the paper's scope.

[14] The only (weakly) significant foreign-interaction is that with foreign research organization, $COOPORGFOR$ (not reported in the text and available on request), which has however a negative sign.

degradation of 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). Although this interpretation applies to the direct absorption of the knowledge produced by the same partner the firm interacts with, as we said above, the NIH syndrome might spurs the absorbing firm to downplay the role of competitors also as "knowledge-brokers" for their PAC.[15]

Finally, quite interesting is the negative moderating role IAT exerts on the PAC impact of extramural R&D ($RDEXT * IAT$ in Model 4). When organizational shocks hit the firms, contracting out $R\&D$ might become counterproductive in the assimilation of external knowledge.[16]

As reported in the the econometric strategy section, we also estimated as a robustness check Equation 1 with a Tobit model. The PAC-antecedents results appear robust also with respect to the different specification of the PAC variable. Indeed, the coefficients of Equation 1 obtained with a Tobit model are very similar to those estimated with a OLS. By re-estimating all of our models with the new measure of PAC, the results, which we do not report here for lack of space (and available from the authors on request), are completely consistent and very similar to the ones reported through the paper.

4.2 PAC effects

Although limited to the final two hypotheses, the analysis of the innovation effects of the firms' PAC yields interesting and original results (compared, for example, with Fosfuri and Tribó (2008)).

With respect to $TURNINNO$, the results are obtained through the hierarchical regression of a Tobit model (using the aforementioned transformation $lnTURNINNO$). That is, in 6 specifications which, starting from the baseline (Model 1) progressively add to PAC and its antecedents and controls, the other covariates of interest, particularly in the relevant interactions (Table 3)[17]

[15] Quite interestingly and consistently, the interaction with IAT makes this NIH argument relevant also with respect to national firms of the same group ($COOPGPNAT$ in Model 4), which had a positive PAC impact and which now gets a (weakly) significant negative interacted impact.

[16] Although controlled for, the IAT interaction with $RDCONT$ and $RDENG$ is not reported as the former are supposed to moderate externally oriented innovation efforts.

[17] Due to the way PAC was built up, some problems of collinearity may arise between PAC and other variables introduced as regressors in the estimations of innovation performance. However, we have conducted a test of multicollinearity finding that VIF value of all variables is never higher than 10.

Table 3: PAC effects

Dependent Variable: *ln*TURNINNO

	1	2	3	4	5	6
	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se
EXPORT	0.20328***	0.18273***	0.19837***	0.20119***	0.20144***	0.18136***
	(0.064)	(0.064)	(0.064)	(0.064)	(0.064)	(0.064)
SMALL	0.36039***	0.36115***	0.36573***	0.39449***	0.38058***	0.39493***
	(0.065)	(0.065)	(0.065)	(0.066)	(0.066)	(0.065)
MEDIUM	0.12294*	0.12305*	0.12822**	0.14202**	0.13705**	0.14156**
	(0.063)	(0.063)	(0.063)	(0.063)	(0.063)	(0.063)
RDENG	0.86610***	0.79818***	0.85817***	0.85448***	0.86339***	0.78617***
	(0.078)	(0.079)	(0.078)	(0.078)	(0.078)	(0.078)
RDCONT	0.61968***	0.57177***	0.59814***	0.59798***	0.60365***	0.55194***
	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)
RDEXT	0.31417***	0.31911***	0.31087***	0.24017***	0.28795***	0.24396***
	(0.058)	(0.057)	(0.057)	(0.058)	(0.058)	(0.058)
PROPAT	0.74670***	0.73768***	0.75006***	0.72029***	0.73553***	0.71250***
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
IAT	0.41807***	0.40971***	0.39614***	0.37283***	0.40557***	0.36318***
	(0.073)	(0.072)	(0.072)	(0.073)	(0.073)	(0.073)
PAC	1.78693***	2.67073***	2.11339***	0.67602***	0.85836***	1.60044***
	(0.135)	(0.188)	(0.164)	(0.238)	(0.314)	(0.266)
INNOCOOP	0.40004***	0.38465***	0.38365***	0.36333***	0.38789***	0.35002***
	(0.053)	(0.053)	(0.052)	(0.053)	(0.053)	(0.053)
SIM1		0.42363***				0.40399***
		(0.050)				(0.050)
SIM1*PAC		-1.94044***				-2.08679***
		(0.249)				(0.249)
SIM2			0.33558***			
			(0.053)			
SIM2*PAC			-1.40789***			
			(0.266)			
HUMANCAP1				0.34864***		0.35205***
				(0.054)		(0.054)
HUMANCAP1*PAC				1.68930***		1.74134***
				(0.278)		(0.277)
HUMANCAP2					0.23014***	
					(0.067)	
HUMANCAP2*PAC					1.16582***	
					(0.341)	
Const	-0.42682***	-0.51541***	-0.47252***	-0.62229***	-0.60383***	-0.70290***
	(0.091)	(0.092)	(0.091)	(0.098)	(0.107)	(0.099)
N	10490	10490	10459	10490	10490	10490
F-test	236.416***	207.067***	203.437***	210.021***	202.026***	189.220***
$PseudoR^2$	0.054	0.058	0.056	0.057	0.055	0.060

