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A new approach for detecting open innovation in patents: the designation of inventor

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Abstract
The purpose of this paper is to understand to what extent open innovation (OI) is utilized in R&D departments by using patents as a main source. The paper adopts the "designation of the inventor" as a new method for detecting open or closed innovation, a method which examines the type of relationship that exists between the inventor(s) and the patent applicant(s). Since the openness or closedness of an invention is mainly measured by analyzing a firm's co-applicants, the patent's designation of the inventor indicates whether or not inventors are employees of the applicant. The paper offers new empirical evidence about whether a patent is open or not without surveying inventors and it complements previous studies that failed to describe whether a patent is based on open or closed innovation. After studying a collection of 231 patents in the wind energy sector obtained from the European Patent database, descriptive statistics show that OI Patents (OIPs) where the inventor is under agreement represent approximately 90% of the total number of OIPs, which in turn account for more than 23% of the total number of closed and open types of patent. Additionally, the designation of inventor method is also able to identify closed innovation-based patents. The results also show that a minority of companies utilize a hybrid type of OI, in which the inventors are composed of a mix of external individuals and employees. The results suggest that the method proposed yields a better understanding of how OI as well as other innovation strategies are utilized by firms in a particular industry or technological field.

Keywords Open innovation · Closed innovation · Patent · Designation of inventor

JEL Classification O30

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1 Introduction

During the last decade, open innovation (OI) has attracted increasing attention from technological and non-tech firms (Chesbrough 2003; Laursen and Salter 2006). As a result of opening the firm's boundaries, research and development (R&D) departments can accelerate the innovation process by utilizing additional or new knowledge from the external environment. Specifically, studies on tech firms specializing in semiconductors (Chesbrough 2003), software (West and Gallagher 2006; Henkel 2006), telecommunications (Dittrich and Duysters 2007; Stuermer et al. 2009; Rohrbeck et al. 2009; Suh and Jeon 2019), biotechnology (Bianchi et al. 2011), high-tech SMEs (Parida et al. 2012), educational institutions (Friesike et al. 2015) or government (Schillo and Kinder 2017) show how these organizations benefit from inbound and outbound OI. Acquiring knowledge from the environment can significantly enhance the innovation process of the firm (Laursen and Salter 2006).

Applying OI may be beneficial for enhancing a firm's intellectual property production and therefore for contributing to the level of innovation of organizations (Alexy et al. 2009). According to the OECD (2004),[1] "patents play an increasingly important role in innovation and economic performance" and thus the production of patents has become increasingly important for measuring the level of innovation both at firm and country level. However, there could be some contradiction in using patent statistics to measure the level of innovation (Griliches 1990).

In the extensive literature, particular attention has been drawn to patents (Cassiman and Veugelers 2002; Alexy et al. 2009; Rothaermel and Alexandre 2009; Lichtenthaler 2009; Arora et al. 2016; Walsha et al. 2016), patent pools (Rayna and Striukova 2010; Van Zimmeren et al. 2011) and intellectual property in general (Hagedoorn and Zobel 2015; Holgersson et al. 2018). Chesbrough (2006b) suggested co-patents as a potential indicator of OI activity. Nonetheless, using patents as a mechanism for determining whether a firm adopts an open or closed type of innovation was primarily analyzed at firm or organization level. For example, licensing, partnerships, co-patenting or co-inventing between firms are considered OI mechanisms. Specifically, Alexy et al. (2009) analyzed three indicators: joint invention, citation and joint application, and their funding. To the best of our knowledge, the above mechanism has not analyzed the inventor as a person and his or her relationship with the firm and the role with OI. On the other hand, Giuri et al. (2007), Walsha et al. (2016) and Bergek and Bruzelius (2010) investigated the relationship between the inventor and the applicant to detect possible OIP using questionnaires and interviews.

The approach proposed in this work is to uncover the hidden relationship between the inventor (person) and the applicant(s) (legal entities) in terms of employment or a subcontracted contract (under agreement) utilizing the official documents of the patent submitted by the applicant. Under this perspective, an open-type organization is the firm (applicant) that utilizes inbound knowledge based on agreements with external experts. On the other hand, a closed type of organization is the firm (applicant) that utilizes internal knowledge developed by employees of the firm.

The method proposed in this paper for measuring open innovation patents offers three main contributions. Firstly, measuring the type of relationship between the applicant and

[1] OECD (2004) Patents and Innovation: Trends and Policy (OECD Publications). Available at: https://www.oecd.org/sti/sci-tech/24508541.pdf.

the inventor provides an additional indicator for OI which is applicable and/or measurable in any industry or technological field. Secondly, our approach pinpoints new OI activities in those patents that were previously not defined as an OI type. Finally, patents show themselves to be a good source for measuring the nature of innovation. Consequently, the innovation activities of firms that are studied by using patents can be more open than expected.

The remainder of the paper is organized as follows: Sect. 2 reviews the literature on open innovation in patents by describing the various techniques utilized to date; Sect. 3 describes the methodology; Sect. 4 shows the main findings organized according to the key questions; Sect. 5 discusses theoretical and practical implications; and finally, Sect. 6 concludes the paper by posing further research questions.

2 Open innovation and patents

2.1 Open innovation

OI is defined as inbound and outbound knowledge flows through pecuniary and non-pecuniary mechanisms (Chesbrough 2003). When the innovation process of a firm is based entirely on internal knowledge, it is possible to assert that the innovation is closed. When a firm starts its open innovation process by obtaining technical knowledge from external sources (Dodgson et al. 2006; West and Borges 2014; Chen et al. 2016) and acquires knowledge from external experts and/or sources (Ferraris et al. 2017), it is called open innovation (Chesbrough 2006a), relying on its internal absorptive capacity to exploit that knowledge (Cohen and Levinthal 1990).

Essentially, the difference between closed innovation (CI) and OI lies in how the firm opens its own innovation boundaries by acquiring or sharing knowledge. This process falls into the inbound or outbound categories as described by Chesbrough (2003), also defined as the outside-in and inside-out process for building OI (Enkel et al. 2009). The combination of both processes and flows is defined as coupled open innovation (Stanko et al. 2017). The OECD Innovation Policy Platform[2] has also devoted particular attention to this matter, defining OI as "a paradigm wherein firms can and should use external ideas, as well as internal ideas, and internal and external paths to market, as they look to advance their technology".

Several mechanisms for leveraging the firm's innovation activities have been suggested to date (Zobel et al. 2016; Aloini et al. 2017). For example, innovation spillovers (Hrdy 2013; Arora et al. 2016) and joint development (Michelino et al. 2017) or strategic alliances (Chiaromonte 2006). Additionally, patent citation (West et al., 2006; Suh and Jeon 2019), co-patenting (Azzola et al. 2010; Belderbos et al. 2014) and co-inventoring (Giuri et al. 2007; Bergek and Bruzelius 2010) have also been suggested as indicators for studying OI in patents.

