SME open innovation for process development: Understanding process-dedicated external knowledge sourcing

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ABSTRACT
Small and medium enterprise (SME) open innovation has received attention only for new product development, overlooking the fact that process innovation is a strategy commonly pursued by SMEs which requires organizing search strategies or external knowledge sourcing for that purpose.
Focusing on 3,348 process-oriented innovative SMEs, defined as those that usually and primarily only introduce process rather than product innovation, this study empirically identifies key external sources of SME innovation for process technologies, linking open innovation to SME performance, and highlighting a very important distinction to literature focused on product development. The results contribute to the literature on SME open innovation.

Introduction
Literature on open innovation has grown rapidly in the past decade (Chesbrough, 2003; Dahlander & Gann, 2010; Dodgson, Gann, & Salter, 2006; Hannigan, Seidel, & Yakis-Douglas, 2018; Lopez-Vega, Tell, & Vanhaverbeke, 2016; Roper, Vahter, & Love, 2013; Vanhaverbeke, 2017; Vanhaverbeke, Frattini, Roijakkers, & Usman, 2018). Small and medium enterprise (SME) open innovation has also received scholarly attention (for example, Bogers et al., 2017; Brunswicker & Vanhaverbeke, 2015; Chen, Vanhaverbeke, & Du, 2016; Kapetaniou & Lee, 2019; Radziwon & Bogers, 2018; Santoro, Vrontis, & Pastore, 2017), although omitting process inno- vation (Chesbrough & Bogers, 2014). Specifically, SME open innovation or search strategy for external knowledge sourcing for process development in SMEs remains largely overlooked, due to the fact that most studies on SME open innovation have not distinguished between product or process inno- vation (for example, Brunswicker & Vanhaverbeke, 2015; van de Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009) or focused solely on product innovation (Kapetaniou & Lee, 2019; Parida, Westerberg, & Frishammar, 2012; Spithoven, Vanhaverbeke, & Roijakkers, 2013). This biased viewpoint assumes that SME open innovation centers only around product development, impeding the understanding of different aspects of SME innovation such as the process-oriented one. Highlighting this gap, Chesbrough and Bogers (2014) call for more research on the context of openness and its importance for SMEs, pointing out the necessity to go further beyond the typical scope of research and development (R&D) and product technologies to fully address process technology and innovation. This study responds to that call and specifically addresses that gap of external knowledge sourcing for process-oriented SMEs.
The extensive focus of scholars on SME open innovation for product devel- opment is a consequence of the abundant literature on SME innovation that has traditionally been focused on the understanding of new product development (Acs & Audretsch, 1988; Hölzl, 2009; Nieto, Santamaria, & Fernandez, 2015; Stam & Wennberg, 2009).

Paradoxically, it is widely recognized that process innovation is a very important and overlooked form of innovation in the European Union (Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012; Hervas-Oliver, Sempere-Ripoll, & Boronat-Moll, 2014; Jespersen, Rigamonti, Jensen, & Bysted, 2017; OECD, 2010; Reichstein & Salter, 2006), to the extent that it is capital for SMEs (see Abel-Koch et al., 2015; Heidenreich, 2009).

Building on previous efforts to disentangle process innovation in SMEs (Hervas-Oliver et al., 2014; Jespersen et al., 2017), this study directly explores the intersection of two less-researched phenomena: process-oriented SMEs and their open innovation strategy. In doing so, rather than just researching on the introduction of process innovation, this article focuses on those SMEs that are process-oriented innovators, defined as those SMEs that usually and primarily only introduce process innovation, and not product innovation, a phenomenon mainly encountered in SMEs (Arundel, Bordoy, & Kanerva, 2007; Heidenreich, 2009; Hervas-Oliver et al., 2014). Following this concep- tualization, process innovation is not a complement or support of product innovation, but the core innovative strategy of those SMEs. In fact, those firms primarily undertake process-oriented activities and develop process- oriented technology and innovative routines, due to their particular business models, position in the supply chain, or hierarchical interdependence with larger firms or product innovators. As a result, process innovation is linked to embodied technology. We assume the fact that fixed capital spending increases the likelihood of firms introducing process innovations (for exam- ple, Heidenreich, 2009; Hervas-Oliver et al., 2014; Parisi, Schiantarelli, & Sembenelli, 2006), the latter being called the embodied hypothesis. Embodied technology, therefore, is strongly linked to process-oriented SME open innovation.

For researching on SME open innovation, we assume that differing search strategies or types of external knowledge sourcing, however, are contingent on the type of innovation capabilities that a firm possesses: external sourcing is facilitated (and limited) by the internal capabilities that a firm possesses (or the lack thereof) (Chesbrough, 2006; Cohen & Levinthal, 1990). For this reason, this study elaborates on both search strategies and their related internal capabilities. In this context, this article investigates inbound open innovation in process- oriented SMEs and focuses on the nature of external knowledge sourcing and the internal capabilities required for facilitating or aligning inbound knowledge flows with the firm's in-house innovative capabilities.

Empirically, key external sources of SME innovation for process technol- ogies are identified, disentangling – for process-oriented SMEs – different innovative strategies based on a distinct mixture of external sources to innovate and also showing how open innovation is linked to SME perfor- mance. It thus sheds light on different aspects, not previously covered, of SME open innovation (for example, Bogers et al., 2017; Brunswicker & Vanhaverbeke, 2015; Grimpe & Sofka, 2009; Radziwon & Bogers, 2018). Overall, this study presents new in-depth insights that reinforce SME hetero-geneity (Ortega-Argiles, Vivarelli, & Voigt, 2009), extending knowledge on SME open innovation (for example, Kapetaniou & Lee, 2019; Vanhaverbeke, 2017; Vanhaverbeke et al., 2018). Our results do clarify previous divergent results encountered on SME innovation that did not account for the distinc- tion between product and process-oriented innovation in SMEs (for example, Hölzl, 2009).

Empirically, this article addresses 3,348 European process-oriented inno- vators, which are SMEs that introduced only process innovation, and no product innovation, over a three-year period, in the 2006 wave of the Community Innovation Survey (CIS).

The structure of the article is as follows. First, we present a framework from which to address process-oriented SME open innovation. Next, we show the empirical design.

Then, we present the findings and discuss the results, followed by conclusions and suggestions for future lines of research.

SME open innovation and internal capabilities

Introduction to SME innovation strategy

The study of external knowledge sourcing, as a form of inbound open innovation, requires the consideration of internal capabilities that comple- ment search strategies (for example, Brunswicker & Vanhaverbeke, 2015; Hervas-Oliver et al., 2014; Laursen & Salter, 2006). Thus, we focus on disentangling how SMEs construct and configure their process-oriented innovation strategy, considering the interplay of both internal and external (search strategies) sources of knowledge to innovate. Internal capabilities represent a firm's in-house innovation activities that also facilitate the access to external sources of knowledge, facilitating integration and exploitation for innovation (Cohen & Levinthal, 1990). In the specific case of process devel- opment, internal capabilities constitute those routines to access, adapt, and integrate external knowledge and enable firms to benefit from those external sources or search strategies (Robertson, Casali, & Jacobson, 2012). Therefore, in this study, we refer to SME innovative strategy as the combina- tion of both internal and external (openness) sources of knowledge to innovate in process-oriented SMEs. Differing search strategies, however, are contingent on the type of innovation capabilities that a firm possesses: External sourcing is facilitated (and limited) by the internal capabilities that a firm possesses (or its lack thereof) (Chesbrough, 2006; Cohen & Levinthal, 1990). This combination builds a complex system of (process-based) cap- abilities, resembling that view of complementarities in the resource-based view of the firm (RBV; for example, Peteraf, 1993). According to this perspective, the combination of internal (to the firm) and external (Dyer & Singh, 1998) sources of knowledge configures a synergistic and complex higher-order capability to innovate. That integration complements and reinforces each component and, thereby, makes interrelationships difficult to imitate: This complex integration of diverse sources produces an inimi- table system that improves all concerned (for example, Rivkin, 2000; Teece, Pisano, & Shuen, 1997), configuring an SME innovative strategy, as we explain further below.

Search strategies: Process-oriented SME open innovation

A firm's external knowledge sourcing indicates how firms build their search strategy to access different types of external (to the firm) knowledge. Thus, the differing and distinct nature of interactions with external innovation actors clarifies our understanding of search strategy in SMEs (Dahlander & Gann, 2010). External knowledge sourcing spans many types of partners providing access to different natures of knowledge such as industry (supply- chain), science, and technology (Kline & Rosenberg, 1986; von Hippel, 1988). This diversity of sources ranges from customers, suppliers, competitors, or consultants to universities, seminars, or research organizations, among many others (for example, Eurostat, 2005; Laursen & Salter, 2006). Each different source of external knowledge to innovate provides a very different value and, more importantly, implies a specific combination with a firm's internal capabilities that enables the access, integration, and utilization of that parti- cular type of external source of knowledge (Brunswicker & Vanhaverbeke, 2015; Cohen & Levinthal, 1990).