***,**,* denote significance at the 1%, 5%, 10% level, respectively.
Robust standard error in parentheses.

First of all, PAC has a significant and positive impact on $TURNINNO$ in all the model specifications, although this is just a "net" effect in those models which contain its interactions with the SIM variables (i.e. Models 2, 3 and 6), where it is still positive as an individual regressor. As expected, a higher capacity of acquiring and assimilating knowledge (i.e. PAC) generally leads to a larger innovation outcome, although the role of social integration mechanisms should be controlled for.

Indeed, our HP5 about the moderating role of SIM is not confirmed, and rather reversed. While both $SIM1$ and $SIM2$ are significantly positive as individual regressors in all the relevant specifications, once interacted with the capacity of bringing home external knowledge, the same mechanisms seem to impoverish its innovation outcome: $SIM1 * PAC$ and $SIM2 * PAC$ are significantly negative.

Although this countervailing effect of SIM on the PAC transformation into RAC does not make it completely "inefficient'[18] such a result is in sharp contrast with the intuition and with other empirical evidence (e.g. Fosfuri and Tribó, 2008), and thus deserves closer scrutiny in our future research. By now, one possible explanation for it could be that the famous process of knowledge "socialization", whose virtues Nonaka and Takeuchi (1997) described for the "knowledge creating company", could have some drawbacks in terms of knowledge transformation. For example, it could imply a "dispersion" of novel external knowledge, which could make its synthesis with the existing competencies harder to occur. In other words, (an excessive) socialization 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 synthesize novel competencies, to which the PAC-RAC transformation can be somehow related. As distinguished from "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*).[19]

[18] In Models 2 and 3 the marginal effects of PAC and of its SIM-interactions on $lnTURNINNO$ (i.e. $\partial E(y|x)/\partial x$) (Cameron and Trivedi, 2009) are respectively: 1.87583 (PAC) and -1.36290 ($SIM1 * PAC$), in Model 2; 1.48967 (PAC) and -0.99238 ($SIM2 * PAC$), in Model 3. Hence, the "net" effect of PAC on the innovation performance is positive even in those cases in which social integration mechanisms are in place (i.e. $SIM1$ or $SIM2$ are equal to 1).

[19] 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 dispersion" see, for example, Cowan and Jonard (2004), who use network theory to show the existence

Unlike HP5, HP6 finds support in our empirical application, with respect to both the proxies of human capital that we considered (i.e. $HUMCAP1$ and $HUMCAP2$). First of all, in general and as expected, a qualified level of human capital increases the firm's innovation outcome *per se*. Furthermore, the individual capabilities of the firm's workers seem to work efficiently in transforming PAC into RAC. Finally, in the most comprehensive model (i.e. Model 6), the positive PAC-moderating role of $HUMCAP2$ stands against the negative one of $SIM1$ (and similar results are obtained for the other combinations of $HUMCAP$ and SIM specifications).