2.2 Patents and OI

The relationship between OI and intellectual property (IP) has been discussed since the beginnings of OI (Chesbrough, 2003) and has received considerable attention from scholars

[2] https://www.innovationpolicyplatform.org/content/open-innovation.

(West et al. 2006; Gassmann 2006; Fabrizio and Di Minin 2008; Lichtenthaler 2009; Fabrizio 2009; Alexy et al. 2009; Pénin 2010; Seldon 2011; Zobel et al. 2016; Belderbos et al. 2014; Du et al. 2014; Hagedoorn and Zobel 2015; Walsha et al. 2016; Cammarano et al. 2017; Suh and Jeon 2019).

Among the various sources available for measuring innovation, patents are used for measuring the type of innovation (Cammarano et al. 2017), identifying information flow between organizations (Huggins et al. 2019), understanding how individuals behave with regard to external search (Dahlander et al. 2016) or how the inventor performs (Scandura 2019), and determining how open or closed the research and development (R&D) of a particular firm is (Du et al. 2014; Giuri et al. 2007; Walsha et al. 2016), in addition to the level of cross-industry activities (Mahnken and Moehrle 2018).

Patents can play two main roles in OI. On the one hand, they have been used as a source of innovation activity for understanding the technology landscape and how firms could benefit from external innovation (Carson et al. 2003; Vanhaverbeke 2006; Du et al. 2014; Germeraad and Vanhaverbeke 2016; Brem et al. 2017; Mahnken and Moehrle 2018). For example, the findings of Jeon et al. (2011) on IBM patent output suggested that "pro-patent practices associated with open innovation may stem the free flow of knowledge across organizational boundaries". Sourcing has been defined as an in-bound mechanism to open up firm's boundaries by acquiring external knowledge (Chesbrough 2003). These flows can be applied while studying how patents are developed within or among organizational boundaries (Bogers et al. 2017). On the other hand, patents have been used as an indicator of innovation outcomes (Du et al. 2014).

Depending on the type of actors involved in patents and the type of collaboration that a firm establishes within the environment (Ma and Lee 2008), it is possible to show the openness or the closedness of the invention. An increasing number of patents produced appear to be associated with an increasing number of OI activities. Zobel et al. (2016) suggested that "patenting increases new entrants' number of open innovation relationships, on average", especially in technology-intensive types of relationship. The opposite also works. For instance, compared with firms that are not using OI, those companies that engage in OI activities are motivated by patenting (Holgersson and Granstrand 2017). A firm can own the IP rights of patents in three ways: internally, externally or through a combination of both. Thus the relationship between the different stakeholders is key for identifying open or closed types of innovation in patents. The following section will discuss three approaches to detecting open or closed innovation.

2.3 Theoretical framework and research questions

Given the diversity of forms of open innovation (Dahlander and Gann 2010) and of networks that a firm may establish in its environment to favor inbound knowledge flow (Colombo et al. 2011), this paper takes the recent perspective adopted by Bogers et al. (2017), which indicates that OI can be analyzed using five levels of analysis: the intra-organizational, the organizational, the extra-organizational, the inter-organizational and the industry level. Any level may be applicable to patents when studying the relationship of applicants and inventors to the owner of the invention. However, in order to understand whether the patent is open or closed, we will use just three of the terms suggested by Bogers et al. (2017), but analyzing the type of relationship between the applicant(s) and the Inventor(s) or co-inventor (Picard 2012).

The Intra-firm relationship

When patents are granted by using only employees and there are no co-applicants or co-inventors that are external, then the innovation is a closed type. The relationship type falls into the intra-firm category only when internal individuals (employees at the time that the patent was invented) are inventors and participate in the R&D process (Dahlander et al. 2016). In this case it is accepted that the applicant may be more than one, but restricted to parent companies. Although significant work has been devoted to the internal resources, this type of relationship in patents has not been studied by many authors (Dodgson et al. 2006). Bergek and Bruzelius (2010), for example, find that almost 23% of the patents of the firm ABB were invented by employees. It is a closed type even if individuals tap into external sources to obtain ideas or any other information that can help to improve the R&D activity (Rothaermel and Alexandre 2009).

The Extra-firm relationship

When an external individual (person) becomes an inventor or applicant of a patent, then the relationship type falls into the extra-firm category and the innovation is an open type. In other words, the extra-firm relationship considers that the inventors are individuals who are not employees of the firm that granted the patent. Therefore, when the patent is developed with external inventors, it may be considered as OI. In general, OI relies on external sources of innovation that may be pecuniary or non-pecuniary (Dahlander and Gann 2010). If the sources are human, then these can be based on the value chain or the market, e.g. suppliers, competitors, clients or customers (Danneels 2002; Laursen and Salter 2006, 2014; Enkel et al. 2012; Vanhaverbeke et al. 2014; Walsha et al. 2016), science-based sources (Du et al. 2014) or technology providers (Chen et al. 2016).

This type of collaboration is widely used among institutions and private organizations. For instance, Murgia (2018) showed that almost half the patents filed by Italian universities were invented by individuals. Bergek and Bruzelius (2010) revealed that almost 15% of the cross-country patents owned by the Swedish multinational firm ABB were produced by inventors outside the multinational. On the other hand, Walsha et al. (2016) observed that about 10% of US patents have an external co-inventor. From a large European inventor-based sample, Giuri et al. (2007) showed that 15% of the EU6 patents are produced by teams composed of inventors from different organizations. These studies show that the research methodology employed for directly retrieving data from inventors was interviews, a mailing questionnaire, and a large survey based on a European project, respectively.

The Inter-firm relationship

When more than one external firm or organization work together as co-applicants, then the consortium or group engages in an inter-firm relationship and the innovation is an open type. Specifically, this type of relationship occurs when the co-applicants (also assignees) or co-inventors are different legal entities which are not parent companies. When more than one external company acts as a co-applicant or co-inventor, it is possible to state that the innovation is open.

Under this perspective, the inter-firm activity is the level that is used for studying patents (Kim and Song 2007; Weck and Blomqvist 2008; Belderbos et al. 2014;

Michelino et al. 2017; Mahnken and Moehrle 2018). Specifically, several studies measured OI through co-applicants among SMEs (Michelino et al. 2017), co-owned patents (Belderbos et al. 2014) or a joint patent field (Kim and Song 2007). Chesbrough (2006a, b) indicated that co-patents could indicate the occurrence of OI strategies within firms.