SMEs use noninternal means of innovation more than large firms, as they consider alliances or networks as ways to extend their technological compe- tences (Edwards, Shaw, & Collier, 2005; Rothwell, 1991), meaning that networking is a crucial strategy to get access to knowledge and thus innovate (Lee, Park, Yoon, & Park, 2010; Robertson et al., 2012, p. 825), especially in bounded regional ecosystems (Radziwon & Bogers, 2018). Despite this pro- pensity to networking, SMEs are still deeply embedded in a networking process, mainly with suppliers and limited to the supply chain (Heidenreich, 2009; Rammer, Czarnitzki, & Spielkamp, 2009; Spithoven et al., 2013). As Heidenreich (2009) points out, suppliers are the most important source for SME innovation. In general, SMEs engage in coopera- tion agreements with actors in the supply chain (industry-based actors), such as suppliers or customers, relatively more intensively than they do with scientific-based agents (universities, technology and research transfer offices, and so forth) (for example, Corsten, 1987; Hervas-Oliver, Albors-Garrigos, & Gil-Pechuan, 2011; Zeng, Xie, & Tam, 2010), a fact that is also confirmed for the case of process-oriented SMEs (Hervas-Oliver et al., 2011, 2014). The reason for that pattern is based on the fact that process-oriented innovation goals include primarily cost reduction, increase of productivity, flexibility and capacity, as well as reverse engineering, imitation, or incremental changes: These objectives are basically supply-chain driven, and are much less driven by universities or other scientifically based sources (for example, Arundel et al., 2007). On the contrary, sourcing science-based sources are more committed to transfer R&D for product, rather than to process innova- tion development (for example, Clausen, Pohjola, Sapprasert, & Verspagen, 2012; Hervas-Oliver et al., 2014; Parisi et al., 2006). Therefore, we state the following hypothesis:

Hypothesis 1 (H1): Process-oriented SMEs show a pattern of intensive supply- chain sourcing and nonintensive science-based sourcing, bounded by their innovation pattern.

In this context, Rammer et al. (2009) empirically show how innovative SMEs rely heavily on external knowledge, primarily that embodied in capital for- mation or that absorbed through direct technological acquisition from sup- pliers. Similarly, Heidenreich (2009) characterizes SMEs as those firms that primarily develop process innovations and present strong dependencies on the external provision of machines, equipment, and software, being suppliers the most important source for their information and knowledge to innovate. This external orientation to suppliers constitutes the typical supplier-driven category (Pavitt, 1984) and fits within that category of SMEs whose innova- tion process is mainly related to learning by doing and learning by using (Cabral & Leiblein, 2001; Hollander, 1965). Also, these SMEs show a nonintensive R&D process (Clausen et al., 2012). Overall, the pattern of innovation of these SMEs resembles that described in Parisi et al. (2006), pointing out how R&D spending is greatly and positively associated with the introduction of new products, whereas fixed capital spending (on embodied knowledge) increases the likelihood of firms introducing process innovations, the latter being called the embodied hypothesis.

These SMEs present a rather weak capacity for absorption of external knowledge, due to weak in-house capabilities (Brunswicker & Vanhaverbeke, 2015; Heidenreich, 2009; Hervas-Oliver et al., 2011, 2014; Robertson et al., 2012). In this context, innovation is led by a nonintensive R&D process, and the external orientation to compensate for their lack of in- house capabilities is intensively based on the incorporation of new capital equipment from suppliers (Arundel et al., 2007; Edquist, Hommen, & McKelvey, 2001; Heidenreich, 2009; Lee et al., 2010; Parisi et al., 2006). In this context, the incorporation of embodied technology supplants the poor internal capabilities to innovate, becoming a hybrid source of capabilities that simultaneously assumes an internal and external character. In this chain of thought, embodied knowledge also substitutes for the low engagement in R&D. Therefore, we state the following hypothesis depicting the embodied knowledge acquisition by SMEs and their low R&D orientation:

Hypothesis 2 (H2): Process-oriented SMEs present weak in-house capabilities and a nonintensive R&D pattern, depending intensively on accessing to embo- died knowledge from suppliers.

Technology and organizational integration

To fully understand technological and organizational activities for process- oriented innovators, it is necessary to take into account organizational innovation capabilities (Damanpour, 2014; Hervas-Oliver et al., 2014; Hollen, Van Den Bosch, & Volberda, 2013). The reason is based on the fact that technological innovation and organizational process innovation are difficult to separate, in the sense that these activities usually occur in con- currence (Damanpour, 2014; Edquist et al., 2001; Ettlie & Reza, 1992). By organizational innovation, we mean "the implementation of a new organiza- tional method in a firm's business practices, workplace organization or external relations" (OECD, 2005, p. 51). Process innovation development usually requires organizational innovation concurrence, to the extent that these two innovation modes tend to overlap and coincide in many different yet intertwined activities (for example, Ettlie & Reza, 1992; Womack, Womack, Jones, & Roos, 1990). This concurrence would serve to reinforce both modes of innovation simultaneously (Damanpour, 2014; Damanpour,

Walker, & Avellaneda, 2009; Hollen et al., 2013). Consequently, the devel- opment of process technologies by process-oriented SMEs is associated with organizational innovation, as a complementary innovation mode (for exam- ple, Hollen et al., 2013). This conjunction builds a complex integration that supports and reinforces process innovation development. In other words, following Hervas-Oliver et al. (2014), the successful adoption of process technologies depends on the simultaneous introduction of appropriate orga- nizational innovation, to integrate technology into organization (Ettlie & Reza, 1992). This integration strengthens firms' internal capabilities, devel- oping processes, routines, and capabilities that are systemically reinforced by their simultaneous and synchronous integration and interrelationship. In the resource-based view of the firm (for example, Barney, 1991; Peteraf, 1993), it is stressed that a firm's unique internal resources are linked to a firm's performance. Following the RBV, the simultaneous introduction of process and organizational innovations, with all their associated processes, routines, tasks, and procedures, conforms a synergistic integration of distinct but related (technology and organizational, respectively) capabilities, forging a complex system of interactions and interrelationships that are difficult to imitate by competitors. This integrated and coherent system of related capabilities reinforces one another and can improve a firm's performance, due to the synergies obtained in the system (for example, Hervas-Oliver, Sempere-Ripoll, Boronat-Moll, & Rojas-Alvarado, 2018; Porter, 1996; Rivkin, 2000). This integration strengthens a firm's internal capability, subsequently reinforcing networking and thus accessing to more and diverse external knowledge because of better absorptive capacity (Cohen & Levinthal, 1990). Therefore, we expect that the simultaneous development of process and organizational innovation in SMEs strengthen SME internal capabilities. Thus, we posit the third hypothesis as follows:

Hypothesis 3 (H3): Process-oriented SMEs strengthen their internal capabilities by introducing organizational innovation, integrating technology into organization.

To sum up, and focusing our arguments on SMEs, therefore, we expect a high degree of heterogeneity and a continuum of different categories of process-oriented innovative SMEs. Overall, and according to the literature review, we posit that process-oriented SME open innovation is contingent on internal capabilities. That is to say, access to different external sources of knowledge differs depending on firms' internal capabilities to innovate. Additionally, we also point out that process-oriented innovation, per se, is not R&D intensive, especially among embodied technology–oriented SMEs whose external orientation compensates for their lack of in-house capabil- ities. All in all, we assume that SMEs configure a different set or variety of external sources of knowledge dependent on SMEs' internal capabilities to innovate (Brunswicker & Vanhaverbeke, 2015; van de Vrande et al., 2009).

Empirical design: Data, sample, and variables

The data used for our analysis originated from the EUROSTAT aggregated microdata[1] program, providing a coherent set of firm-level data. This survey is administered by EUROSTAT and is based on the core Eurostat Community Innovation Survey, described in the Oslo Manual (Organisation for Economic Co-operation and Development, 2005). Other studies working on the same topic of innovation also utilized CIS data for the UK (for example, Laursen & Salter, 2006) or Germany (for example, Heidenreich, 2009), among many others[2]. We worked on 3,348 SMEs (employing fewer than 250 employees) that recorded having introduced solely process innovation over the period 2004–2006 in Belgium (289), Spain (2,157), Portugal (662), and Norway (240). We focused on these countries because process innovators outnumber product ones (firms that engaged in either technological processes or technological product innova- tion, but not both) in Belgium, Portugal, and Spain. We also added Norway. See Table 1. Industries were identified based on the NACE 2-digit classification. Our sample includes both manufacturing and service SMEs[3].

Insert Table 1 here.

According to the framework developed and the hypotheses stated, we selected three dummy variables, available in Table 2, which describe the main inputs of process-oriented innovative SMEs and thus processed a cluster technique for finding preliminary SME categories. The BUYEQUIP variable refers to the acquisition of advanced machinery or other equipment, as well as computer hardware or software. This variable is important because process innovation has been defined mainly as something that occurs with the introduction of new technologies and equipment – that is to say, in accordance with the embodied knowledge hypothesis. The RDINT variable addresses internally generated or in- house R&D expenditures. The ORGANIZATION variable refers to organiza- tional innovations. See Table 2.

Insert Table 2 here

Regarding external sourcing or search strategies, the study operationalizes strategic types of (inbound) openness in process innovation in SMEs. We focused on external knowledge sourcing over the last three years (2004–2006) as regular interactions (External Sources

[1]Aggregated microdata supplied by Eurostat differ slightly from that directly accessible to each national statistical office across countries, as the latter are not aggregated.

[2] For instance, Hervas-Oliver, Sempere-Ripoll, Boronat-Moll, and Rojas (2015), Hervas-Oliver, Ripoll- Sempere, and Boronat-Moll (2016), De-Miguel-Molina, Hervás-Oliver, and Boix (2019) or Hervas-Oliver, Sempere-Ripoll, Estelles-Miguel, and Rojas-Alvarado (2019), among many others.

