Open Innovation in the Pharmaceutical Industry: An Empirical Analysis on Context Features, Internal R&D, and Financial Performances

Francesca Michelino, Emilia Lamberti, Antonello Cammarano, and Mauro Caputo

***Abstract*—This paper aims at investigating the relationships between the adoption of open innovation by companies and their context features, internal R&D, and financial performances. Two proxies for openness—variety and intensity—are defined, and six hypotheses are formulated and tested on a sample of 68 worldwide top R&D spending pharmaceutical companies. The period of 2008–2012 was analyzed for a total of 340 statistical units. Our results suggest that open innovation is a very pervasive behavior among smaller and younger companies, for which internal R&D is complementary to openness; still being in the development phase, they derive most of their revenues from open innovation itself and show negative financial performances. Yet, a wider range of open transactions are performed by larger and longer established firms, exhibiting good financial performances and adopting open innovation as a substitution to internal R&D efforts. Through an in-depth review of the literature, this paper contributes to the research on open innovation by providing an accounting measurement system, testing six hypotheses among open innovation and some firm-level variables, and positioning the obtained results within the current debate.**

***Index Terms*—Financial performances, inbound, innovation metrics, open innovation (OI), outbound, pharmaceutical industry.**

I. Introduction

In his seminal work, Chesbrough [1] argued that firms are switching from a closed to an open innovation (OI) model in which they increasingly rely on external sources of information and/or collaboration with external partners to support their innovation activities. In contrast to the vertical integrated innovation model (see [2] and [3])—where all knowledge is internalized and controlled by the firm—the OI paradigm can be characterized by its porous innovation process and the strong interaction between the company and its environment (see [4] and [5]). In particular, Chesbrough and Crowther [6] differentiated between two dimensions of OI.

1) Inbound: establishing relationships with external organizations with the purpose of accessing their technical and scientific competences.
2) Outbound: unused technologies are acquired by external organizations whose business models are better suited to commercialize them.

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The literature discussing OI has expanded rapidly over the last years. The scientific community started investigating the new paradigm first theoretically (see e.g., [1] and [7]), then with both qualitative case studies (see e.g., [8]–[12]) and large-scale quantitative empirical works (see e.g., [13]). Although practice and theory seem to indicate that the OI approach is beneficial for companies, innovation measurement is still looking for an appropriate metrics system. Such system should monitor the investments and the impacts of open versus closed innovation approaches to help companies find their right balance. Even if the possibilities of opening the innovation process are growing, metrics systems are not yet adapted to monitor and measure the value of OI activities. Only specific measurement systems will allow for the successful implementation of OI and support the right capabilities [14].

In order to fill such a gap, two proxies for openness are suggested—variety and intensity—based on the pecuniary flows that OI transactions generate [15]. Starting from this approach, the relations between the adoption of OI and some firm-level variables are investigated.

Particularly, the aim of this paper is to analyze the relationship between the adoption of OI practices by companies and a set of variables linked to context features, internal R&D, and financial performances. Our research questions are as follows.

1) How the adoption of OI practices can be linked to the size and the age of companies?
2) How inbound and outbound practices are related to each other and to internal R&D?
3) How the adoption of OI practices is linked to financial performances of firms?

The hypotheses were tested on a sample of 68 worldwide top R&D spending pharmaceutical companies according to *The 2011 EU Industrial R&D Investment Scoreboard*. Audited consolidated financial statement data were collected for the period 2008–2012 for a total of 340 statistical units.

In Section II, after the review of how OI is measured, the relationships between OI and the other phenomena under study are investigated and the hypotheses are formulated. In Section III, the data sample and the measurement of variables are presented. Sections IV and V point out results and discussions. Conclusions close the work.

II. Background and Hypotheses

In this section, a review of the OI literature is provided in order to identify theoretical contributions concerning the measure of the openness degree, and lay the foundations for the