Inter-firm collaboration also shows itself to be a common practice among organizations. According to Du et al. (2014), firms can engage in a wide range of collaboration with external market-based actors in R&D projects such as an industry-university collaboration (Lee et al. 2015). Outsourcing R&D with external technological partners may be driven by cost reduction, according to Gassmann (2006). The identification of partners may be time-consuming and it may involve a proactive search activity (Yoon and Song 2014) or, in contrast, a reactive one. In both cases, the collaborative efforts involved among firms do not include parent companies.

In addition to the types of collaboration mentioned above, organizations may adopt a mixed type of collaboration in which several stakeholders are involved in the invention, as suggested by the study by Suh and Jeon (2019). Therefore, a patent could be applied for using nine combinations of possible relationships, one of which embraces all three types: the intra, extra- and intra-firm.

In the context of this paper, these three relationships play a key role in determining the openness or closedness of a patent. However, as we showed earlier, the primary focus of OI literature has been the inter-firm level which describes co-ownership of a patent. Table 1 shows a summary of the three types of relationship by combining the legal link of the inventor(s) and applicant(s). Furthermore, a fourth quadrant describes the patents that are developed when external and internal inventors work together. This group creates an intra-extra-firm relationship and although the innovation falls into the open classified type, it is not strictly due to the proportion of internal employee resources utilized for the invention of the patent.

OI literature has extensively described the potential mechanisms to be used when a firm opts to jointly develop an innovation. Several attempts have been made to measure the openness of firms using co-inventors (Giuri et al. 2007; Bergek and Bruzelius 2010; Walsha et al. 2016), which falls into the intra-firm relationship category outlined earlier. On the other hand, co-patenting or co-applicants were also used for detecting OI (Azzola et al. 2010; Belderbos et al. 2014; Arora et al. 2016; Walsha et al. 2016; Giuri et al. 2007). All these methods fail, if the information cannot be retrieved directly from the applicant.

Alternative methods have also been proposed in order to study open innovation in patents. For example, Suh and Jeon (2019) proposed an alternative method for measuring open innovation using forward and backward citations of patents in order to understand how knowledge flows between assignees. On the other hand, the number of patents deriving from collaborative R&D activities is considered as a proxy of OI (Kim and Song 2007; Al-Ashaab et al. 2011; Vanhaverbeke et al. 2014; Chen et al. 2016). In addition, universities and scientific partners can be involved in developing prototypes and handling patents and licenses (Cyert and Goodman 1997). Other studies suggested a minimum number of two external actors involved in the collaborative effort (Arora et al. 2016). Table 2 provides a summary of the different methods used for studying OI.

Consequently, little attention has been devoted to studying the type of innovation by looking at the assignee data which is disclosed in patent documents. Therefore, to our knowledge, there are no works that devote particular attention to the relationship between the inventor(s) and the applicant(s). By only focusing on the relationship between different

Table 1 Four relationships between inventors and applicants

	Inventor and/or co-inventors		
	Employee(s)	External person(s)	Employee(s) and external person(s) (The percentage of employees and externals is not defined/studied in this paper)
Applicant or co-applicants			
Employer's firm	Intra-firm relationship	Extra-firm relationship	Hybrid extra-firm relationship
	Closed innovation	Open innovation	Open innovation
Employer's firm and other firm(s)	Inter-firm relationship	Inter-firm relationship	Inter-firm relationship
	Open innovation	Open innovation	Open innovation

Table 2 Type of relationships used by scholars for detecting OI

Type of relationship	Source	Methods used for data collection
Co-applicants, co-patenting: collaboration with external organization or individuals	Azzola et al. (2010), Belderbos et al. (2014), Arora et al. (2016), Walsha et al. (2016)	Self-reported questionnaire, surveys and/or interview
	Murgia (2018)	Patent bibliometrics
Inventors who are not employees	Giuri et al. (2007), Bergek and Bruzelius (2010)	Personal interview and/or case study
Patent citation: forward and/or backward	West et al. (2006), Suh and Jeon (2019)	Patent Bibliometrics
OI proxies (R&D projects)	Kim and Song (2007), Al-Ashaab et al. (2011), Vanhaverbeke et al. (2014), Chen et al. (2016)	Various

firms, the conclusions drawn from these studies lead to an incomplete understanding of how a patent has been developed within the framework of innovation.

In view of this, this paper seeks to fill the research gap at the intra-firm and extra-firm level. The purpose of this paper is to examine the type of innovation at the inventor level by identifying OIPs that are produced with the engagement of external individuals who are not employees, using the designation of the inventor which is disclosed in patent documents. The research questions that this study aims to address are the following:

- To what extent does the designation of inventor method detect new OIPs?
- Do firms use OIPs or CIPs exclusively or a mix of OIPs and CIPs?
- To what extent does the number of OIPs increase over time?

In order to answer these three main questions and identify additional OIPs, the following methodology was applied.

3 Research design and methodology

The patent data used in this work is from companies in the field of wind energy technology. Wind technology in conjunction with solar PV showed the highest growth rate in patenting according to the report of UNEP et al. (2010).[3] As there is little literature on the application of the OI paradigm in the wind industry (González et al. 2012) and the number of patents available is relatively small compared to other industries, the research approach must be exploratory.

The patents analyzed were obtained from the European Patent Office (EPO). Only EP patents were selected because only patents that are granted with a European Patent number must be accompanied with the "designation of inventor" document. The EPO is the only Patent authority which discloses the details of the relationship between the inventor(s) and the applicant(s). Strictly speaking, the EPO obliges an applicant who is not the inventor to declare the "designation of inventor". The World Intellectual Property Organization (WIPO), for example, does not disclose this type of information. The search strategy utilized to retrieve the sample of Wind Energy patents was the following:

> "wind energy" in the title or abstract AND "EP" as the publication number AND F03D11 as the IPC classification.[4]

This search retrieved 265 documents in total. However, those patents (34 in total) in which the applicant(s) is or are individual(s) were excluded from this sample. The focus of this study is understanding the human resources involved in R&D processes developed by firms that were granted patents in the wind energy sector, rather than analyzing individual applicants.[5] The final sample consists of 231 documents found in the worldwide database

[3] The report can be downloaded from: www.epo.org/clean-energy.

[4] The strategy used can be viewed at the following link: https://worldwide.espacenet.com/searchResults?submitted=true&locale=en_EP&DB=EPODOC&ST=advanced&TI=&AB=wind+energy&PN=EP&AP=&PR=&PD=&PA=&IN=&CPC=&IC=F03D11&Submit=Search.

[5] Although the majority of individual applicants were also inventors of the patent, we found that 2 documents were invented by other individuals who are "under agreement".

between the years 1979 and 2014. The documents were analyzed using the priority date, which is the date most closely related to the R&D activity.