[3] For the sake of brevity, more available on request. With regard to the differences between manufacturing and service sectors, this study is grounded on an integration approach (Gallouj & Savona, 2009; Salter & Tether, 2006), assuming that both manufacturing and service sectors can be concurrently analyzed, albeit while respecting certain key differences.

variables) with Customers, Suppliers, Universities, Research Organizations, Competitors, Consultants and others (Conferences, Publications, and Associations). By focusing on these knowledge sources (External Sources), we addressed the external search strategies of firms or the external sources of knowledge they accessed. The CIS question- naire presents a 4-point Likert scale to capture the intensity of each source of knowledge as valuable information for each firm's innovation process. Both breadth and depth can then be characterized as a firm's openness to external search processes (Chesbrough, 2003), following the same procedures as Laursen and Salter (2006). Similarly, we controlled for performance, to assess how differing process-oriented innovative strategies pay off. Thus, perfor- mance variables are also shown in Table 2, capturing production and market-based effects. Each performance variable ranged from 0 (none) to 3 (high). We constructed one variable aggregating those performance variables into an innovation performance one, ranging from 0 to 21.

Methods and results

The methods utilized for the empirical analysis were the cluster technique, ANOVAS, and a double-truncated Tobit. We chose Tobit, or a censored regression model, to estimate linear relationships between variables when there was both left- or right-censoring in the dependent variable (innovation performance variable). Innovation focus studies have also used cluster analysis (a nonhierarchical one) such as Evangelista (2000) and Hollenstein (2003). Similarly, Evangelista and Vezzani (2010) also used cluster analysis with CIS data and Laursen and Salter (2006), measuring open innovation, also used a double-truncated Tobit with CIS data for the UK.

Tables 3 and 4 show the descriptive statistics and the correlation matrix, respectively.

Insert Table 3 here

Insert Table 4 here

A classification of SMEs by internal capabilities

We applied a multivariate analysis to the sample, using cluster (both hier- archical and nonhierarchical) methods, the latter based on K-means (Varimax rotation) techniques[4]. The key independent variables depicting internal capabilities from the hypothesis (RDINT, BUYEQUIP, ORGANIZATION) were then used to identify clusters of process-oriented innovators, obtaining three groups or clusters regarding internal capability to innovate, as shown in Table 5 and Figure 1.

Insert Figure 1 here.

Then, we applied ANOVA tests, with all variables showing statistically significant differences ($p<.01$) among the three identified groups.

Insert Table 5 here.

According to Table 5, the first group contains 1,393 firms (embodied SMEs; 41.16 percent of the total sample), the second group 1,359 (networking SMEs; 40.59 percent of the total sample) and the third group (advanced SMEs, 17.8 percent of the total sample) 596 firms. The first group is made up of companies who engage in process innovation by

[4] K=3 was selected as a result of the previous tests of the hierarchical cluster techniques, following (Hair, Anderson, Tatham, & Black, 1998) procedures for cluster analysis.

largely relying on investing in machinery or other equipment, showing a nonintensive R&D or organizational innovation process.
The second group (named networking SMEs), in contrast, is composed of firms that invest mainly in advanced equipment and integrate technology into organizational innovations. This group is not intensive with regard to R&D activities; instead, they acquire embodied knowledge and also strengthen the effectiveness of process innovations by developing organizational innovations to integrate process technologies in the organization. Then, the advanced group, the smallest, is characterized by a more intense R&D than previous ones, complementing it with organizational innovation, showing a nonintense use of external embodied knowledge.

SME open innovation
Once we have the internal capabilities developed in each category of SMEs, we add search strategies that capture external knowledge sourcing, extending our knowledge of the three groups and presenting a more complete innova- tive strategy. For this purpose, we use Internal and External Sources vari- ables. This application allows us to explore internal and external knowledge sourcing, focusing on the nature of diversity of innovation agents and differing flows of knowledge accessed by SMEs, relating them to the specific internal capabilities to innovate. See Table 6.

Insert Table 6 here.

As shown in Table 6, the highest source of innovation is that from internal means (Internal), reflecting information to innovate coming from internal sources of knowledge (different sections, departments, units, or plants), even higher than Suppliers, which is the second most used and accessed by process-oriented SMEs. As expected, Suppliers is the external source most used by the sample, indicating clearly how important for process innovation that type of knowledge is. After Suppliers, then Customers and Competitors follow, all agents from the supply chain, constituting one and all the mostly utilized. After the supply-chain agents, information from Conferences, Publications, and Associations are also greatly used by firms, even more intensively than those representing other more formal- based sources. Similarly, after Consultants, University, and Public Research Organizations (PRO) (science-based sources), representing a more formal and highly intense internal capability demand for integration, are the least used by firms in the sample.

Insert Table 7 here.

Then, in Table 7, broken down by different SME categories, we found a variety of patterns of open innovation, indicating clearly an association with internal capabilities characterized in different SME categories. With regard to embodied SMEs, it is clearly shown that these SMEs are the least open of all the firms in the sample, being mainly driven by Suppliers, albeit lower than the average of the sample. These SMEs score the least in all indicators. Their internal capabilities are just restricted to investing in new equipment, representing the traditional embo- died knowledge category and confirming the low internal capability and high dependence on Suppliers. In other words, we have identified an embodied-like group that is engaged in a supplier-driven mode of innovation, using Pavitt's classification (1984). Within this group, innovation activities are mainly centered on the acquisition of embodied knowledge showing an embodied technology strategy (Heidenreich, 2009; Parisi et al., 2006).

Apparently, the networking SMEs clearly are the most open firms, out- performing the rest of the categories, even the advanced, in all types of sources except those related to science (University and PRO): they score the highest in supply-chain (Suppliers, Customers, and Competitors), as well as in other sources such as Conferences, Publications, and Associations. Clearly, they are the ones achieving a high connection with the industrial sources of knowledge. With regard to their internal capabilities, these SMEs are devel- oping organizational innovation to strengthen process innovation and also investing in embodied knowledge.

Finally, the advanced group, those leading SMEs that invest more inten- sively in R&D and also use organizational innovation, present the highest score in science-based sources (Universities and PRO), even the highest in Consultants, but are not as open to the supply chain as the networking group. These firms substitute external knowledge by conducting more inter- nal R&D while the networking ones do the opposite. These firms can be oriented to R&D (Hölzl, 2009; Stam & Wennberg, 2009), developing rela- tively more diverse networking (Lee et al., 2010), even showing a high degree of interaction with universities and research organizations (for example, Brunswicker & Vanhaverbeke, 2015).

Accordingly, for roubstness checks, we also conducted ANOVA tests to strengthen evidence. As observed in Table 7, we conducted mean compar- isons of the main measures of external sources across different process- oriented SME categories. See Table 7. For the sake of brevity, all Scheffé tests are available on request.

When considering the breadth variable from Table 7, taking only the six most important external sources (Suppliers, Customers, Competitors, Consultants, PRO, and University; named breadth_6) added together (Cronbach's alpha 0.701; a firm with the highest value can take 18), we observe that the networking group outperforms all others, albeit, networking and the advanced group do not present statistical differences ($p > .1$), as both use on average all sources similarly. Both outperform the embodied group ($p < .01$). But when adding the nine (all sources, Cronbach's alpha 0.806: breadth_9) external sources, we do find differ- ences ($p < .01$) in favor of the networking group, which shows a higher degree of openness (breadth) than the advanced, being statistically significant (Sceffe pair comparison at $p < .05$). Regarding depth, results in Table 7 show how, generally, the networking group engages with more intensity (depth, Cronbach's alpha 0.749) with supply-chain sources (Suppliers, Customers, and Competitors). Finally, the innovative performance variable also shows differences ($p < .01$), favoring the networking group. See Table 7. In Figure 2 a graphic representation of the three groups is offered. See Figure 2.

Insert Figure 2 here.

Different openness and performance: What really pays off?

In this section, our study tests the differing impacts or innovation performance of the differing groups of SMEs, using ANOVA and regression methods. The effect of developing process innovation by SMEs is measured using performance indicators from Table 2. Our findings are shown in Table 7.

The results from ANOVA tests in Table 7 show that all the variables measuring cost are higher for the networking category and statistically significant at $p < .01$. Also, the variables capturing market performance (RANGE, QUAL AND MARK), present statistical differences (only FLEX and CAP do not show statistical differences). That is to say, there are statistical differences in performance, presenting higher values for the net- working group.

The results are revealing, as they indicate that the intermediate group of networking SMEs presents a higher performance than the advanced group. To reinforce findings, a double-truncated Tobit is also conducted on innovative performance variable (adding them up, Cronbach's alpha, 0.772), checking the relationship of the internal and external sources of knowledge on performance.

Insert Table 8 here.

In Table 8, Specification 1, capturing only internal capabilities, it is shown that internal capabilities are positive and statistically significant at $p < .01$ (RDINT, ORGANIZATION, and BUYEQUIP), except SIZE, which indicates that smaller firms outperform bigger ones for process innovative performance.