TABLE I
LITERATURE CONTRIBUTIONS ON OI METRICS

Study	Data source	Metric(s)	Kind of variables	Treatment
Chesbrough and Crowther [6]	Primary	Practices to bring in and take out IP and technology	Nominal	*N* different items
		External sources of ideas and technology	Nominal	*N* different items
Laursen and Salter [13]	UK Innovation Survey 2001	External search breadth	Dummy	Sum of *N* items
Keupp and Gassmann [21]	Swiss Innovation Survey 1996–2005			
Hwang and Lee [22]	Korean Innovation Survey 2005	External search depth	Ordinal	Sum of *N* items
Idrissia *et al.* [23]	Primary			
van der Meer [16]	Primary; Dutch National Innovation Survey 2004	Importing mechanisms	Dummy	Sum of *N* items
		Exporting mechanisms	Dummy	Sum of *N* items
Chiaroni *et al.* [17]	Primary; Annual reports 2000–2005; Professional databases and reports	Generation of innovation	Quantitative	Count of occurrences
		Exploitation of innovation	Quantitative	Count of occurrences
Lichtenthaler [18]	Primary; Financial databases and annual reports	Outbound innovation strategy	Ordinal	Mean of *N* items
Lichtenthaler and Ernst [31]	Primary	Extent of external technology acquisition	Ordinal	One item
		Extent of external technology exploitation	Ordinal	One item
van de Vrande *et al.* [26]	EIM 2005	Technology exploration	Dummy	*N* different items
		Technology exploitation	Dummy	*N* different items
Barge-Gil [35]	PITEC 2004–2006	Openness imp.	Ordinal	One item
		Openness sour.	Ordinal	One item
Faems *et al.* [28]	Belgian CIS 4; BELFIRST	Diversity of technology alliance portfolio	Dummy	Sum of *N* items
Hung and Chiang [40]	Primary	OI proclivity	Ordinal	Mean of *N* items
Ili *et al.* [32]	Primary	Outside-in methods	Ordinal	*N* different items
		Inside-out methods	Ordinal	*N* different items
Lazzarotti *et al.* [36]	Primary	Partner variety	Ordinal	One item
		Phase variety	Ordinal	One item
Spithoven *et al.* [20]	Belgian CIS 3	Knowledge externalities	Ordinal	Sum of *N* items
		Research cooperation	Dummy	One item
		Appropriability	Dummy	Mean of *N* items
Inauen and Schenker-Wicki [37]	Primary	Stakeholder cooperation intensity	Ordinal	*N* different items
Podmetina *et al.* [33]	Primary	Technology acquisition	Ordinal	One item
		Technology commercialisation	Ordinal	One item
Schroll and Mild [34]	Primary	Inbound cooperation	Ordinal	Mean of *N* items
		Inbound acquisition	Ordinal	Mean of *N* items
		Outbound	Ordinal	Mean of *N* items
		Total OI adoption	Ordinal	Mean of *N* items
Chaston and Scott [41]	Primary	OI scale	Ordinal	Mean of *N* items
Salge *et al.* [24]	Mannheim Innovation Panel 2003–2004	Search openness	Dummy	Sum of *N* items
Sandulli *et al.* [29]	PITEC 2003–2008; SABI	Open	Dummy	One item
Teirlinck and Poelmans [19]	Biannual OECD business R&D survey for Belgium 2004–2005; BELFIRST	Degree of openness of R&D activities	Nominal	*N* different items
Ahn *et al.* [38]	Korean Innovation Survey 2008	Inventive capacity	Ordinal	Sum of *N* items
		Absorptive capacity	Ordinal	Sum of *N* items
		Transformative capacity	Ordinal	Sum of *N* items
		Connective capacity	Ordinal	Sum of *N* items
		Innovative capacity	Ordinal	Sum of *N* items
		Desorptive capacity	Ordinal	Sum of *N* items
Berchicci [39]	Surveys of Italian Manufacturing Firms 2001–2004	External R&D	Ordinal	One item
Spithoven *et al.* [20]	Belgian CIS 4	Search strategy	Dummy	Mean of *N* items
		External R&D	Dummy	Mean of *N* items
		Cooperation	Dummy	Mean of *N* items
		Protection	Dummy	Mean of *N* items
		OI	Dummy	Mean of *N* items
		OI practices-intensity	Ordinal/quantitative	Numerator: mean of dummies, Denominator: No. of employees
Wagner [30]	Mannheim Innovation Panel 2005	Innovation source	Ordinal	*N* different items
Laursen and Salter [25]	UK Innovation Survey 2005	External search breadth	Dummy	Mean of *N* items
		Innovation collaboration breadth	Dummy	Mean of *N* items

theory development and the reasoning of our hypotheses. The bibliometric search was intended to cover studies on OI metrics published between 2003 and 2014. The EBSCO database was used and the term "*open innovation*" was searched in the titles, keywords, or abstracts. In this study, only the papers dealing with the issues treated in the hypotheses—context features, OI modes, internal R&D, and financial performances—are discussed.

A. OI Metrics

Given that this paper intends to suggest a new measurement system for the openness degree of companies, the approach to the systematization of the literature is focused on the methodological issues of the different contributions. In particular, three aspects are considered: 1) the data source; 2) the kind of variables used; and 3) their treatment (see Table I).