This last result is quite interesting, as it suggests that the two mechanisms we addressed are indeed controversial in the transformation of PAC into RAC. In particular, for the investigated firms the presence of qualified human capital seems able to, and actually necessary, to prevent the same transformation from being inefficient in those cases in which SIM dampen the innovation effects of PAC.[20]

More in general, the same result suggests that the research stream on the role of human capital for AC – which has been diffusing quite independently from the organizational one, as somehow secondary to it (e.g. Minbaeva et al., 2003; Volberda et al., 2010) – deserves larger consideration. Not only does the accumulation of experience of the employees increases the tacit knowledge of the firm and, through it, its innovation outcomes, as the evolutionary theories of innovation have established since long (e.g. Dosi, 1988). Human capital is decisive also in other AC respects. Highly educated employees typically have more frequent interactions with other individuals outside the firm, with whom they are able to create "communities of practice", which facilitate the access to external knowledge and above all its utilization (e.g. Mangematin and Nesta, 1999). On the one hand, the firm's human capital favors the creation of in-firm "knowledge brokers", which are essential in driving external knowledge within the firm (Brown and Duguid, 1998, p. 103). On the other hand, employees with high education levels are more capable of valuing new external knowledge and then pivotal in the "know-how trading" within the firm (Carter, 1989).[21]

of a trade-off between efficiency and equity in knowledge diffusion.

[20] In Model 6 the marginal effects of PAC and of its SIM- and $HUMCAP$-interactions on $lnTURNINNO$ (i.e. $\partial E(y|x)/\partial x$) (Cameron and Trivedi, 2009) are respectively: 1.12592 (PAC), -1.46808 ($SIM1 * PAC$), and 1.22505 ($HUMCAP1 * PAC$). A negative PAC-RAC transformation would actually thus occur for those firms in which $SIM1$ is equal to 1 and $HUMCAP1$ is equal to 0.

[21] Of course, human capital is necessary, but not sufficient, for this PAC-RAC transformation to occur. Strictly related to it is the need of devising proper practices of HRM, whose complementarities have been found crucial for innovative performance (e.g. Laursen and Foss, 2003).

Similarly to what we did for the PAC antecedents, as a robustness check, we carried out the analysis of the PAC effects with the measure of PAC obtained from a Tobit estimation of Equation 1. The results (still available from the authors on request) appear to be robust and consistent to the ones reported above. Robust appear also the results of the PAC-effects analysis obtained with a probit estimation with $INNOPROD$ as outcome variable. The coefficients of PAC and the other regressors and interaction terms actually yield fully consistent outcomes (Table 4).[22]

5 Conclusions

The paper starts from the idea, recently elaborated in the dynamic capabilities literature, that "absorptive capacity" (AC) is in the business realm a complex process, whose final innovation outcome relies on different firm's capacities. One thing is for the firm to look for and bring new external knowledge within its organizational boundaries. Another thing is to combine external knowledge with that available internally and transform it into new products and/or processes. The first denotes a Potential of Absorptive Capacity (PAC), for which experience of external learning is crucial. The latter refers to its Realization (RAC), for which integrating and recombining new and existing knowledge is instead pivotal. On this basis, the analysis of AC splits into that of the PAC antecedents and that of its effects, as determined by the firm's RAC.

Although it places in an already developed research stream – at the intersection between innovation and management studies – the paper contributes to it with some elements of originality and various policy and strategic implications.

Consistently with the original idea by Cohen and Levinthal (1989), PAC actually seems the "second face" of R&D. Furthermore, any kind of R&D engagement – even occasional, and/or contracted out – seems enough for the firm to increase its identification and assimilation capacities of external knowledge. While supporting the growing concern of the European Com-

[22]To control for the existence of a possible bias due to sample selection, we re-estimate Model 1-5 with a series of Heckman selection models. In the selection equation we include an exclusion restriction: we add $INNOPROD$, which is likely to affect the selection (i.e. $lnTURNINNO > 0$) but not the amount of $lnTURNINNO$, to the sets of independent variables we use Model 1-5. The results which are not reported here, but available upon request, demonstrate that the 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.