Then, we add external sources in Specifications 2, 3, and 4, improving the model in Table 8 and observing, across all specifications, that R&D turns out to be nonstatistically significant, being substituted by the extensive use of external sources. This result suggests that in process-oriented SMEs external sources are each and every one positively related to innovative performance, and their development makes R&D nonpositively related to performance: It is clearly a substitution effect in terms of Rammer et al. (2009), indicating that R&D efforts do not pay off in process-oriented SME. In Specification 2, the Breadth variable is statistically significant (0.118 at $p < .01$) and Specification 3 shows the same for Depth (0.245 at $p < .01$). With regard to external sources in Specification 4, all main external sources are positively related to innovation ($p < .01$), except for those that are scientific based: Universities and RTO, which are nonsignificant ($p > .1$); also Publications and Associations are nonsignificant. This result confirms previous findings, indicating that the supply-chain external sources (Suppliers 0.370, Customers 0.164, and Competitors 0.225, all at $p < .01$) are positively related to innovative performance, constituting the external sources most used by firms and also the ones with the highest impact on performance, with suppliers standing out. As shown above, evidence does reinforce the role of the supply-chain sources and minimizes the importance of others like Universities or RTO, less used and with less impact on performance. Finally, the Internal variable (capturing a source of knowledge) is also intensively used and directly related to performance, being always statistically significant at $p < .01$. Then, in Specification 5, we conduct a factor analysis on all the external sources of knowledge, obtaining two factors representing open innovation (KMO = 0.82; Variance explained 0.61): Industry (Supplier, Customer, Competitor, Conferences, Publications, and Associations variables) and Science (Consultant, RTO, University variables). As observed, both are statistically significant ($p < .01$), but clearly the Industry variable stands out with a 0.70 coefficient versus the 0.16 of the Science variable, showing comparatively how important the supply-chain external sources are for process- oriented innovation in SMEs over science-based (Universities and RTO) sourcing. See Table 8.

Insert Table 9 here.

Subsequently, we also split the sample into the three groups (embodied, net- working, advanced). In doing so, we try to get a more refined insight of the model across the three categories. In this new model, Tobit is also utilized across the three subsamples, omitting the internal capability variables so as not to duplicate effects (the split itself in the three categories is made up of the internal capabilities). In Table 9 these results are shown. Overall, the same results shown above in Table 8 are also observed in each category of embedded (Specifications 1 to 5), networking (6 to 10) and advanced (11 to 15).

Interestingly, the model perfectly replicates in each of the subsamples. In particular, we observe that the supply-chain provides the most important sources impacting positively performance. Remarkably, the variable Industry is consistently higher than Science across the three models (Specification 5, 10, and 15), but it is especially intense and higher than Science in the embodied group. Coefficients among groups were not compared because the subsamples are different. See Table 9.

Insert Table 10 here.

Insert Table 11 here.

To reinforce findings and seeking additional insights, four new double- truncated Tobit regressions are also run on two different (dependent) performance variables. We conducted a factor analysis (KMO 0.759, Chi-square at $p < .01$) over the effects variables, getting two factors or components. Then, adding up the individual variables within each component two dependent variables are con- structed: the market-based and the production-based performance. See Table A1 in Appendix for the components of the factor analysis. One factor addresses market- based innovative performance (effects on product range, quality, and market share variables; Cronbach's alpha, 0.77), and the other one refers to production-based innovative performance (effects on flexibility, capacity, costs and energy; Cronbach's alpha, 0.709), the latter depicting productivity effects. Tobit regressions and their results are showed in Tables 10 and 11. Overall, in Table 10, addressing productivity effects (production-based performance), we observe the same results previously depicted in Table 8. Findings suggest, as expected, that the embodied knowledge (BUYEQUIP) and Suppliers are strong indicators of production-based performance, as well as the ORGANIZATION variable. Similarly, supply-chain variables (Supplier, Customers, Competitors) are positively related to performance, and R&D activities do not pay off. Overall, Industry is stronger than the Science variable ($p < .01$). All these variables are statistically significant across Specifications 1 to 5. See Table 10.

In Table 11, however, results on market-based innovative performance present new and interesting insights, adding unpredicted fine-grained results that complement and enrich previous findings. In Table 11, for market-based performance indicators, we observe three important findings that support the inconclusive point of R&D activities found previously, especially those referred to the advanced group. R&D activities are positively related ($p < .01$) to market-based performance, consistently across all different specifications (coefficient 0.671, 0.382, 0.419, 0.371, 0.406 at $p > .01$, Table 11, Specifications 1 to 5, respectively). Then, the BUYEQUIP variable is nonsignificant in any specification in Table 11. In addition, the Suppliers variable is also nonsignificant in any specification of Table 11, albeit the supply chain (Customers and Competitors) still positively strong and significant. Industry is still stronger than Science, both variables being positive and significant ($p < .01$). These effects hold only for the market-based performance, and do not occur for the production-based performance. Overall, these results mean that when process development is oriented to improve products (market-based effects, such as better product quality), rather than productivity, then R&D activities contribute to performance and the traditional process-oriented activities (embodied knowledge or Suppliers) do not pay off. See Table 11. On the contrary, when process-development innovations are aimed at improving productivity (production-based performance), then R&D activities do not pay off and the traditionally associated process-

based indicators (embodied knowledge, suppliers, organization, and so forth) are the key variables explaining performance, as shown in Table 10.
With regard to the different results from the groups of firms, as we can see in Table 12, regressing external sourcing variables on market-based performance, results hold except for a key issue already pointed out. For the networking and the advanced group, coherently with the results displayed in Table 11, Suppliers are statistically nonsignificant (see Table 12, specifica- tions 9 and 14), being only statistically significant for the embodied group (see Table 12, Specification 4). This is coherent with the fact that, when measuring market-based performance (process innovation aimed at improving product effects) the embodied hypothesis does not work and the R&D activities pay off, similar to results from Table 11. The rest of the points remain similar, being Industry (0.798, $p < .01$) stronger than Science (0.302, $p < .01$) in Specification 5, the latter persistently observed in Specifications 10 and 15 in Table 12.

Insert Table 12 here

Insert Table 13 here.

Then, in Table 13, regressing external sourcing variables on production-based performance across the groups of firms, results point out the expected results in coherence with Table 10 (with a nonsignificant R&D and a positive and significant BUYEQUIP and ORGANIZATION), being Suppliers a positive and significant source (see Specifications 4, 9, and 14 in Table 13). Also, results are similar to those from Table 9 explaining external sourcing on innovative performance. As expected, Industry shows systematically higher coefficients than Science (Specifications 5, 10, and 15 in Table 13). These results are persistently visible across all groups (embodied, networking, and advanced), confirming and reinforcing previous results from Tables 8–10. See Table 13.

Summary of results

First, for process-oriented SMEs, encompassing the full sample of process- oriented SMEs, Suppliers become the relatively most used external source of innovation, along with the rest of the supply-chain actors (Customers and Competitors). Consultants, Universities, and RTO are the least used external sources. In fact, the higher coefficient goes for Suppliers (0.370, $p < .01$, then, Competitors 0.22 and Customers 0.164, Specification 4, Table 8). Industry's coefficient (representing the entire supply-chain sourcing) impacts positively on performance 0.7, while Science (scientific-based sourcing) impact accounts for just 0.16 (both $p < .01$, Table 8, Specification 5). This pattern is also observed in the Tables 9, 10, and 13. These results confirm H1, linking primarily supply-chain sourcing to process-oriented SMEs, reinforcing the view that industry-based sourcing is more important for process innovators, rather than scientific or science-based linkages. Results hold for production- based performance, but do not for market-based performance (as observed in Table 11, Specification 4 and Table 12, Specification 9 and 14). Our focus on process innovators brings embodied technology and Suppliers to the fore- front. Regardless of the group identified, Suppliers are always the preferred external source for process-oriented SMEs. Having said that, it is also important to point out that all sources of external knowledge accessed are relevant for firms' innovation strategies: The key difference among groups, however, is their intensity on the different sources.
Second, process-oriented SMEs present a high reliance on external sources of knowledge in the form of acquired embodied technology that is a substitute for (the lack of) internal

capabilities, confirming literature (for example, Heidenreich, 2009), in line with the embodied knowledge hypothesis (for example, Parisi et al., 2006), confirming H2. The BUYEQUIP variable is the strongest one in all specifications (coefficient 0.458, 0.518, 0.533, 0.41, .0466, all $p < .01$, from Specification 1 to 5 respectively, Tables 8 and 10), versus ORGANIZATION's or R&D's coefficients. In Tables 8 and 10 R&D activities do not pay off, as we measure innovative performance or production-based performance. R&D activities, however, are positive and statistically significant in Table 11 (Specifications 1 to 5), contradicting H2 when measuring market-based performance. Our results on open innovation for process development differ remarkably from those based on product innovation mentioned in the literature. As a matter of fact, Grimpe and Sofka (2009) found that investments in R&D pay off if they are combined with a search pattern that targets market knowledge (customers and competitors) or technological knowledge (universities and suppliers). The advanced group, however, develops its technological capabilities through an intense investment in in-house R&D and organizational innovations, configuring high-order capabilities that potentially substitute for external sources and are supporting a stronger absorptive capacity. This pattern is typically indicative of high-growth firms (for example, Hölzl, 2009), showing also a propensity to source from science-based sources (Universities and PRO) and, especially, Consultants, becoming relatively less engaged with the supply chain. This advanced group is clearly interested in accessing novelty and new trends by engaging science-based sources such as university-industry rela- tionships. All in all, these results clearly confirm H2, remarking that process- oriented SMEs present clearly weak in-house capabilities, are nonintensive in R&D activities, and primarily depend on embodied knowledge from suppliers, except for the advanced group that differs and when measuring market- based performance. Thus, the fact that more advanced firms can be oriented to R&D is compatible with existing literature on SMEs (for example, Hölzl, 2009; Stam & Wennberg, 2009). As mentioned above, as our sample is constituted by process-oriented SMEs, totally differing from those high- growth and product-based settings; therefore, the results are not contradictory, but complementary because they are addressing differing types of SMEs. Rather than confronting or pointing out opposite findings with those studies focused on product innovation, our results are complementary and compatible with previous studies with differing results, as they implicitly refer to different categories of SMEs and their related innovative strategies.