As to the *sources*, primary versus secondary data collection can be used. The former is characterized by original interviews or questionnaires specially tailored and administered by the authors; the latter is represented either by *community innovation survey* (CIS) data or other datasets applied in accordance with the specific research focus. Moreover, some authors combine primary and secondary sources (see [16]–[18]) in order to provide additional insights and increase the validity of results.

As regards to the *kind of variables*, most contributions adopt either dummy or ordinal data, while only a limited number of studies use quantitative data [17], nominal variables (see [6] and [19]), or dummy to quantitative ratios [20]. The metrics based on dummy variables describe whether or not the company, draws from certain external sources of knowledge (see [13] and [20]–[25]); use different mechanisms for importing and exporting knowledge, ideas, and projects (see [16] and [26]); employs various protection methods for innovation (see [20] and [27]) and collaborates with different innovation partners (see [20], [25], [27], [28], and [29]). On the other hand, the metrics based on ordinal variables explain the extent to which a certain source or mechanism is used. They enclose the degree of use of different partners as a source of innovation [30]; the degree of importance of the external sources of knowledge (see [13], [21]–[23], and [27]); the extent to which inbound or outbound methods are employed (see [18] and [31]–[34]); the authorship of innovation and the relative importance of internal versus external sources of innovation [35]; the intensity of cooperation with different stakeholders (see [36]; and [37]) or in different phases of the innovation process [36], the relevance of OI capacities [38]; the percentage level of R&D activities outsourced [39]; and the overall degree of involvement in OI (see [40] and [41]).

As of the *treatment* of variables, in some instances (see [19], [27], [29], [31], [33], [35], [36], and [39]), only one item is adopted to define the specific metric. Yet, in most cases more than one item is investigated. In this instance, they can be either summed or averaged out to obtain a single indicator, or used as separate entities, or hierarchically aggregated. The hierarchical approach allows identification of comprehensive metrics containing several submetrics, referring either to different inbound and outbound practices (see [17], [26], and [34]) or to various collaboration stakeholders and partners (see [30] and [37]).

In conclusion, the use of primary data gives the opportunity to design measures best fitting the evaluation of specific OI phenomena, but reduces the immediacy of the comparisons among different contributions enabled by the employment of secondary data. Furthermore, when dummy variables are either summed or averaged out, they indicate the variety of the open behaviors, while when they are treated individually, each one identifies the presence of a specific open behavior. On the other side, ordinal variables, regardless of their treatment, always denote the importance of open behaviors. A final remark regards the hierarchical approach which enables both to examine the specific OI modes or innovation partners separately and to frame them together.

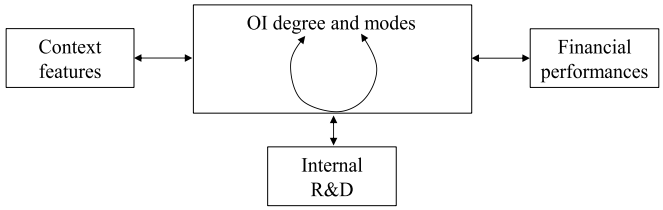

Fig. 1. Conceptual framework.

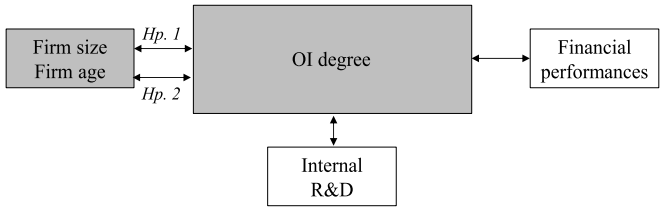

Fig. 2. Conceptual framework: Context features.

This study relies on secondary data sources from consolidated annual reports, both dummy and quantitative metrics, and hierarchical approach that defines a comprehensive measure of openness by combining different components.

B. Development of the Hypotheses

In what follows the studies are examined in order to underline their contribution to the theory development and the reasoning of the hypotheses. In Fig. 1, the relationships between context features, OI degree and modes, internal R&D, and financial performances are conceptualized.

OI degree is evaluated after two perspectives, by measuring its variety (i.e., range of different open transactions) and intensity (i.e., importance of such transactions on the total business of the company). According to the mainstream literature [6], two different adoption modalities of OI are taken into account: inbound and outbound.

Context features are analyzed in terms of firm size and age. Internal R&D is assessed as the R&D expenses sustained by companies only for closed activities. Finally, financial performances are measured after a closed perspective by excluding all the revenues and costs deriving from OI.