Table 4: PAC effect

Dependent Variable: $INNOPROD$

	1	2	3	4	5	6
	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se
EXPORT	0.24806***	0.23925***	0.24845***	0.24728***	0.24714***	0.23898***
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
SMALL	0.01088	0.01184	0.01259	0.02488	0.01732	0.02563
	(0.042)	(0.042)	(0.042)	(0.043)	(0.043)	(0.043)
MEDIUM	-0.02324	-0.02283	-0.02108	-0.01607	-0.01946	-0.01597
	(0.042)	(0.042)	(0.042)	(0.043)	(0.042)	(0.043)
RDENG	0.44437***	0.42066***	0.44637***	0.43758***	0.44242***	0.41459***
	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)
RDCONT	0.32582***	0.29917***	0.32117***	0.31883***	0.31955***	0.29334***
	(0.036)	(0.037)	(0.036)	(0.036)	(0.036)	(0.037)
RDEXT	0.11314***	0.11812***	0.11221***	0.07832**	0.10012***	0.08316**
	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)
PROPAT	0.49717***	0.49502***	0.50710***	0.48558***	0.49262***	0.48400***
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
IAT	0.24831***	0.24951***	0.23410***	0.22866***	0.24414***	0.22977***
	(0.055)	(0.055)	(0.055)	(0.056)	(0.056)	(0.056)
PAC	0.95783***	1.23244***	1.03155***	0.40171***	0.44816***	0.71228***
	(0.076)	(0.100)	(0.089)	(0.119)	(0.156)	(0.136)
INNOCOOP	0.24683***	0.23565***	0.23797***	0.23009***	0.24159***	0.22001***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
SIM1		0.21663***				0.20583***
		(0.028)				(0.028)
SIM1*PAC		-0.69801***				-0.76182***
		(0.145)				(0.148)
SIM2			0.11332***			
			(0.031)			
SIM2*PAC			-0.40798**			
			(0.164)			
HUMANCAP1				0.14737***		0.14552***
				(0.028)		(0.028)
HUMANCAP1*PAC				0.91739***		0.90809***
				(0.151)		(0.150)
HUMANCAP2					0.10248***	
					(0.033)	
HUMANCAP2*PAC					0.65934***	
					(0.176)	
Const	-0.62369***	-0.68289***	-0.64573***	-0.70204***	-0.69910***	-0.75601***
	(0.051)	(0.052)	(0.051)	(0.054)	(0.057)	(0.055)
N	10151	10151	10120	10151	10151	10151
$Wald\chi^2$	1962.74***	2067.46***	2009.71***	1950.99***	1964.20***	2067.31***
$PseudoR^2$	0.1626	0.1689	0.1655	0.1670	0.1643	0.1732

***,**,* denote significance at the 1%, 5%, 10% level, respectively.
Robust standard error in parentheses.

mission for an increase of the firms' expenditure in R&D, at the intensive margin, this result suggests the opportunity of increasing it also at the extensive margin, for example by spurring them to resort to extramural R&D, should problems of minimum threshold prohibit intramural one. Such a policy implication is thus particularly important for SMEs. However, we also obtained evidence of the fact that, contracting out R&D could diminish the firm's PAC, should that be driven by the reaction to internal organizational shocks. This result, which is quite common in the R&D management, seems to suggest that the externalization of R&D has both pros and cons, also and above all with respect to the firm's potential absorptive capacity.

Having experience of patenting activities seems to increases PAC too, possibly because of the external knowledge management that it entails, along with 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, in which firms look for complementarity between internal and external knowledge.

The most relevant result of the paper concerns the PAC-impact of firm's experience of innovation cooperation. As suggested by different research streams, interacting with an external partner has an impact in nurturing the firm's general PAC which is dependent on the manifold kind of distance (or "proximity") which separates them. In particular, research organizations work as "innovation hubs" for the firm only if they interact in the same national setting. On the other hand, a business kind of interaction augments the firm's PAC in both national and global value chains. More in general, the geographical distance intertwines with the functional one, and points to different absorptive capacities for different kinds of knowledge. From a policy perspective, national systems of innovation still maintain a role in the acquisition of external knowledge, and thus deserve proper system kind of policies, even in front of firms which simultaneously source their knowledge within global value chains.

Relevant for the firm's PAC is also the organizational distance which separates it from the innovation partner, as it might be proxied by their eventual belonging to the same business group. Organizational proximity appears to reverse the PAC impact of global business interactions, possibly because it induces "competition" effects of the kind of the notable "Not-Invented-Here" syndrome. This is an interesting result for management practitioners, as it poses them the delicate choice of favoring (organizationally) distant innovation partnerships, even at the cost of giving up the advantages of local innovation search. Similar management implications emerge from the results on those organizational shocks (the so-called "Internal Activation Triggers"

(IAT)) which usually spur the search for external knowledge. Indeed, their role in positively moderating the PAC impact of external cooperation appears limited to the firm's customers and suppliers, with respect to which NIH problems are less probable. Even out of the business realm, the same results should be retained by the policy makers in devising initiatives of inter-firm networkings, especially in the attempt of overcoming R&D scale problems which are typical of the European area: in some cases, these initiatives might end up in a "zero-sum" game.