Third, the integration of process technology and organization pays off. The ORGANIZATION variable is positively related to performance, showing statistically significant effects across all specifications (0.334, 0.271, 0.278,
0.266, 0.266 from Specification 1 to 5, respectively, all at $p < .01$, Table 8; also in Tables 10 and 11, across all specifications). In this chain of thought, the networking SMEs present better internal capabilities from that integration of technology and organization, showing a particular focus on their supply chain. It also accounts for the highest degree of openness and intensity, presenting a better performance than the advanced group. Findings about the networking group (which is a process-oriented non-R&D category) are also coincident with the findings of Rammer et al. (2009), which point out that SMEs rely heavily on external knowledge such as that embodied in capital formation or management practices that sometimes even substitute for formal R&D. In short, those SMEs that integrate technology and organization build up better high-order capabilities from a synergistic integration. This confirms H3.

Fourth, open innovation strategy drives performance. Although all external knowledge sources are important, those referring to the supply chain matter the most for process-oriented innovators and impact strongly on firms' performance indicators.

Additionally, it is shown how each different performance indicator (production-based versus market-based) of innovation presents fine-grained insights that solve that apparent contradiction on the effect of R&D. For process-oriented SMEs, R&D works and positively impacts on performance when measured by product effects (market-based performance): Process innovation seeking to accomplish better products is influenced by R&D activities, and the embodied knowledge and the Supplier sourcing present nonsignificant effects, as shown in Tables 11 and 12. On the contrary, when measuring productivity (production-based performance), R&D is not related to performance and Supplier and embodied knowledge take the lead, as shown in Tables 8, 10, and 13.

Conclusions

This article investigates inbound open innovation in process-oriented SMEs and focuses on the nature of external knowledge sourcing and the internal capabilities required. Focusing on 3,348 process-oriented SMEs in Europe, this article deciphers their open innovation strategy. In doing so, this study responds to the call by Chesbrough and Bogers (2014) and specifically addresses that gap of external knowledge sourcing for process-oriented SMEs. This study empirically identifies key external sources of SME innovation for process technologies and shows how open innovation is linked to SME performance, highlighting an important distinction to the existing literature focused on open innovation for product development. In short, this study's results confirm the three stated hypotheses, showing that process- oriented SMEs show a pattern of external knowledge sourcing primarily focused on industry-based (supply-chain) linkages, and less intensive on scientific-based sources. Process-oriented SMEs present, generally, a lack of in-house capabilities and strong dependence on accessing to embodied knowledge from suppliers, being less oriented to perform R&D activities. Also, the integration of technology and organization develops relatively better in-house capabilities. These conclusions, however, depend on using market-based versus production-based performance. As such, R&D pays off when process-oriented SMEs are aimed at improving product effects (market-based performance), rather than improving productivity (production- based performance). In this particular case, Suppliers do not constitute a key source of external knowledge (except for the embodied group) and the embodied knowledge is not a key driver of process innovation. Beyond this nuance, our general results are consistent when measuring SMEs' process innovation aimed at improving productivity (production-based performance). Therefore, process-oriented SMEs aimed at improving productivity (production-based performance) comply with our arguments, opening a new research avenue on the study of SME open innovation.

Overall, our conclusions shed light on the overlooked phenomenon of process-based SME open innovation. First, there are different taxonomies of external knowledge sourcing for process-oriented SMEs, and each category represents a distinct mix of external interactions and flows of knowledge from different yet related agents, observing different propensities to interact with them. The combination of internal and external sources to innovate presents a diverse set of innovation strategies: an embodied group, mainly interacting with suppliers and showing low internal capability to innovate and dependent on embodied technology acquisition; a networking group mostly engaged in interactions with the supply chain and showing the highest degree of openness and innovative performance, and a nonintensive R&D pattern; and an advanced group that presents a high degree of openness and higher propensity to interact with Consultants and scientific sources (Universities and PRO), along with an intensive R&D pattern. Second, this diverse set or distinct mixture of external sources of knowledge are related to SMEs' innovative performance. Complementarily, the supply-chain external sources are the ones paying off the most in terms of innovative performance, outperforming other scientific-based (and Consultants) external sources. Third, focusing on process innovation, R&D is not the norm and it does not facilitate the relatively highest breadth nor the depth. In fact, it does not consistently make a difference in performance. On the contrary, a pattern of nonintensive R&D innovation opens the most and presents a relatively higher intensity with external sources, outperforming the rest of the categories.

Implications and limitations

This study has implications for scholars studying open innovation in small firms. First, process innovation strategies deserve to be given more attention, beyond the well-researched product-based open innovation. Second, process- oriented SMEs are not always intensive in R&D. Third, this study confirms others (for example, Brunswicker & Vanhaverbeke, 2015) that point out how heterogeneous configurations of external knowledge sources are closely dependent on firms' internal capabilities to innovate. These outputs need to be considered in further investigations.

The implications of this article for practitioners and policymakers are also relevant. Managers, on the one hand, must maximize enterprise performance by engaging in open innovation that better fits their internal capabilities. A manager undertaking process-oriented innovation in SMEs needs to pay attention to all related organizational innovation activities for integrating technology into the organization and should also understand the importance of embodied technology. Similarly, managers need to know how relying only on embodied technology limits options to innovate. Policymakers, on the other hand, need to pay attention to the different external knowledge sourcing that process-oriented SMEs develop, incorporating specific open innovation configurations in the policy mix, understanding clearly that product and process orientations bring differences for accessing external knowledge. To best capture innovation in SMEs, process innovation and process-dedicated or -oriented SMEs need to be on the research agenda and part of policymaking efforts: One-size-fits-all does not work for SMEs, nor for those that are process oriented. Renewal of equip- ment, organizational innovation, and promotion of networking, beyond classical R&D initiatives, need to be considered. Limitations to search strategies for accessing public research organizations or universities also need to be assumed. This study presents limitations. First, the sample is limited by excluding those process innovators that are coupled with product innovations, due to our isolation mechanism explained in the Methodology section, therefore omitting those that conduct process innovation in tandem with product innovation. By reducing the sample to firms with only process innovations, there might be a bias in understanding how open innovation in process technology works, as the majority of firms do both product and process innovation in tandem. The reason to select only those conducting or introducing solely process innovation is based on the aim of isolating the external sources (open innovation) that are devoted only to process innovation. Firms simultaneously introducing process and product are not the setting for doing so, as there is no method or strategy to identify external sources devoted primarily for developing product or process innovations. Therefore, our empirical strategy permits us to isolate the external sources (open innovation) for process innovation, aligning our study's objective and our sample selection. In addition, our sample may suffer from the fact that firms may undertake process and product or even product innovation in the previous or subsequent periods of the one we chose (2004–2006). Second, our findings are limited to specific European countries (Spain, Portugal, Belgium, and Norway) that are not R&D intensive. Furthermore, the results are also limited by the time span used (three-year period). For future studies, a more in-depth analysis of the role of single process innovators should be carried out by especially comparing more countries within Europe, thus evaluating the generalization of this study's results and comparing product innovators.

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TABLES AND FIGURES

Table 1. Country and type of innovation in the EU-27.

GEO/TYPE_INN	Total firms	Product and/or process innovative	Product innovative firms only	Process innovative firms only
Belgium	14,523	7,580	1,573	1,944
Spain	82,432	27,699	5,623	11,664
Portugal	21,254	8,774	1,503	3,346
Norway	8,864	3,149	1,092	593

Source: https://ec.europa.eu/eurostat/web/science-technology-innovation/overview.

Table 2. Variables used for process-oriented SMEs

BUYEQUIP	Whether a firm acquires machinery or other equipment, or computer hardware or software.	Dummy (0–1)
RDINT	Whether a firm has developed in-house R&D by investing in R&D expenditures.	Dummy (0–1)
ORGANIZATION	Whether a firm has introduced at least one of the following organizational innovations: new business practices in the work management or processes of the company; new knowledge management systems; new management methods of the work place; new methods of management of external relationships.	Dummy (0–1)
SIZE (control variable)	<50 employees (0), 50–250 (1)	Dummy (0–1), provided by the CIS data
INTERNAL	INTERNAL: importance given to the degree which the firm uses internal knowledge sources for innovation	0-3

	activities, 0–3 continuous variable (degree of use of the internal knowledge source for innovation: 1 little importance; 2 intermediate importance; 3 much importance; 0 otherwise).	
EXTERNAL SOURCES	Importance given to the degree to which the firm uses external knowledge sources: Customers, Competitors, Suppliers, Consultants, Universities, Research Organizations and Technology Centers (RTO), Conferences, Publications and Professional Associations. Single variables scaled from 0 to 3 (degree of use of the industrial knowledge source for innovation: 1 little importance; 2 intermediate importance; 3 much importance; 0 otherwise).	0-3
PERFORMANCE VARIABLES		
EF_PRODUCTION_FLEXIBILITY (FLEX)	Innovation effects on higher flexibility in production or service delivery.	0-3 (0 is none, 1 is low, 2 intermediate and 3 is high)
EF_PRODUCTION_CAPACITY (CAP)	Innovation effects on reduced labor cost per produced unit.	0-3
EF_PRODUCTION_COSTLAB	Innovation effects on using less materials and energy per produced unit.	0-3
EF_PRODUCTION_MAT_ENERGY (MAT_ENER)	Innovation effects on using less materials and energy per produced unit.	0-3
EF_PRODUCT_RANGE (RANGE)	Innovation effects on providing a broader range of goods or services.	0-3
EF_PRODUCT_MARKET (MARK)	Innovation effects on entering into new markets or increasing market share.	0-3
EF_PRODUCT_QUALITY (QUAL)	Innovation effects on higher quality of products.	0-3

Source: Author, from Oslo Manual (2005) and CIS (2006) questionnaire.