1) Context Features: The first two hypotheses of the research concern the relationships between firm size and age, and the openness degree of companies (see Fig. 2).

The size of the firm is used by various studies as a variable potentially influencing OI adoption. The large majority of the contributions discovered a positive relation between firm size and use of external sources (see [13], [21], [23]–[25], and [30]); inbound and outbound practices, as well as technology exploration and exploitation (see [26], [31], and [34]); alliance portfolio diversity [28]; and collaboration (see [25] and [29]).

TABLE II
THEORY DEVELOPMENT AND REASONING OF HP. 1

Study	Metric(s)	Effect
Laursen and Salter [13]; Keupp and Gassmann [21]; Idrissia *et al.* [23]	External search breadth and depth	Positive
Lichtenthaler and Ernst [31]	Extent of external technology acquisition and exploitation	Positive
van de Vrande *et al.* [26]	Technology exploration and exploitation	Positive
Barge-Gil [35]	Openness imp.; openness sour.	Null
Faems *et al.* [28]	Diversity of technology alliance portfolio	Positive
Inauen and Schenker-Wicki [37]	Stakeholder cooperation intensity: competitors; cross-industry firms; consulting firms; universities	Positive
	Stakeholder cooperation intensity: customers; suppliers	Null
Podmetina *et al.* [33]	Technology acquisition	Negative
	Technology commercialisation	Positive
Schroll and Mild [34]	Total OI adoption	Positive
Salge *et al.* [24]	Search openness	Positive
Sandulli *et al.* [29]	Open	Positive
Teirlinck and Poelmans [19]	Degree of openness of R&D activities	Null
Berchicci [39]	External R&D	Negative
Spithoven *et al*. [20]	Search strategy; external R&D; cooperation; protection; OI	Positive
	OI practices-intensity	Negative
Wagner [30]	Innovation source: suppliers; customers; competitors; consultants; universities; all partners	Positive
Laursen and Salter [25]	External search breadth; innovation collaboration breadth	Positive

A limited number of studies (see [19], [33], [35], and [37]) does not provide a definite direction of the linkage between firm size and OI, precluding a general conclusion on this relationship. Spithoven *et al.* [20] found opposite results depending on the operationalization of the OI metrics. In terms of breadth, large firms significantly make more use of OI practices than SMEs. Conversely, in terms of intensity, SMEs implement more OI practices than large companies. Finally, only one contribution uncovered a negative correlation between size and external R&D, meaning that larger firms tend to perform R&D activities mainly in-house [39].

All the analyzed studies on the relationship between firm size and OI adoption are summarized in Table II, which reports the direction of the impact for each contribution.

Many literature contributions support the idea that openness is more relevant for large firms and this is always true when dummy variables are employed to assess the variety of the open behaviors. Actually, we believe that the size has a positive impact on the likelihood of adopting OI strategies. Larger companies have stronger technological positions and greater resources enabling them to access a wide variety of external sources of knowledge, manage a broad set of relationships, and implement several OI practices. Consequently, we posit the following hypothesis: *firm size positively influences the adoption of OI (Hp. 1)*.

The second context feature analyzed is firm age (see Table III). The relationship between OI and age seems to be fairly underresearched if compared to the size. Some scholars

TABLE III
THEORY DEVELOPMENT AND REASONING OF HP. 2

Study	Metric(s)	Effect
Keupp and Gassmann [21]	External search breadth and depth	Null
Schroll and Mild [34]	Total OI adoption	Null
Idrissia *et al.* [23]	External search breadth and depth	Positive
Teirlinck and Poelmans [19]	Degree of openness of R&D activities	Both positive and negative
Berchicci [39]	External R&D	Negative

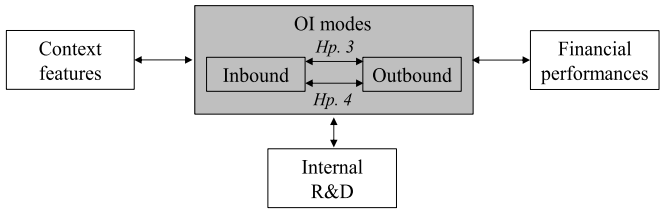

Fig. 3. Conceptual framework: OI modes.

found that age does not seem to have any influence on general OI adoption (see [21] and [34]). Teirlinck and Poelmans [19] uncovered different relationships between age and openness in different industries. Idrissia *et al.* [23] found that a decrease in the age of the firms also decreases the likelihood for SMEs to be in an open cluster. Finally, the study by Berchicci [39] discovered a negative correlation between age and external R&D meaning that younger firms tend to outsource more of their R&D activities.