In order to gather the data about whether or not a firm uses an open innovation patent strategy, a closed one or a mix of both, each original patent document was carefully examined. The relationship between applicant(s) and inventor(s) was retrieved from the European Patent Register,[6] which stores the official document of the "designation of inventor" (in PDF format). This work was done manually and an additional search was performed by using the number of each patent.

An Excel file was used to organize all the patent data and the information about the "designation of inventors", as well as the names of the applicants and the inventors of each document. The classification of each patent applied the following rules:

Open Innovation Patents (OIPs)

1. If the inventors:
   a. Are two or more individuals who have been designated as "under agreement", then the patent is classified as an OIP.
   b. Are two or more individuals who are not employees of the applicant(s) and whose relationship can be identified by other means, then the patent is classified as an OIP.
   c. Are two or more legal entities that are not parent companies, then the patent is classified as an OIP.
2. If the applicants: Are two or more legal entities (not parent companies), then the patent is classified as an OIP.
3. A combination of rule 1 and rule 2

Closed Innovation Patents (CIPs)

4. If the inventor(s) is designated as "employee", then the patent is classified as a CIP.
5. If the inventor is the applicant, then the patent is classified as a CIP.[7]

Open and Closed Innovation Patents (OIPs&CIPs)

6. A combination of rule 1a and rule 4.

Information Not Available (NA)

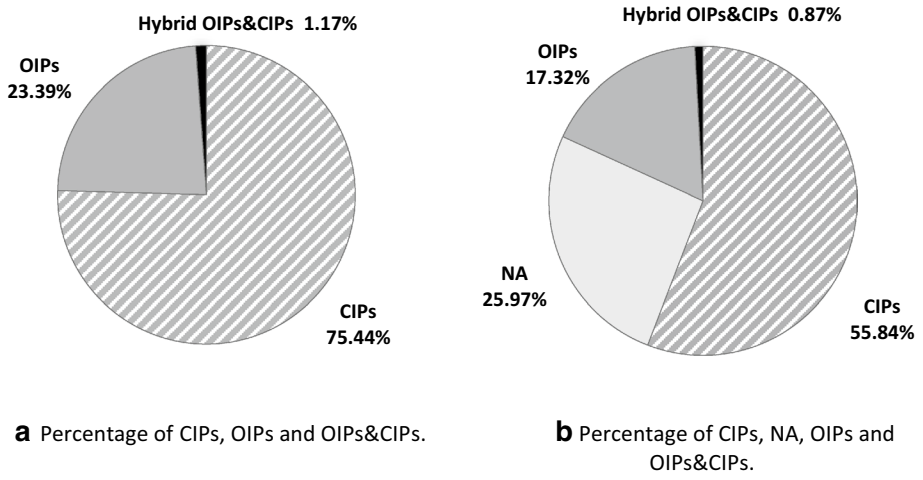
7. If no information was provided in the "designation of inventors" document or no document is available, then the patent is classified as NA.

Data was analyzed using descriptive statistics. Several comparative tables and graphs were prepared to understand the type of patent. The year used for the comparison is the priority date of a patent, which is defined by the EPO[8] as the "filing date of the very first

[6] https://register.epo.org/regviewer.

[7] The rule only considers legal entities. Individual inventors that are also applicants were excluded from the sample.

[8] See https://worldwide.espacenet.com/help?locale=en_EP&topic=prioritydate&method=handleHelpTopic [visited on 14/05/2017].



a Percentage of CIPs, OIPs and OIPs&CIPs.

b Percentage of CIPs, NA, OIPs and OIPs&CIPs.

Fig. 1 **a** Percentage of CIPs, OIPs and OIPs&CIPs. **b** Percentage of CIPs, NA, OIPs and OIPs&CIPs

patent application for a specific invention". In other words, it indicates the year in which the applicant requested the protection of the invention.

4 Main findings

Descriptive statistics and analysis have yielded three main findings.

Finding 1: **To what extent does the designation of inventor method detect new OIPs?**

Based on the results presented hereunder, the method proposed (designation of inventor) makes it possible to identify a higher number of patents invented using external collaborations. This increase was quite considerable in the sample of patents employed by this study, since the number of OIPs increased ninefold compared with the number of OIPs that could be detected by other means. Similarly, the method is also applicable to the identification of closed patents. In this case, three times more CIPs were detected.

CIPs dominate the sample of patents in the Wind Energy sector with 129 patents—75.44% of all patents that can be identified as exclusive OIPs, exclusive CIPs or a hybrid of Open and Closed patents (see finding 2 for more details about this definition). The number of CIPs has been calculated using the information available from patents under rule 4 and 5. On the other hand, the total number of OIPs measured by the sum of patents where the inventor was declared "under agreement" in the designation of the inventor (rule 1a) and the patents where there are two applicants (rule 2) is 40, representing 23.39% of our sample. Finally, the number of patents that employ a mix of the aforementioned types of relationship, identified by using rule 6, is 2, representing 1.17% (see Fig. 1).

However, if we include patents with no information available (rule 7) in the analysis, OIPs and CIPs represent 17.32% and 55.84% respectively (see Fig. 2). There are 60 patents where information about the type of relationship between the applicant(s) and the inventor(s) is unavailable. These patents represent 25.97% of the total sample. No patents were found that can be classified under rules 1b and 1c.

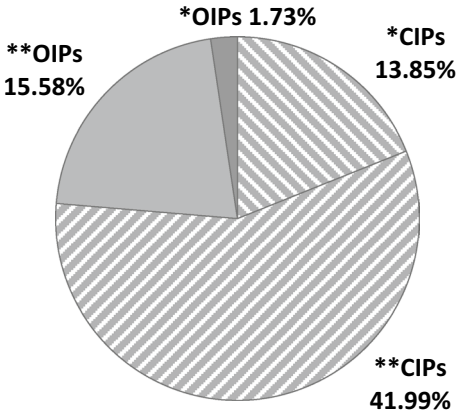


Fig. 2 Percentage of *CIPs, **CIPs, **OIPs and *OIPs

On the other hand, Fig. 2 shows the percentage of patents for OIPs and CIPs that have been identified using the "designation of the inventors" (rules 1a and 4), highlighted with two asterisks (**) and in bright color, and those patents that are identifiable under rules 2 and 5, highlighted with an asterisk (*) and in light color. For the open type subsets of patents **OIPs (under rule 1a) and *OIPs (under rule 2), the number of documents is 36 (15.58%) and 4 (1.73%) respectively. For the closed type subsets of patents **CIPs (under rule 4) and *CIPs (under rule 5), the number of documents is 97 (41.99%) and 8 (13.85%) respectively. As can be observed, the difference between the two subsets of OIPs and CIPs is remarkable. **OIPs is eight (8) times bigger than *OIPs, and for the closed type subsets of patents, **CIPs is two (2) times bigger than *CIPs.