Last, but not least, the extent to which PAC translates into actual innovation has given us some preliminary insights on the complex relationship between PAC and RAC, for which we did not have direct proxies. Apparently, those "Social Integration Mechanisms" which have been found important by other studies 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 PAC. The PAC effects in terms of innovation rather seem to crucially depend on the firm's human capital, whose manifold role in facilitating the absorption of external knowledge thus deserves larger consideration. This result has also important strategic and policy implications. On the one side, firm-training and on-the-job education initiatives also seems to have a "second face" in terms of absorptive capacity, as much as R&D. On the other side, investing public resources in education and training finds in it a further important justification, which make them twice as important for reaching targets of "smart" growth.

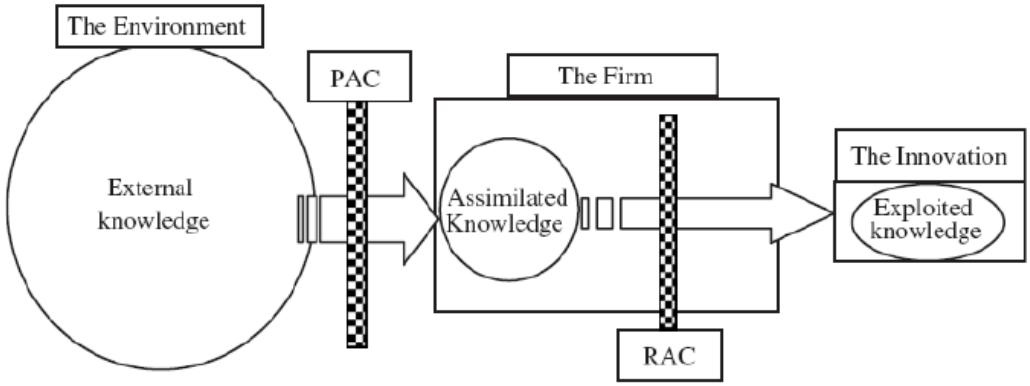
While these are the most substantial added values of the paper, when compared with previous works using a pretty similar methodology, other elements of originality have been introduced at the methodological level too. The "residual" role of PAC in explaining the importance firms attribute to external knowledge, for example, has been better retained by considering their eventual belonging to MNCs. The role of external knowledge experience has been addressed more extensively, by retaining a number of different kinds of sources. The analysis of the PAC impact has been carried out with more reliable innovation proxies and by controlling for a wider array of moderating factors.

Of course, the paper is not free from limitations, to whose solution future research will be devoted. The most notable is, as we said, the lack of a reliable RAC proxy, with which to evaluate the efficiency of the PAC transformation into it. Further efforts also requires the definition of the "Internal Activation Triggers", whose role has been at most elicited, as well as that of the "Social Integration Mechanism" and of "Human Capital". All of these variables, along with possibly others, have been defined on the basis of the available CIS

data. Last, but not least, while the current application has somehow made previous ones more general in terms of geographical coverage, it remains a pure cross-sectional one. This requires us to be cautious and interpret the results as associations among variables, rather than as causal relationships. The use of longitudinal data, possibly coming from the availability of more CIS waves, would remedy to this limitation.

A Appendix

Figure 1: The Zara & George AC decomposition



Adapted from Fosfuri and Tribó (2008)