Even though the analyzed studies do not give an indication on the prevalent direction of the impact, we believe that the age has a positive effect on OI adoption. Aging enables firms to gain experience and learning to strengthen their available resources and to consolidate both their reputation and market position which, in turn, will ease relationships and contacts. As a matter of fact, opening up the innovation process involves building relations and trust between the company and its external partners. Trust can be developed only through continuing interactions, which may need time to be established. Therefore, we posit the following hypothesis: *firm age positively influences the adoption of OI (Hp. 2)*.

2) OI Modes: The following hypotheses examine the extent of adoption of inbound versus outbound OI modalities and their dependence relationship (see Fig. 3). The contributions analyzed are summarized in Tables IV and V.

Even if, by definition, for every inbound activity that an organization takes, another organization must generate a reciprocal outbound activity [42], almost all the contributions found higher levels of inbound practices adoption than outbound ones (see [6], [16], [17], [26], [29], [31], [32], and [34]). Only Lichtenthaler [18] discovered use of outbound strategies in many firms, contrasting the limited extent of outward technology transfer.

Even if, in theory, we might expect a perfect symmetry between the adoption of inbound and outbound, the empirical evidences gathered from almost all of the studies lead us to

TABLE IV
THEORY DEVELOPMENT AND REASONING OF HP. 3

Study	Inbound higher than outbound
Chesbrough and Crowther [6]	Yes
van der Meer [16]	Yes
Chiaroni *et al.* [17]	Yes
Lichtenthaler [18]	No
Lichtenthaler and Ernst [31]	Yes
van de Vrande *et al.* [26]	Yes
Ili *et al.* [32]	Yes
Schroll and Mild [34]	Yes
Sandulli *et al.* [29]	Yes

TABLE V
THEORY DEVELOPMENT AND REASONING OF HP. 4

Study	If inbound then outbound
Lichtenthaler and Ernst [31]	Yes
Schroll and Mild [34]	Yes

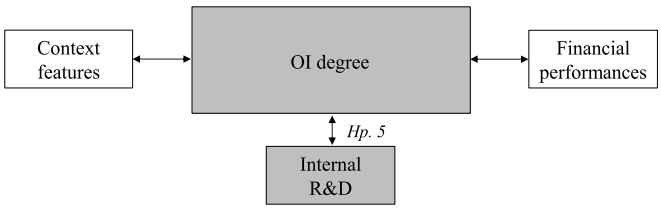

Fig. 4. Conceptual framework: Internal R&D.

hypothesize that *the adoption of inbound OI is higher than the adoption of outbound OI (Hp. 3)*.

Two of the previous contributions also examined how inbound and outbound influence each other (see Table V). Lichtenthaler and Ernst [31] discovered that the barrier to adopt outbound activities becomes lower with the adoption of inbound ones. This finding is in line with Schroll and Mild [34] who uncovered that the more a company adopts inbound OI methods, the more it will also adopt outbound ones. In fact, if a firm is using inbound activities for additional creation of innovations, it is probable that it will leverage unused parts of its increased pool of innovations and intellectual property (IP) by the means of outbound innovation.

Consistently with both the studies, we expect a higher likelihood for a company of pursuing outbound practices when it already adopts inbound OI. Thus, we posit the following hypothesis: *the adoption of inbound OI positively influences the adoption of outbound OI (Hp. 4)*.

3) Internal R&D: The fifth hypothesis pertains to the substitutive versus complementarity relationship between internal R&D effort and OI adoption (see Fig. 4). The issue has been widely discussed in the literature (see Table VI).

On one hand, internal R&D is usually employed as a proxy for absorptive capacity [43] that can be related to higher ability of the firm to integrate external knowledge into the product development process and, consequently, to a smoother adoption of the OI paradigm. On the other hand, companies with lower internal R&D might need more external knowledge. Hence, this variable may have contradictory effects on the adoption of OI: a large number of studies (see [6], [19], [20], [21], [24]–[27], [33], and [36]) suggest the role of OI as a complement for internal R&D, while a smaller number of contributions support a substitutive effect (see [13], [28], [29], and [39]).

Some studies failed to provide a definite direction of the linkage between openness and internal R&D; thus, precluding a general evidence on the relationship. Barge-Gil [35] found that open innovators are less R&D intensive than semiopen ones, but more R&D intensive than closed innovators. Similarly, Inauen and Schenker-Wicki [37] uncovered no significant correlations between R&D investment and all their OI indicators. Also Idrissia *et al.* [23] stated that the variables related to absorptive capacity have a limited explaining force in their study. For instance, the presence of R&D employees does not explain at all any of the open clusters.