Finding 2: **Do firms use OIPs or CIPs exclusively or a mix of OIPs and CIPs?**

The great majority of companies in the Wind Energy sector use exclusive open or closed innovation models (22.22% and 75.00% respectively). This result can be measured by counting both the patents (Fig. 1a) and the number of companies that adopt them (Table 3). However, there is a very small percentage of companies (2.78%) that use a non-exclusive patent portfolio (defined as hybrid), and therefore each patent has both external and internal inventors.

In order to understand what companies (of a total of 72) are using OIPs, a comparison was made between firms that use OIPs or CIPs in an exclusive or hybrid OIP form (in which external collaborators and employees are inventors) and firms that use both types of innovation.[9] Descriptive statistics reveal the following:

> The **"Exclusive OIPs"** innovation type occurs when firms exclusively adopt patents that are invented by inventors under agreement (40 in total). OIPs are concentrated in a relatively small group of firms (16 in total), compared to the total number of applicants (54 in total) that remain completely closed in their R&D activity. In the OIPs group there are large firms such as "Robert Bosch GmbH", "Siemens AG" and "Hitachi Ltd.", but there are also small and medium-sized firms such as "Wilic Sarl", "Schwieger", "Hartwig" and "Sieb & Meyer AG". This last group of

[9] Companies that have at least one NA patent were excluded from the list, as they do not fit into any of the three categories. NA means that the "designation of inventor" document was not available, even if required.

Table 3 Firms using OIPs and/or CIPs

Form of innovation	Exclusive OIPs	Hybrid OIPs + CIPs	Exclusive CIPs	Mixed: Exclusive OIPs and exclusive CIPs
No. patents (%)	40 (23.39)	2 (1.17)	129 (75.44)	–
No. firms (%)	16 (22.22)	2 (2.78)	54 (75.00)	3
Name of firms (with more than two patents)	**GEN ELECTRIC (17)****	**ROBERT BOSCH GmbH (1)****	NORDEX ENERGY GmbH (27)**	**GEN ELECTRIC (17 and 4)**
	SIEMENS AG (5)**	**SIEMENS AG (1)****	WOBBEN ALOYS (21)*	**SIEMENS AG (5 and 6)**
	WILIC Sarl (4)**		SENVION GmbH (14)**	**GAMESA INNOVATION & TECHNOLOGY, S.L. (1 and 1)**
	ROBERT BOSCH GmbH (1)**		**SIEMENS AG (6)****	
	DAUBNER & STOMMEL GBR (2)**		**GEN ELECTRIC (4)****	
			WESERWIND GmbH (3)**	
			W2E WIND TO ENERGY GmbH (3)	
			REPOWER SYSTEMS SE (3)**	
			STRABAG Offshore Wind GmbH (2)**	
			AB SKF (2)**	
			ALSTOM and ALSTOM Tech. (2)**	
			WOBBEN PROPERTIES GmbH (2)*	
			HEIDELBERG MOTOR GESELLSCHAFT FUER ENERGIEKONVERTER MBH (2)*	

When patents are marked with two asterisks (**), it means that the patents are identified using the "Designation of inventor", in contrast to those patents marked with only one asterisk (*), which are identified using other rules. The list has been limited to those firms that have at least two patents

firms only filed one patent in wind energy technology.

The **"Exclusive CIPs"** innovation type occurs when firms exclusively adopt patents that are invented exclusively by employees. CIPs account for the largest group of firms (54 in total) as well as the largest number of patents granted (129 in total). Firms such as "Nordex Energy GmbH", "Wobben Aloys" and "Senvion GmbH" lead this group with a significant number of CIPs (see Table 3). As discussed earlier in the methodology, this paper focuses exclusively on patents where at least one legal entity appears as an applicant and not on those patents where only natural persons are listed (34 in total). By default, inventors who apply for a patent at the same time belong to the closed invention type.

The **"Hybrid OIPs&CIPs"** innovation type occurs when firms adopt patents which are co-invented by inventors under agreement and employees. For instance, in 2013 "Robert Bosch Gmbh" granted a patent co-invented by an employee and an external individual. Similarly, "Siemens AG" granted a patent co-invented by three employees and one external inventor. This form is adopted by these two firms alone, with one patent granted each. Therefore, firms that adopt a hybrid OIP model are a minority in our sample.

The **"Mixed"** innovation type occurs when exclusive OIPs and exclusive CIPs are used by firms in their IP portfolio. In the sample, only three firms, namely "General Electric", "Siemens AG" and "Gamesa Innovation & Technology, S.L.", opt for a mix of open and closed innovation by granting both OIPs and CIPs. In this last group, however, General Electric is the only firm that has a very strong orientation towards using external sources for managing innovation, clearly favoring exclusive OIPs.

Table 3 shows different strategies adopted by firms. Specifically, "Wilic Sarl" exclusively used an OI strategy by granting 4 OIPs. In contrast, "Nordex Energy GmbH", "Wobben Aloys" and "Senvion GmbH", which adopted the opposite strategy with 27 and 15 CIPs respectively, maintain an exclusive focus on closed innovation. It is particularly interesting to note that a review of the different brands under "exclusive" CIPs indicates that these companies are also highly specialized in wind energy. On the other hand, there are three firms that use both open and closed innovation in their patent portfolio, adopting an exclusive approach, namely Gen Electric, Siemens AG, and "Gamesa Innovation & Technology, S.L.". Additionally, two companies, "Robert Bosch GmbH" and "Siemens AG", use external and internal resources for developing inventions. On the basis of these results, it may be observed that, in terms of the number of companies, closed innovation dominates in the wind energy sector. Finally, only the firm "Siemens AG" uses all four innovation types in this sector.

Finding 3: **To what extent does the number of OIPs increase over time?**

An analysis of the patents shows that OIPs do not increase over time, although these have been used in a recent period from the year 2012 (Fig. 3). The clear distinction between OIPs and CIPs reveals that OIPs have now been used in the last eleven years, but CIPs still tend to dominate the patent portfolio.

The first OIPs were filed in 2002 and 39 OIPs were filed between the years 2002 and 2012, representing 15.88% of all published patents in this period of time. This group of patents is almost wholly represented by **OIPs (36 documents). Only 3 *OIPs were part of the OIP group in the same period of time.