Table 5: Sample statistics

	Germany		Italy		Spain		Total	
Size*	Number	%	Number	%	Number	%	Number	%
Small (0-49)	765	33.51	1287	47.30	3029	54.95	5081	48.32
Medium (50-249)	763	33.42	954	35.06	1792	32.51	3509	33.37
Large (> 250)	755	33.07	480	17.64	691	12.54	1926	18.31
Total	2283	100	2721	100	5512	100	10516	100
NACE Sectors**								
DA	145	6.35	226	8.31	653	11.85	1024	9.74
DB	105	4.60	215	7.90	303	5.50	623	5.92
DC	21	0.92	0	0.00	82	1.49	103	0.98
20-21	135	5.91	100	3.68	250	4.54	485	4.61
22	123	5.39	134	4.92	198	3.59	455	4.33
DF-DG	202	8.85	203	7.46	672	12.19	1077	10.24
DH	143	6.26	149	5.48	318	5.77	610	5.80
DI	91	3.99	179	6.58	356	6.46	626	5.95
27	91	3.99	131	4.81	165	2.99	387	3.68
28	286	12.53	399	14.66	536	9.72	1221	11.61
DK	277	12.13	331	12.16	663	12.03	1271	12.09
DL	422	18.48	362	13.30	615	11.16	1399	13.30
DM	140	6.13	163	5.99	343	6.22	646	6.14
DN	102	4.47	129	4.74	358	6.49	589	5.60
Total	2283	100	2721	100	5512	100	10516	100

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

** We excluded 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 rev. 1.1 30 (belonging to DL) as it resulted in the aggregation of small, medium and large firms into a unique dimensional class.

Table 6: Variables description*

Variable name	Description	Obs	Mean	SD
PAC	See Sec. 3.2.1	10490	0.000	0.196
TURNINNO (Rescaled $[0, 1]$	% Turnover (2004) due to product innovations new to the market or firm	10516	0.196	0.287
INNOPROD^d	Introduced a product innovation	10177	0.574	0.495
RDENG^d	Engagement in intramural R&D	10516	0.673	0.469
RDCONT^d	Continuous engagement in intramural R&D	10516	0.480	0.500
RDEXT^d	Acquisition of extramural R&D	10516	0.187	0.390
PROPAT^d	Filed at least 1 patent application	10516	0.265	0.441
INNOCOOP^d	Engagement in innovation cooperation agreements	10490	0.269	0.444
COOPFIRMNAT^d	Coop. with national firms	10516	0.172	0.378
COOPFIRMFOR^d	Coop. with foreign firms	10516	0.091	0.287
COOPORGNAT^d	Coop. with national research organizations	10516	0.150	0.357
COOPORGFOR^d	Coop. with foreign research organizations	10516	0.034	0.180
COOPGPNAT^d	Coop. with national firms of the same group	10066	0.057	0.232
COOPGPFOR^d	Coop. with foreign firms of the same group	10063	0.043	0.203
COOPSUPNAT^d	Coop. with national suppliers	10102	0.105	0.307
COOPSUPFOR^d	Coop. with foreign suppliers	10098	0.042	0.200
COOPCUSNAT^d	Coop. with national customers	10134	0.080	0.271
COOPCUSFOR^d	Coop. with foreign customers	10137	0.045	0.208
COOPCOMNAT^d	Coop. with national in-industry competitors and firms	9973	0.044	0.205
COOPCOMFOR^d	Coop. with foreign in-industry competitors and firms	9976	0.023	0.150
COOPINSNAT^d	Coop. with national, private research institutes, commercial labs or consultants	9949	0.078	0.269
COOPINSFOR^d	Coop. with foreign, private research institutes, commercial labs or consultants	9949	0.018	0.133
		9949	0.018	0.133
COOPUNINAT^d	Coop. with national universities or higher education	10213	0.115	0.319
COOPUNIFOR^d	Coop. with foreign universities or higher education	10197	0.022	0.146
COOPPUBNAT^d	Coop. with national governments or public research	10046	0.043	0.203
COOPPUBFOR^d	Coop. with foreign governments or public research	10031	0.008	0.089
IAT^d	Introduction of: 1) new or improved Knowledge Management System AND 2) major change in work organization AND 3) improved marketing method	10516	0.079	0.270
SIM1^d	Information from within the firm or from the enterprise group highly relevant for the firm's innovation	10490	0.484	0.500
SIM2^d	As from SIM1 AND high or medium production flexibility	10459	0.310	0.462
HUMCAP1^d	1) No problems due to lack of qualified workers OR 2) Presence of training program	10516	0.635	0.482
HUMCAP2^d	1) No or low problems due to lack of qualified workers OR 2) Presence of training program	10516	0.797	0.402
EXPORT^d	Export to foreign markets	10516	0.726	0.446
SMALL^d	Less than 51 employees (2002)	10516	0.483	0.500
MEDIUM^d	More than 50 and less than 250 employees (2002)	10516	0.334	0.472

*Defined on the period 2002-04 unless differently specified;
^{d}: dummy variable.

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