However, none of the above scholars distinguished between inbound and outbound modes of OI. The only exceptions are the studies by Lichtenthaler and Ernst [31] and Schroll and Mild [34]. The former found that firms pursue an external technology acquisition as a complement to internal R&D, while R&D intensity does not have a significant influence on the technology exploitation; the latter proved that OI is generally a complement for internal R&D, but an increased use of inbound activities is employed as a substitute for internal R&D. Hence, inbound OI activities can reduce the R&D intensity of a company.

Although some contributions underline a substitution effect, we hypothesize a complementary one. As a matter of fact, higher levels of internal R&D imply higher level of absorptive capacity and, thus, favor inbound practices. Furthermore, the higher levels of internal R&D generate more innovative outputs that can be leveraged by the means of outbound OI. Hence, we posit the following hypothesis: *OI is complementary to internal R&D (Hp. 5)*.

4) Financial Performances: The last hypothesis investigates the linkage between OI adoption and financial performances (see Fig. 5). The topic has been explored by several studies (see Table VII).

Different contributions support the existence of a positive relationship between OI and firm performances (see [18], [19], [40], and [41]), whereas others outline a negative linkage (see [28] and [36]). Ahn *et al.* [38] found that four OI capacities positively associate with sales, while connective and innovative capacities negatively associate with them. Hwang and Lee [22] discovered that both search breadth and depth have a significant influence on labor productivity. Particularly, breadth has a U-shaped relationship with labor productivity, while depth an inverse-U trend: the moderate use of external knowledge sources increases labor productivity, but only the limited number of external sources with innovative importance are effective in improving it.

Even though several studies suggest a positive direction of the impact, we believe that, within an OI adoption strategy, not only benefits have to be considered, but also its costs. As a matter of fact, beyond a certain value of the degree of openness, it is reasonable to expect that the advantages deriving from

TABLE VI
THEORY DEVELOPMENT AND REASONING OF HP. 5

Study	Metric(s)	Effect
Chesbrough and Crowther [6]	Practices to bring in and take out IP and technology	Complementary
Laursen and Salter [13]	External search breadth and depth	Substitution
Keupp and Gassmann [21]	External search breadth and depth	Complementary
Lichtenthaler and Ernst [31]	Extent of external technology acquisition	Complementary
	Extent of external technology exploitation	Null
van de Vrande *et al.* [26]	Technology exploration and exploitation	Complementary
Barge-Gil [35]	Openness imp.; openness sour.	Null
Faems *et al.* [28]	Diversity of technology alliance portfolio	Substitution
Lazzarotti *et al.* [36]	Partner variety and phase variety	Complementary
Spithoven *et al.* [20]	Knowledge externalities; research cooperation; appropriability	Complementary
Inauen and Schenker-Wicki [37]	Stakeholder cooperation intensity: customers; suppliers; competitors; cross-industry firms; consulting firms; universities	Null
Podmetina *et al.* [33]	Technology acquisition and commercialization	Complementary
Schroll and Mild [34]	Inbound cooperation and acquisition; outbound; total OI adoption	Both complementary and substitution
Idrissia *et al.* [23]	External search breadth and depth	Null
Salge *et al.* [24]	Search openness	Complementary
Sandulli *et al.* [29]	Open	Substitution
Teirlinck and Poelmans [19]	Degree of openness of R&D activities	Complementary
Berchicci [39]	External R&D	Substitution
Spithoven *et al.* [20]	Search strategy; cooperation; protection; OI	Complementary
	external R&D	Null
Laursen and Salter [25]	External search breadth; innovation collaboration breadth	Complementary

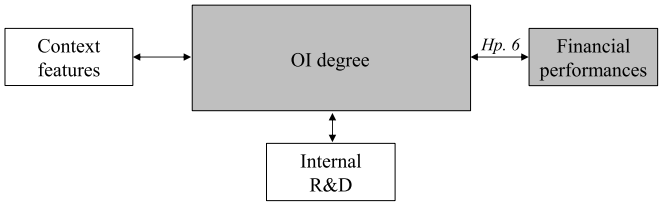

Fig. 5. Conceptual framework: Financial performances.