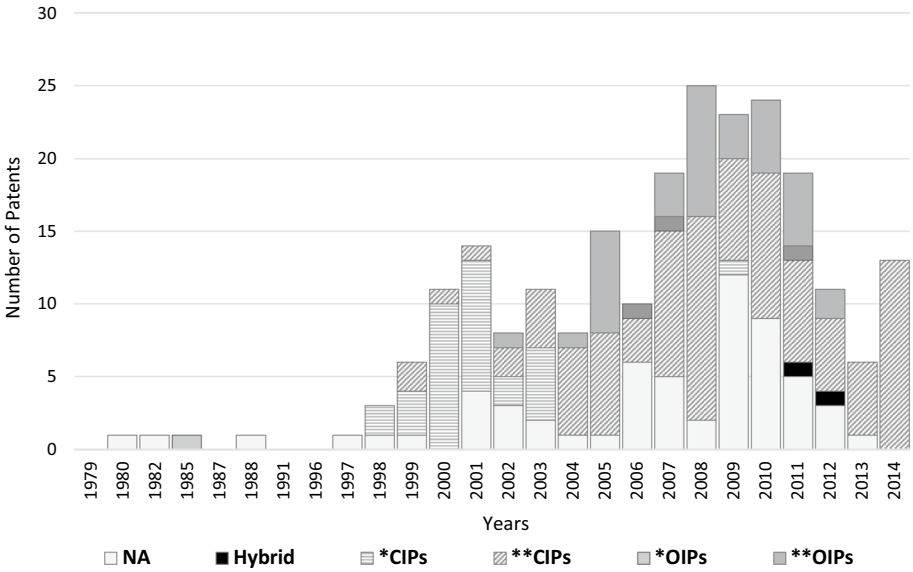


Fig. 3 Evolution of Patent types based on priority date (231 documents)

With respect to CIPs, the number of **CIPs is the biggest group representing all the CIPs. It is particularly interesting that **CIPs are concentrated between 2004 and 2014 and *CIPs before 2004. This shows that after the year 2004 firms have been changing their innovation strategy, using more employees (Inter-firm relationship) rather than other types of patent.

Descriptive statistics of the evolution of patents show that the number of patents in the Wind Energy sector increased up until the year 2008 and declined thereafter. This evolution also reflects CIPs. According to Harhoff and Wagner (2009), a patent can take an average of 5 to 6 years to be granted by the EPO, which may pose limitations when analyzing a recent period of time. Indeed, not a great many patents appear to have been granted since 2014. Figure 3 illustrates the results of the evolutionary analysis of the patents, differentiating between Open and Closed patents.

On the other hand, Table 4 shows the trends in OIPs and CIPs since they first appeared in the sample. The graph and the table also show those patents for which no information was included (NA).

5 Discussion and Implications

5.1 Discussion

This exploratory study introduces a new method for measuring OI in patents. Based on the analysis made, the results clearly show that delving into the declaration of the designation of inventor(s) yields important information about the nature of the invention itself. For the purpose of discussing the results, the following text will be organized according to the previous results.

Table 4 Trends in OIPs and CIPs

Patent type (value)	Years													
	1979–2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
**OIPs														
No.	–	1	–	1	7	–	3	9	3	5	5	2	–	–
%	–	12.50	–	12.50	46.67	–	15.79	36.00	13.04	20.83	26.32	18.18	–	–
*OIPs														
No.	1	–	–	–	–	1	1	–	–	–	1	–	–	–
%	2.56	–	–	–	–	10.00	5.26	–	–	–	5.26	–	–	–
**CIPs														
No.	4	2	4	6	7	3	10	14	7	10	7	5	5	13
%	10.26	25.00	36.36	75.00	46.67	30.00	52.63	56.00	30.43	41.67	36.84	45.45	83.33	100.0
*CIPs														
No.	24	2	5	–	–	–	–	–	1	–	–	–	–	–
%	61.54	25.00	45.45	–	–	–	–	–	4.35	–	–	–	–	–
Hybrid														
No.	–	–	–	–	–	–	–	–	–	–	1	1	–	–
%	–	–	–	–	–	–	–	–	–	–	5.26	9.09	–	–
NA														
No.	10	3	2	1	1	6	5	2	12	9	5	3	1	–
%	25.64	37.50	18.18	12.50	6.67	60.00	26.32	8.00	52.17	37.50	26.32	27.27	16.67	–
Total														
No.	39	8	11	8	15	10	19	25	23	24	19	11	6	13

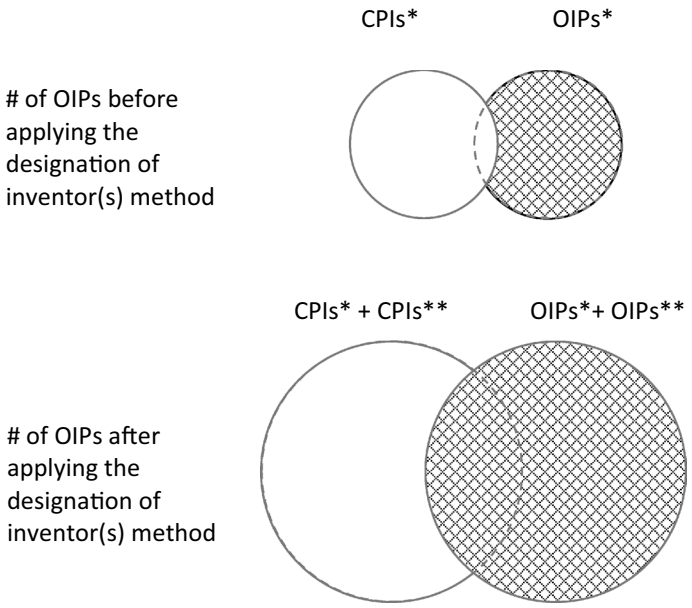


Fig. 4 Intersection of two groups of patents before and after the application of the designation of inventor(s) method

Finding 1: Increase of OIPs

The total number of OIPs increased significantly by using the designation of Inventor (extra-firm methodology described), rising from 1.73% to 23.39% in the sample used. Similarly, CIPs increased from 13.85% to 75.44%. Despite the fact that, in some samples, joint or inter-firm patents may provide sufficient data for establishing the presence of OI (Picard 2012) in those samples where the number of inter-firm patents is small (Belderbos et al. 2014), the method will not be able to show any OI. In this sample of patents, the differences made by the application of the inventor's designation are extremely evident. In fact, if it were not applied, it would not be possible to detect any open patents. In other words, if the inter-firm method were to be used in this sample, no OI activity would be detected at all.

The designation of inventor method sheds new light on those patents that do not show any inter-firm collaboration and were therefore excluded a priori from being OI candidates. Under these circumstances, the designation of inventor shows that any inter-firm method needs to be complemented. In our opinion, not only does the method provide an alternative way of detecting OI activity, but it can be crucial for identifying additional open and closed innovation in two key situations. When open or closed innovation has been clearly identified using some of the previously discussed methods, then the designation of inventor complements these studies. It is possible to assume that the level of complementarity between the two methods may vary depending on the sample of patents studied. However, when no OIPs or an insignificant number have been detected, then the designation of inventor might be an alternative method.