Table 3. Descriptive statistics.

Variable	Mean	Std. Dev.	Min.	Max.
SIZE	0.376	.484	0	1
BUYEQUIP	0.689	.462	0	1
RDINT	0.366	.481	0	1
ORGANIZATION	0.580	.493	0	1
INTERNAL	1.902	1.068	0	3
BREADTH_6	5.674	3.760	0	18
BREADTH_9	8.448	5.741	0	27
DEPTH	2.880	2.313	0	9
SUPPLIER	1.724	1.037	0	3
CUSTOMERS	1.237	1.101	0	3
COMPETITOR	1.045	1.074	0	3
CONSULTANT	0.772	1.025	0	3
UNIVERSITY	0.503	0.916	0	3
RTO	0.389	0.802	0	3
CONFERENCES	1.040	1.053	0	3
PUBLICATIONS	0.949	1.022	0	3
ASSOCIATIONS	0.836	1.009	0	3

INNOVATION PERFORMANCE	9.765	4.864	0	21

Table 4. Correlation matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	SIZE	1.00																
2	BUYEQUIP	−0.04	1.00															
3	RDINT	0.10*	−0.18*	1.00														
4	ORGANIZATION	0.05	0.01	0.13*	1.00													
5	INTERNAL	0.05	−0.11*	0.22*	0.11*	1.00												
6	BREADTH_6	0.03	0.03	0.18*	0.16*	0.16*	1.00											
7	BREADTH_9	0.03	0.04	0.19*	0.18*	0.14*	0.92*	1.00										
8	DEPTH	0.01	0.05	0.16*	0.16*	0.10*	0.84*	0.93*	1.00									
9	SUPPLIER	0.01	0.14*	−0.06*	0.09*	0.05	0.44*	0.38*	0.35*	1.00								
10	CUSTOMERS	−0.01	0.01	0.16*	0.09*	0.18*	0.66*	0.61*	0.57*	0.15*	1.00							
11	COMPETITOR	0.01	0.06*	0.06*	0.13*	0.07*	0.69*	0.66*	0.62*	0.19*	0.53*	1.00						
12	CONSULTANT	0.06	−0.04	0.18*	0.13*	0.13*	0.67*	0.61*	0.55*	0.14*	0.26*	0.32*	1.00					
13	UNIVERSITY	0.04	−0.03	0.21*	0.08*	0.11*	0.65*	0.61*	0.54*	0.05	0.224*	0.24*	0.41*	1.00				
14	RTO	0.03	−0.03	0.14*	0.06*	0.06*	0.65*	0.62*	0.55*	0.07*	0.22*	0.25*	0.42*	0.68*	1.00			
15	CONFERENCES	−0.01	0.05	0.14*	0.14*	0.06	0.47*	0.70*	0.68*	0.17*	0.33*	0.36*	0.27*	0.30*	0.31*	1.00		
16	PUBLICATIONS	0.02	0.01	0.17*	0.15*	0.08*	0.50*	0.74*	0.70*	0.16*	0.34*	0.38*	0.32*	0.35*	0.35*	0.66*	1.00	
17	ASSOCIATIONS	0.02	0.04	0.09*	0.14*	0.03	0.51*	0.72*	0.68*	0.14*	0.33*	0.40*	0.35*	0.34*	0.39*	0.53*	0.61*	1.00
18	PERFORMANCE	−0.05	0.07*	0.10*	0.08*	0.21*	0.40*	0.41*	0.38*	0.23*	0.36*	0.34*	0.22*	0.16*	0.17*	0.29*	0.28*	0.25*

*$p < 0.01$.

Table 5. Means from the cluster classification.

	Embodied	Networking	Advanced
RDINT	0.21	0.38	0.50
BUYEQUIP	0.99	0.98	0.03
ORGANIZATION	0.02	0.98	0.58

Figure 1. Groups of firms from cluster analysis.

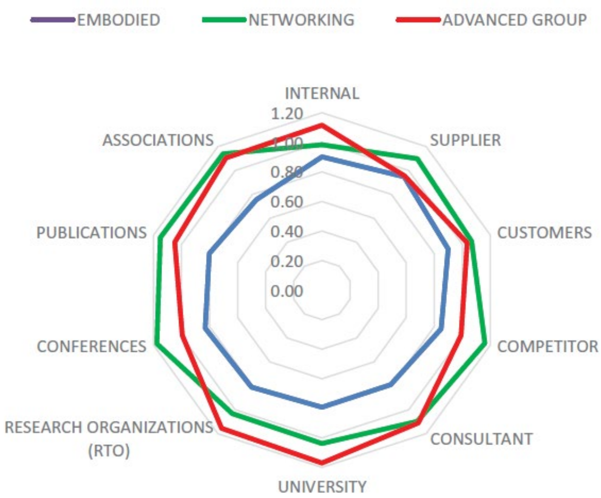

Table 6. External sources most used in the sample.

SAV VARIABLES	TOTAL N= 3348	
EXTERNAL SOURCES VARIABLES	MEAN	Std. Dev.
INTERNAL	1.91	1.067
SUPPLIER	1.74	1.029
CUSTOMERS	1.25	1.099
COMPETITOR	1.06	1.076
CONFERENCES	1.05	1.055
PUBLICATIONS	0.96	1.024
ASSOCIATIONS	0.84	1.012
CONSULTANT	0.78	1.028
UNIVERSITY	0.51	0.918
RESEARCH ORGANIZATION (RTO)	0.39	0.806

Souce: Authors' own.

Table 7. External sources and performance and differences across taxonomies.

	EMBODIED (E)	NETWORKING (N)	ADVANCED (A)		
Variables	Mean (S.d.)	Mean (S.d.)	Mean (S.d.)	F(sig)*	Interpretation
INTERNAL	1.77(1,136)	1.93(1.01)	2.19(0.96)	33.34	A > N > E
				(0.00)	
BREATH_6	5.03(3.69)	6.30(3.63)	6.03(3.79)	43.39	N > A > E
				(0.00)	
BREATH_9	7.35(5.59)	9.67(5.53)	8.97(5.67)	60.84	N > A > E
				(0.00)	
DEPTH	2.46(2.23)	3.31(2.30)	2.9(2.3)	49.45	N > A > E

				(0.00)	
Innovative Performance	9.61(4.96)	10.42(4.67)	9.32(4.67)	17.27	N > E > A
				(0.00)	

Statistically significant at *$p < 0.01$; ** $p < 0.05$; BREADTH_6 Cronbach's alpha = 0.701; BREADTH_9 Cronbach's alpha = 0.806; DEPTH: Cronbach's alpha 0.772. Bold means that the values are the highest.

Figure 2. Graphic visualization of open innovation across groups.

Table 8. Tobit regression, explaining internal and external variables on performance for process- oriented SMEs.

	Spec. 1	Spec.2	Spec.3	Spec.4	Spec.5
SIZE	−0.0466 (0.125)	−0.111 (0.121)	−0.0789 (0.122)	−0.0899 (0.120)	−0.0832 (0.120)
RDINT	0.272** (0.124)	−0.0855 (0.124)	−0.0380 (0.124)	0.00670 (0.126)	−0.0460 (0.124)
BUYEQUIP	0.458*** (0.139)	0.518*** (0.134)	0.533*** (0.135)	0.410*** (0.135)	0.466*** (0.135)
ORGANIZATION	0.334*** (0.0214)	0.271*** (0.0213)	0.278*** (0.0215)	0.266*** (0.0213)	0.266*** (0.0213)
INTERNAL		0.350*** (0.0619)	0.371*** (0.0623)	0.339*** (0.0622)	0.353*** (0.0618)
BREATH_9		0.118*** (0.0118)			
DEPTH			0.245*** (0.0289)		
SUPPLIER				0.370*** (0.0622)	
CUSTOMERS				0.164** (0.0667)	
COMPETITOR				0.225*** (0.0686)	
CONSULTANT				0.0554 (0.0636)	
UNIVERSITY				−0.0497 (0.0863)	
RTO				0.0875 (0.0985)	
CONFERENCES				0.127*	

				(0.0748)	
PUBLICATIONS				0.128 (0.0825)	
ASSOCIATIONS				0.0396 (0.0754)	
INDUSTRY					0.701*** (0.0663)
SCIENCE					0.164*** (0.0589)
COUNTRY dummies	YES	YES	YES	YES	YES
INDUSTRY dummies	YES	YES	YES	YES	YES
Intercept	2.792*** (0.298)	1.393*** (0.314)	1.639*** (0.313)	1.000*** (0.324)	2.434*** (0.309)
No. observations	3,348	3,348	3,348	3,348	3,348
No. left-censured observations	49	48	48	48	48
No. right-censured observations	0	0	0	0	0
Pseudo-R^2	0.126	0.185	0.174	0.199	0.190
Log likelihood	−4140.5	−4095.28	−4105.1	−4089.3	−4089.1
Chi-square	1477.2	1551.3	1531.454	1569.21	1558.37

All specifications significant at $p < 0.01$; ***$p < 0.01$;**$p < 0.05$;*$p < 0.1$

Table 9. Tobit regression, explaining internal and external variables on performance for process-oriented SMEs across the three identified clusters.