TABLE VII
THEORY DEVELOPMENT AND REASONING OF HP. 6

Study	Metric(s)	Effect
Lichtenthaler [18]	Outbound innovation strategy	Positive
Faems *et al.* [28]	Diversity of technology alliance portfolio	Negative
Hung and Chiang [40]	OI proclivity	Positive
Hwang and Lee [22]	External search breadth	U shape
	External search depth	Inverse-U shape
Lazzarotti *et al.* [36]	Partner variety and phase variety	Negative
Chaston and Scott [41]	OI scale	Positive
Teirlinck and Poelmans [19]	Degree of openness of R&D activities	Positive
Ahn *et al.* [38]	Inventive, absorptive, transformative and desorptive capacity	Positive
	Connective and innovative capacity	Negative

leveraging external technologies may be exceeded by the costs resulting from the complexity of managing different external relationships. Accordingly, we posit the following hypothesis: *financial performances of companies have an inverted-U relationship with OI adoption (Hp. 6)*. A synthesis of the six research hypotheses is provided in Table VIII.

TABLE VIII
CONTEXT FEATURES, OI MODES, INTERNAL R&D, AND FINANCIAL PERFORMANCES: HYPOTHESES FORMULATION

Hypothesis	Formulation
Hp. 1	Firm size positively influences the adoption of OI
Hp. 2	Firm age positively influences the adoption of OI
Hp. 3	The adoption of inbound OI is higher than the adoption of outbound OI
Hp. 4	The adoption of inbound OI positively influences the adoption of outbound OI
Hp. 5	OI is complementary to internal R&D
Hp. 6	Financial performances of companies have an inverted-U relationship with OI adoption

III. METHODS

A. Data

The hypotheses were tested by analyzing a sample of pharmaceutical companies. The industry was selected since it is an early pioneer of OI (see [6], [44]–[47]) with a broad spectrum of OI models, which have already become a standard in it [48].

A sample of 68 worldwide top R&D spending pharmaceutical companies,[1] ranked by *The 2011 EU Industrial R&D Investment Scoreboard* was considered. Consolidated annual reports from 2008 to 2012 were downloaded from the internet, and data were examined after a cross section perspective for a total of 340 statistical units. The Scoreboard lists 120 pharmaceutical companies, but 52 firms were left out either because they were acquired during the five-year period or since their annual reports

[1] 4-digit ICB code 4577 as reported in the Scoreboard.

TABLE IX
FINANCIAL STATEMENT ITEMS FEATURING OI

Costs	Revenues	Additions	Disposals
		7) of R&D	12) of R&D
1) from R&D collaboration	4) from R&D collaboration	8) of patents	13) of patents
2) from R&D outsourcing	5) from R&D services on behalf of third parties	9) of product rights	14) of product rights
3) from in-licensing	6) from out-licensing	10) of technology	15) of technology
		11) of goodwill	16) of goodwill

were not filling IFRS or US GAAP standards. The final sample consists of 44 European companies and 24 non-European ones; the most represented country is USA with 19 firms, followed by UK (9) and Germany (6).

B. Measure of Variables

An accounting approach to the measurement of the openness degree of companies is adopted by analyzing all the OI transactions taken from their audited consolidated annual reports. Inbound activities will generate either costs or new investments in intangibles (additions); similarly, outbound practices will result in either revenues or divestments of intangibles (disposals). OI costs and revenues can be disclosed either directly in the income statement or in its notes, while additions and disposals will be detected in the notes to the balance sheet. The analysis of costs and revenues is mirror-like, since every OI activity typically generates costs for a company and revenues for another one. In particular, open costs and revenues can derive from:

1) collaborative and contract development, which refer to joint development projects with third parties under long-term agreements, such as development partners' reimbursements, cost or profit sharing agreements, share of results of research associates, contract fees, development milestone payments and achievements;
2) outsourcing of R&D services or development of R&D services on behalf of third parties,[2] which regard a more spot behavior than the previous one, such as research services received from subcontractors or provided to third parties;
3) in-licensing costs, out-licensing revenues, and royalty fees paid or received.

In the same way, the analysis of new investments and divestments of intangibles is mirror-like, including additions and disposals of:

1) in-process R&D and development costs;
2) licenses, patents, IP rights, and industrial property;
3) trademarks, product rights, brands, and product-related intangibles;
4) technology and technology rights;
5) goodwill, related to research spin-ins and spin-offs.

[2]Within revenues deriving from R&D performed on behalf of third parties, a particular category is defined by grants received by the company for R&D activities, R&D tax credit and research funding, which can be considered as open revenues by defining the government as an entity that remunerates the company for its innovation efforts, even if it is not interested in owning the outcomes of such innovation. In fact, unlike a private entity, the government aims at the development of innovation for the community, rather than for itself.