Thus the method used in this work makes an important contribution to OI research specifically applied to patents. The Venn diagram in Fig. 4 shows the benefits of using the designator of inventor to detect new OIPs in the sample used in this work. The two

segments[10] in the diagram show the functional intersection of two groups of patents (*CIPs and *OIPs) identified before the application of the method and after (*CIPs+ **CIPs and *OIPs+ **OIPs). Specifically, the intersection shows the OIPs that are hidden when the method of designating the inventor(s) is not applied. Additionally, through the sizes of the circumference, the figure shows that the number of OPIs and CIPs increased after applying the designator of inventor. Although the result cannot be extrapolated to other patent samples or to all patents, given that a convenient sample was used, we are convinced that at least the number of OIPs can be increased. The opposite is definitely not possible.

Finding 2: Companies are using CIPs exclusively

Descriptive statistics show that the majority of the patents are CIPs and the majority of firms favor the closed innovation approach. However, based on a broad concept of OI, these patents do not necessarily show strictly closed innovation. Patent portfolios can be used strategically and in different ways. For instance, Arora et al. (2016) observed that there is a close relationship between openness and patenting. Even if an invention is developed internally, knowledge thereof can be transferred to the public domain (outbound innovation).

On the other hand, the results of this work also show that there are some companies that use OIPs exclusively. Perhaps these firms have a positive trade off in using OIPs, as suggested by Aloini et al. (2017) and Lee et al. (2015). In contrast, other firms used a focused closed innovation strategy. Perhaps specialized firms in a specific industry or sector tend to be closed rather than open.

Furthermore, companies can be open and closed at the same time, such as General Electric and Siemens for example, which are, according to Enkel et al. (2012), firms that "invest simultaneously in closed as well as open innovation activities". The bipolar strategy may work well for some companies, but it is not applicable to all (see Table 3). These results may support the findings of Noailly and Ryfisch (2015), who stated that, on the whole, energy industry firms still relay their own R&D activities internally. Differences between industries might be expected. Again, the designation of inventor method provides additional details to highlight the possible strategies to be found among firms in a patent sample.

In view of these results, the adoption of a closed innovation model by a relatively high number of companies is possibly due to their size and degree of specialization. It would appear that large companies tend to have a much more balanced portfolio, perhaps on account of market opportunities. In contrast, companies that are highly specialized in the field of Wind Energy tend to work with their own resources and develop their core competences.

Finding 3: OIPs appeared in a short period of time but they are not increasing

Since OI is a relatively new phenomenon, the number of patents focused on OI is still relatively small compared to CIPs. However, the method used in this study shows a number of OIPs, although these are concentrated in a very small group of companies in the field of Wind Energy technology.

We believe that companies may have been encouraged to begin to use open patents by the growth of the sector and the consequent need to develop new technologies. Furthermore, if we look at the type of company that has used open patents in this period of time,

[10] Please note that the circles are not proportional to the number of patents in each group. The diagram is for illustrative purposes only.

we may observe that they are multinationals, such as Siemens, Bosch and General Electric (Table 3). This would suggest that these companies did not have the internal resources to respond to greater market demand.

Finally, if the designation of inventor method is applied in conjunction with the inter-firm method, it definitely offers added value and a wider application of OI. The method itself increases an understanding of:

1. The type of innovation strategy utilized by firms in a specific sector and the difference between them
2. The resources employed by the R&D department when patenting
3. The mechanism favored by a particular industry or sector

Although this study is limited to a restricted set of patents, the designation of inventor method clearly demonstrates that it is sufficiently capable of challenging those patents that are considered closed or undefined by inter-firm methods.

5.2 Theoretical implications

The results of this study show that about 23% of the patents in the sample are open. This result is consistent with the study of Walsha et al. (2016), who found that 25% of US firms tend to have multiple partners in external co-inventions. To our knowledge, besides these studies, there are no other empirical studies focused on patents which further an understanding of the extent to which firms use OIPs. However, in order to compare the results of this paper with other studies, R&D projects might be used as a possible indicator. Vanhaverbeke et al. (2014) argued that most of the patents developed by large firms "can be linked to one (or a few) particular R&D project(s)". In this respect, the study made by Du et al. (2014) found that more than half of the 489 R&D projects developed by large European multinationals were open innovation. In emerging countries, the number of patents can be quite small with respect to the production of innovation, as suggested by Chen et al. (2016).

On the other hand, the findings described in Table 4 show that firms can adopt both inter- and extra-firm relationships. Although our research shows this dual strategy in a minority of firms, the findings are consistent with the perspective of the five levels of analysis described by Bogers et al. (2017), whereby firms can move between the different levels.

Regarding firm size, the names of the companies listed in Table 4 show that OIPs are predominantly used by large multinational companies such as General Electric, Siemens AG or Robert Bosch GmbH. This result is consistent with the findings of Laursen and Salter (2004), who maintained that OI depends on firm size and the extent of R&D investment, but it does not contradict the fact that small and medium-sized enterprises (SMEs) can be very active in OI (Van de Vrande et al. 2009), although they can fight several challenges in applying OI (Carayannis and Meissner 2017). On the other hand, Walsha et al. (2016) found that the difference between SMEs and large firms regarding the use of external co-inventors was not statistically significant. Perhaps wind energy is not the best sector in which to analyze the relationship between size and OIP activity, because the high entry barriers and the considerable investment required do not allow SMEs to play an active role in this business. Table 5 shows a summary of the several works published to date with relation to OI and patents.

Table 5 Support of current literature and results

Findings	Discussed by	Consistent with (empirical studies)	In contradiction with (empirical studies)
Open type of patents are still a minority with respect to CIPs	Du et al. (2014)	Giuri et al. (2007) (This study showed that the UK was the country with the highest percentage (21.1%) of patents with external co-inventors based on the PatVal questionnaire); Bergek and Bruzelius (2010), Walsha et al. (2016)	Partially with Du et al. (2014), who found that OI R&D projects account for 57.67% of the total sample used
			Zobel et al. (2016) Technology-intensive industries tend to have the largest number of OIPs
The number of OIPs has increased appreciably since 2003	Enkel et al. (2012), Holgersson et al. (2018)	–	–
Large firms tend to be more open with respect to SMEs	Holgersson et al. (2018)	Consistent with Laursen and Salter (2004), Bhaskarabhatla and Hegde (2014)	Partially in contradiction with Walsha et al. (2016)
		Partially with Van de Vrande et al. (2009)	
Inter-firm approach reveals new OIPs	Picard (2012), Belderbos et al. (2014), Bogers et al. (2017) and Dahlander et al. (2016)	Enkel et al. (2009), Bergek and Bruzelius (2010), Walsha et al. (2016)	–

5.3 Practical implications

The findings of this paper provide several practical implications. First of all, the number of OIPs in recent years appears to be relatively important, since they represent nearly a quarter of the total. Consequently, R&D managers should consider external experts when launching a new R&D project. The strategy of using external sources may be very beneficial for a firm, with a significant impact on financial results (Rothaermel and Alexandre 2009; Chen et al. 2016), although it is not clear if these benefits stem from firms pursuing collaborative R&D projects (Vanhaverbeke et al. 2014) rather than internally focused projects. At least R&D teams improve their ability to learn from others specifically when they use a hybrid model of Open Innovation.