	EMBODIED					NETWORKING					ADVANCED				
	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5	Spec. 6	Spec. 7	Spec. 8	Spec. 9	Spec. 10	Spec. 11	Spec. 12	Spec. 13	Spec. 14	Spec. 15
SIZE	−0.718*** (0.204)	−0.765*** (0.195)	−0.705*** (0.197)	−0.726*** (0.195)	−0.732*** (0.194)	−0.143 (0.153)	−0.203 (0.148)	−0.150 (0.149)	−0.157 (0.148)	−0.183 (0.148)	−0.0935 (0.188)	−0.125 (0.181)	−0.129 (0.182)	−0.118 (0.181)	−0.0671 (0.181)
INTERNAL	0.538*** (0.0839)	0.407*** (0.0815)	0.448*** (0.0818)	0.419*** (0.0825)	0.417*** (0.0810)	0.557*** (0.0762)	0.439*** (0.0750)	0.466*** (0.0751)	0.435*** (0.0754)	0.440*** (0.0746)	0.522*** (0.0905)	0.377*** (0.0890)	0.400*** (0.0892)	0.378*** (0.0892)	0.390*** (0.0889)
BREATH_9		0.170*** (0.0183)					0.134*** (0.0145)					0.140*** (0.0161)			
DEPTH			0.389*** (0.0470)					0.296*** (0.0351)					0.323*** (0.0406)		
SUPPLIER				0.362*** (0.0893)					0.444*** (0.0789)					0.326*** (0.0861)	
CUSTOMERS				0.189* (0.1000)					0.286*** (0.0802)					0.186* (0.0983)	
COMPETITOR				0.391*** (0.108)					0.160* (0.0820)					0.399*** (0.110)	
CONSULTANT				0.194* (0.116)					0.0835 (0.0784)					0.102 (0.0990)	
UNIVERSITY				−0.0199 (0.167)					−0.138 (0.104)					−0.0395 (0.129)	
RTO				−0.110 (0.191)					0.102 (0.119)					0.156 (0.155)	
CONFERENCES				0.163 (0.125)					0.201** (0.0911)					−0.0166 (0.118)	
PUBLICATIONS				0.232 (0.145)					0.131 (0.0994)					0.0848 (0.132)	
ASSOTIATIONS				0.0441 (0.131)					0.0833 (0.0913)					0.0992 (0.123)	
INDUSTRY					1.010*** (0.101)					0.836*** (0.0821)					0.808*** (0.0922)
SCIENCE					0.189* (0.102)					0.156** (0.0713)					0.227** (0.0886)
COUNTRY	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Intercept	5.368*** (0.519)	4.093*** (0.515)	4.438*** (0.514)	3.747*** (0.529)	5.579*** (0.494)	4.742*** (0.428)	3.635*** (0.432)	3.957*** (0.428)	2.905*** (0.456)	4.750*** (0.418)	4.060*** (0.331)	3.071*** (0.339)	3.354*** (0.333)	2.799*** (0.349)	4.248*** (0.322)
Nº of observations	1,393	1,393	1,393	1,393	1,393	1,359	1,359	1,359	1,359	1,359	596	596	596	596	596
Nº left censored observations	10	10	10	10	10	6	6	6	6	6	10	13	13	13	13
Nº right censored observations	9	9	9	9	9	10	10	10	10	10	9	8	8	8	8
Pseudo-R2	0.061	0.140	0.125	0.161	0.152	0.044	0.102	0.092	0.124	0.113	0.038	0.104	0.094	0.124	0.109
Log likelihood	−2211.8	−2189.7	−2194.6	−2179.9	−2186.3	−2852.1	−2824.7	−2830.9	−2813.6	−2817.7	−2041.5	−2020.2	−2024.9	−2013.5	−2016.7
Chi-square	724.2***	768.5***	758.8***	*783.4******	770.7***	901.5***	956.2***	943.9***	973.1***	964.9***	642.3***	684.8***	675.45***	698.3***	691.9***

All specifications significant at $p < 0.01$; ***$p < 0.01$;**$p < 0.05$;*$p < 0.1$; Internal capability variables are not included because they are classifying the three identified groups.

Table 10. Tobit regression for process-oriented SMEs on production-based innovative performance.

	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
SIZE	−0.276*** (0.0835)	−0.111 (0.121)	−0.0789 (0.122)	−0.0899 (0.120)	−0.0832 (0.120)
RDINT	0.109 (0.0934)	−0.0855 (0.124)	−0.0380 (0.124)	0.00670 (0.126)	−0.0460 (0.124)
BUYEQUIP	0.406*** (0.0859)	0.518*** (0.134)	0.533*** (0.135)	0.410*** (0.135)	0.466*** (0.135)
ORGANIZATION	0.110*** (0.0148)	0.271*** (0.0213)	0.278*** (0.0215)	0.266*** (0.0213)	0.266*** (0.0213)
INTERNAL	0.174*** (0.0428)	0.350*** (0.0619)	0.371*** (0.0623)	0.339*** (0.0622)	0.353*** (0.0618)
BREATH_9		0.118*** (0.0118)			
DEPTH			0.245*** (0.0289)		
SUPPLIER				0.370*** (0.0622)	
CUSTOMERS				0.164** (0.0667)	
COMPETITOR				0.225*** (0.0686)	
CONSULTANT				0.0554 (0.0636)	
UNIVERSITY				−0.0497 (0.0863)	
RTO				0.0875 (0.0985)	
CONFERENCES				0.127* (0.0748)	
PUBLICATIONS				0.128 (0.0825)	
ASSOCIATIONS				0.0396 (0.0754)	
INDUSTRY	0.683*** (0.0459)				0.701*** (0.0663)
SCIENCE	0.211*** (0.0408)				0.164*** (0.0589)
INDUSTRY dummies	YES	YES	YES	YES	YES
COUNTRY dummies	YES	YES	YES	YES	YES
Intercept	0.354* (0.214)	1.393*** (0.314)	1.639*** (0.313)	1.000*** (0.324)	2.434*** (0.309)
Nº of observations	3,348	3,348	3,348	3,348	3,348
Nº left censored observations	49	48	48	48	48
Nº right censored observations	55	55	55	55	55
Pseudo-R2	0.1514	0.1592	0.1572	0.1612	0.1601
Log likelihood	−4140.54	−4095.28	−4105.1	−4083.73	−4089
Chi-square	1477.29	1551.03	1531.39	1569.07	1558.5

*** p < 0.01, ** p < 0.05, * p < 0

Table 11. Tobit regression for process-oriented SMEs on market-based innovative performance.

	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
SIZE	−0.247*** (0.0885)	−0.298*** (0.0840)	−0.267*** (0.0847)	−0.250*** (0.0824)	−0.276*** (0.0835)
RDINT	0.671*** (0.0883)	0.382*** (0.0861)	0.419*** (0.0867)	0.371*** (0.0864)	0.406*** (0.0859)
BUYEQUIP	0.110 (0.0986)	0.149 (0.0934)	0.166 (0.0943)	0.132 (0.0926)	0.109 (0.0934)
ORGANIZATION	0.169*** (0.0152)	0.116*** (0.0148)	0.121*** (0.0150)	0.105*** (0.0146)	0.110*** (0.0148)
INTERNAL		0.173*** (0.0431)	0.191*** (0.0434)	0.143*** (0.0425)	0.174*** (0.0428)
BREATH_9		0.116*** (0.00818)			
DEPTH			0.257*** (0.0202)		
SUPPLIER				0.0171 (0.0426)	
CUSTOMERS				0.398*** (0.0456)	
COMPETITOR				0.244*** (0.0469)	
CONSULTANT				0.0586 (0.0435)	
UNIVERSITY				−0.0531 (0.0591)	
RTO				0.133** (0.0674)	
CONFERENCES				0.233*** (0.0512)	
PUBLICATIONS				−0.0185 (0.0565)	
ASSOCIATIONS				0.00380 (0.0516)	
INDUSTRY					0.683*** (0.0459)
SCIENCE					0.211*** (0.0408)
INDUSTRY dummies	YES	YES	YES	YES	YES
COUNTRY dummies	YES	YES	YES	YES	YES
Intercept	0.404* (0.211)	−0.669*** (0.219)	−0.453** (0.219)	−0.689*** (0.222)	0.354* (0.214)
Nº of observations	3,348	3,348	3,348	3,348	3,348
Nº left censored observations	603	600	600	600	600
Nº right censored observations	0	0	0	0	0
Pseudo-R2	0.3804	0.3873	0.384	0.394	0.3887
Log likelihood	−2435.99	−2406.16	−2419.49	−2378.86	−2399.81
Chi-square	2991.49	3042	3015.93	3093.21	3051.32

*** p < 0.01, ** p < 0.05, * p < 0

Table 12. Tobit regression, explaining external sourcing variables on market-based performance for process-oriented SMEs across the three identified clusters.