Secondly, firms can use a variety of innovation patent-based strategies. Although this study has not deciphered the reasons that motivate companies to use OI, some companies stand out in the use of OI more than others. By identifying these activities, companies can better understand not only the competencies of their competitors, but also their strategic intentions, in order to study the specific reasons that have motivated these firms to employ OI in a particular project. R&D managers can reinforce their knowledge about their counterparts' strategies by looking not only at the inter-firm collaboration, but also at what human resources are used in their counterparts' projects. For instance, firms that specialize in wind energy tend to use CIPs in comparison with others that are more multi-business. This strategy may be due to the high degree of technological specialization in this industry. This analysis offers a greater understanding of competitor competences, allowing similar or alternative innovation strategies to be adopted. We also believe that with greater knowledge, firms can leapfrog competitors in a technology field or perhaps advance more in competitive terms. Identifying the right external resource to be embedded into the technological innovation process needs careful attention. The European Patent Office claimed that there are many inventions for which firms apply for a patent that were invented before. It is argued that external technology sourcing is used extensively in R&D projects (Vanhaverbeke et al. 2014; Chen et al. 2016), possibly in more than one third of all projects, according to Enkel and Gassmann (2008). Similarly, use of external sources can also be found when a patent is developed (Rothaermel and Alexandre 2009). Perhaps a good practice for identifying the best and/or potential candidate for incorporation into a project is using technology scouting (Rohrbeck 2010). However, technology scouting and technology intelligence is not free, and the resources needed to be abreast of any technological change increase significantly according to the innovation intensity of the environment (Comai 2016).

Thirdly, OIPs show that actors in a specific technology ecosystem exchange knowledge. Not only do firms acquire external knowledge from human resources (Enkel et al. 2009), but human resources also offer knowledge to firms. When OIPs are measured by using the designation of inventor, it is possible to see that human resources are available in the market and these can provide knowledge to boost the firm's innovation outputs through patents.

Fourthly, the mix of innovation strategies adopted by the firms Gen Electric, Siemens AG and Wobben Aloys to produce OIPs as well as CIPs is consistent with Holgersson and Granstrand (2017). The authors noted that any innovation ecosystem can vary over time and so it can adopt a variety of closed and open innovation patent strategies. Comparing the two OIP and CIP portfolios, it may be noted that these companies use different patent strategies during the timeframe. The possible conclusion would be that

the strategy of OIPs and CIPs may be effective in a particular period of time. Moreover, CIPs are not necessarily related to an absolutely closed innovation setting. A firm may prepare the setting for a future open innovation project (Holgersson and Granstrand 2017).

Finally, the various benefits discussed in the Open Innovation literature by adopting OI strategy are definitely reinforced by the methodology proposed in this paper. In other words, finding a greater number of patents that are open instead of closed clearly supports OI's overall results and may attenuate or challenge results to the contrary.

6 Limitations and future research

Whilst these results enhance the number of Open Innovation applications and their value, there are several limitations and further studies are needed.

First of all, the data extraction method needs intensive manual work for extracting the information about the designation of inventor. To our knowledge, this is the only technique available, since at present patent databases like the EPO do not provide any coded data about the designation of the inventor. Consequently, extracting the metadata manually becomes less attractive when working with a large number of patents. Bibliometric analysis techniques from codified data available on large datasets can show an inter-firm relationship by comparing the legal entity names of the co-inventors or co-applicants. However, this technique could prove to be unsatisfactory when the number of OIPs and CIPs is insignificant and therefore insufficient for extracting conclusions. The Wind energy sample reflects this limitation by adopting bibliometric techniques that rely on few of the rules previously discussed. Perhaps the use of a web crawler would make it possible to retrieve the information in an automated manner, or we will see this information as key metadata in some open or commercial patent database available in the market in the near future. If this were to happen, great care must be exercised when working with legal entities, and data cleaning is needed to produce a harmonized database (Van Looy et al. 2006; Comai 2018), even if the names of legal entities are accessible from the majority of patent databases using text-mining techniques (Trappey and Trappey 2008).

Secondly, although the EPO requires the applicant to declare the designation of inventors,[11] this is not provided in many cases. As shown in Fig. 2, almost one third of patents in our sample are undefined and therefore it is not possible to classify them as open or closed using any method. Thus, in order to see whether OIPs have increased significantly in the last decade, an extensive sample of patents is required. Perhaps technology-intensive industries are the best candidates, since these industries are the source of the largest number of OIPs (Zobel et al. 2016).

Thirdly, another limitation may be related to the definition of the intra-firm relationship adopted in this paper. A patent is defined as closed innovation when the inventor(s) is/are an employer(s) of the applicant or owner of the patent. Clearly, it is the relationship between the applicant and the inventor that determines whether a patent is closed or open. If the field of application is expanded, the number of OIPs could increase significantly when the study is focused on SMEs.

[11] The rules and articles relating to the designation of inventor can be found in the Guide for applicants, part 1 (http://www.epo.org/applying/european/Guide-for-applicants/html/e/ga_c_i_7.html).

Fourthly, the data used to analyze the openness or closedness of patents was obtained from granted patents published by the EPO. However, not all patents that are applied for are granted. Therefore, caution must be exercised before generalizing the relationship between OIPs and OI projects. It may be asserted that only those projects related with granted patents are open or closed, and the evaluation resulting from this data cannot be applied to all the R&D projects of a specific firm.

Finally, as discussed previously, a final observation should be made about the sample used. A higher number of patents will definitely contribute to a greater understanding of the openness and closedness of patents, the types of relationships of a firm within its environment and the balance between internal and external human resources adopted in R&D projects. In conclusion, more research is clearly needed to study OI in patents further. We consider that there are several interesting questions, namely:

- What proportion of external inventors is needed in a team which also includes internal inventors for classification as open innovation?
- Do specialized firms concentrate more on CI practices? What is the reason for this?
- Do emerging sectors use more IO than established sectors?
- Do diversified firms opt for a mix of CI and OI practices?
- What are the different innovation strategies employed by industry-specialized firms compared with those employed by multi-business firms?

We believe that this research will inspire scholars to pursue further studies about OIPs and how this type of patent is produced.

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