	EMBODIED					NETWORKING					ADVANCED				
	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5	Spec. 6	Spec. 7	Spec. 8	Spec. 9	Spec. 10	Spec. 11	Spec. 12	Spec. 13	Spec. 14	Spec. 15
SIZE	−0.109 (0.135)	−0.150 (0.125)	−0.0984 (0.127)	−0.118 (0.125)	−0.133 (0.125)	−0.133 (0.125)	−0.239** (0.103)	−0.185* (0.104)	−0.207** (0.101)	−0.230** (0.103)	−0.181 (0.118)	−0.227* (0.119)	−0.230* (0.120)	−0.187 (0.117)	−0.181 (0.118)
INTERNAL	0.297*** (0.0555)	0.184*** (0.0521)	0.221*** (0.0528)	0.164*** (0.0526)	0.189*** (0.0520)	0.189*** (0.0520)	0.251*** (0.0523)	0.274*** (0.0524)	0.209*** (0.0519)	0.251*** (0.0520)	0.181*** (0.0579)	0.180*** (0.0583)	0.204*** (0.0589)	0.147** (0.0577)	0.181*** (0.0579)
BREATH_9		0.148*** (0.0117)					0.139*** (0.0101)					0.124*** (0.0106)			
DEPTH			0.328*** (0.0303)					0.323*** (0.0245)					0.277*** (0.0268)		
SUPPLIER				0.174*** (0.0570)					−0.0273 (0.0543)					0.0661 (0.0557)	
CUSTOMERS				0.385*** (0.0638)					0.442*** (0.0552)					0.401*** (0.0636)	
COMPETITOR				0.154** (0.0688)					0.270*** (0.0564)					0.251*** (0.0714)	
CONSULTANT				0.155** (0.0737)					0.109** (0.0539)					0.0716 (0.0640)	
UNIVERSITY				0.0531 (0.107)					−0.0520 (0.0718)					0.0655 (0.0835)	
RTO				0.0748 (0.122)					0.144* (0.0817)					−0.0435 (0.1000)	
CONFERENCES				0.183** (0.0796)					0.235*** (0.0627)					0.228*** (0.0764)	
PUBLICATIONS				0.109 (0.0926)					0.0111 (0.0684)					0.0641 (0.0854)	
ASSOTIATIONS				0.0123 (0.0837)					0.0497 (0.0628)					−0.0449 (0.0795)	
INDUSTRY					0.798*** (0.0649)	0.798*** (0.0649)				0.796*** (0.0572)	0.796*** (0.0572)				0.740*** (0.0601)
SCIENCE					0.302*** (0.0653)	0.302*** (0.0653)				0.296*** (0.0497)	0.296*** (0.0497)				0.197*** (0.0577)
COUNTRY	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Intercept	0.957*** (0.343)	−0.148 (0.329) 1393	0.172 (0.332)	−0.260 (0.338)	1.131*** (0.317)	1.131*** (0.317)	0.379 (0.301)	0.671** (0.299)	0.407 (0.314)	1.530*** (0.291)	1.265*** (0.210)	0.165 (0.222)	0.439** (0.220)	0.106 (0.226)	1.265*** (0.210)
Nº of observations	1393	1393	1393	1393	1393	1359	1359	1359	1359	1359	596	596	596	596	596
Nº left censored observations	348	348	348	348	348	389	389	389	389	389	387	387	387	387	387
Nº right censored observations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudo-R2	0.059	0.196	0.163	0.216	0.200	0.200	0.168	0.158	0.211	0.180	0.179	0.165	0.141	0.204	0.179
Log likelihood	−1103.9	−1078.3	−1083.7	1068.6	−1073.1	−1703.4	−1686.2	−1693.6	−1659.8	−1678.52	−1196.9	−1177	−1179	−1159	−1168.6
Chi-square	1377	1428	1417.2	1447.6	1438.6	2025.2	2059.7	2044.9	2108.4	2071.1	1541.1	1580.9	1575.1	1612.8	1593.7

All specifications significant at $p < 0.01$; ***$p < 0.01$;**$p < 0.05$;*$p < 0.1$; Internal capability variables are not included because they are classifying the three identified groups.

Table 13. Tobit regression, explaining external sourcing variables on production-based performance for process-oriented SMEs across the three identified clusters.

	EMBODIED					NETWORKING					ADVANCED				
	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5	Spec. 6	Spec. 7	Spec. 8	Spec. 9	Spec. 10	Spec. 11	Spec. 12	Spec. 13	Spec. 14	Spec. 15
SIZE	−0.732*** (0.194)	−0.765*** (0.195)	−0.705*** (0.197)	−0.726*** (0.195)	−0.732*** (0.194)	−0.183 (0.148)	−0.203 (0.148)	−0.150 (0.149)	−0.157 (0.148)	−0.183 (0.148)	−0.0935 (0.188)	−0.125 (0.181)	−0.129 (0.182)	−0.118 (0.181)	−0.0671 (0.181)
INTERNAL	0.417*** (0.0810)	0.407*** (0.0815)	0.448*** (0.0818)	0.419*** (0.0825)	0.417*** (0.0810)	0.440*** (0.0746)	0.439*** (0.0750)	0.466*** (0.0751)	0.435*** (0.0754)	0.440*** (0.0746)	0.522*** (0.0905)	0.377*** (0.0890)	0.400*** (0.0892)	0.378*** (0.0892)	0.390*** (0.0889)
BREATH_9		0.170*** (0.0183)					0.134*** (0.0145)					0.140*** (0.0161)			
DEPTH			0.389*** (0.0470)					0.296*** (0.0351)					0.323*** (0.0406)		
SUPPLIER				0.362*** (0.0893)					0.444*** (0.0789)					0.326*** (0.0861)	
CUSTOMERS				0.189* (0.1000)					0.286*** (0.0802)					0.186* (0.0983)	
COMPETITOR				0.391*** (0.108)					0.160* (0.0820)					0.399*** (0.110)	
CONSULTANT				0.194* (0.116)					0.0835 (0.0784)					0.102 (0.0990)	
UNIVERSITY				−0.0199 (0.167)					−0.138 (0.104)					−0.0395 (0.129)	
RTO				−0.110 (0.191)					0.102 (0.119)					0.156 (0.155)	
CONFERENCES				0.163 (0.125)					0.201** (0.0911)					−0.0166 (0.118)	
PUBLICATIONS				0.232 (0.145)					0.131 (0.0994)					0.0848 (0.132)	
ASSOTIATIONS				0.0441 (0.131)					0.0833 (0.0913)					0.0992 (0.123)	
INDUSTRY	1.010*** (0.101)				1.010*** (0.101)	0.836*** (0.0821)				0.836*** (0.0821)					0.808*** (0.0922)
SCIENCE	0.189* (0.102)				0.189* (0.102)	0.156** (0.0713)				0.156** (0.0713)					0.227** (0.0886)
COUNTRY Intercept	YES 5.579*** (0.494)	YES 4.093*** (0.515)	YES 4.438*** (0.514)	YES 3.747*** (0.529)	YES 5.579*** (0.494)	YES 4.248*** (0.322)	YES 3.635*** (0.432)	YES 3.957*** (0.428)	YES 2.905*** (0.456)	YES 4.750*** (0.418)	YES 3.071*** (0.339)	YES 3.071*** (0.339)	YES 3.354*** (0.333)	YES 2.799*** (0.349)	YES 4.248*** (0.322)
Nº of observations	1393	1393	1393	1393	1393	1359	1359	1359	1359	1359	596	596	596	596	596
Nº left censored observations	24	24	24	24	24	21	21	21	21	21	38	38	38	38	38
Nº right censored observations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudo-R2	0.152	0.140	0.125	0.161	0.152	0.109	0.102	0.092	0.124	0.113	0.038	0.104	0.094	0.124	0.109
Log likelihood	−20,141.5	−2027	−2014.9	−2013.5	−2016.7	−2852,1	−283.5	−2830.9	−2813.6	−2817.7	−2211.8	−2185.2	−2194.6	−2179.9	−2186.3
Chi-square	642	671,2	675	698.4	691.9	901.5	932.6	943.9	973.1	946.9	724.2	757.4	758.8	783	770.7

All specifications significant at $p < 0.01$; ***$p < 0.01$;**$p < 0.05$;*$p < 0.1$; Internal capability variables are not included because they are classifying the three identified groups.

APPENDIX

Table A1. Factor analysis for the innovative performance variables.

Variable	Market-based	Production-based
EF_PRODUCT_RANGE	0.8468	0.0961
EF_PRODUCT_MARKET	0.8617	0.1707
EF_PRODUCT_QUALITY	0.7354	0.1928
EF_PRODUCTION_FLEXIBILITY	0.152	0.6876
EF_PRODUCTION_CAPACITY	0.0913	0.7494
EF_PRODUCTION_COSTLAB	0.2022	0.7597
EF_PRODUCTION_MAT_ENERGY	0.2981	0.6245