The first four categories have a clear connotation within innovation, while the innovative nature of goodwill can be questionable. Given the definition itself of goodwill as *"future economic benefits arising from assets that are not capable of being individually identified and separately recognized"* (IFRS 3), we think that it can be identified with the skill, the know-how, the technical and organizational expertize of the workforce. This is consistent with most of the definitions of goodwill found in the annual reports of companies, as well as with contributions claiming that goodwill can be regarded as a black box containing a bundle of intangible assets [49], and that a significant part of it comprises intellectual capital [50].

Once the financial statement items featuring OI are delineated (see Table IX), two different approaches can be followed to analyze the data. First, the different categories of open costs, revenues, additions, and disposals can be counted, in order to identify how many different OI practices are performed by companies. This can be done by introducing 16 dummy variables, one for each category: the variables will take value 1 if the company under analysis shows the specific category in its annual report during the analyzed fiscal period, 0 otherwise. Summing all the dummies, the *openness variety* for each firm can be defined, whose values will range from 0 to 16, corresponding, respectively, to no practice at all and all open practices performed by the company during the period of analysis. Moreover, following the same procedure, *inbound variety* and *outbound variety* can be obtained, including only the costs and additions or the revenues and disposals, respectively. Hence, each of these two proxies ranges from 0 to 8.

Second, in order to understand how pervasive OI is within the business of a company, open costs, revenues, additions, and disposals can be compared to its total business in terms of total R&D and IP costs, total revenues, and total intangibles.

$$C = \frac{\text{open costs}}{\text{total R\&D and IP costs}}$$
$$R = \frac{\text{open revenues}}{\text{total revenues}}$$
$$A = \frac{\text{additions of intangibles}}{\text{total intangibles}}$$
$$D = \frac{\text{disposals of intangibles}}{\text{total intangibles}}.$$

In this way, four dimensionless variables are obtained which can be combined together after a hierarchical perspective: if costs, revenues, additions, and disposals are considered as the four Cartesian axes in the R^4 space, each company can be

TABLE X
SPEARMAN CORRELATION COEFFICIENTS (** THE CORRELATION IS SIGNIFICANT AT 0.01 LEVEL)

Variable	1.	2.	3.	4.	5.	6.
1. Openness variety	1					
2. Inbound variety	0.806(**)	1				
3. Outbound variety	0.617(**)	0.063	1			
4. Openness intensity	0.047	0.048	0.036	1		
5. Inbound intensity	0.364(**)	0.515(**)	-0.058	0.604(**)	1	
6. Outbound intensity	0.071	-0.271(**)	0.499(**)	0.541(**)	-0.024	1

represented as a 4-D point whose *openness intensity* is proportional to the Euclidean distance of the point from the origin of the axes.

$$\text{Openness intensity} = \sqrt{\frac{C^2 + R^2 + A^2 + D^2}{4}}$$

the factor ¼ being used to normalize the values of intensity to the range [0, 1], where 0 corresponds to a completely closed behavior and 1 to a completely open one.

After the same approach, *inbound intensity* and *outbound intensity* can be defined.

$$\text{Inbound intensity} = \sqrt{\frac{C^2 + A^2}{2}}$$

$$\text{Outbound intensity} = \sqrt{\frac{R^2 + D^2}{2}}.$$

Variety is a discrete measure of OI which, by assessing the range of different practices performed by companies, provides similar information to different literature contributions (see [13], [16], [21]–[24], and [28]). On the contrary, intensity is a continuous proxy suggesting a radically new approach to the measurement of OI.

In addition to openness metrics, the following variables were employed to test the hypotheses:

1) *firm size*, measured in number of employees;
2) *firm age*, assessed in number of years from the date of establishment;
3) *closed R&D per employee*—where closed R&D is measured as total R&D and IP costs net of open costs—as a proxy of R&D focalization of human resources;
4) *closed ROA* (i.e., closed EBIT divided by total assets) as a measure of financial performances, where closed EBIT is calculated as EBIT net of open revenues less open costs.

The data were examined after a cross section perspective, since five years are not enough for a longitudinal study, especially in an industry where the development time horizon can be longer than ten years.

IV. ANALYSIS AND RESULTS

Table X shows correlations between variety and intensity metrics, while Tables XI and XII exhibit descriptive statistics and correlations between the two different sets of OI metrics and the other variables under study.

No significant correlation is uncovered between the two metrics for openness as a whole, suggesting that the use of different proxies can lead to very different results. Yet, positive correlation is found between the two metrics as to both inbound and outbound, indicating that the two different measurement approaches are more robust when specific OI modalities are described, rather than when the whole OI phenomenon is investigated.

A. Context features

Hp. 1: Firm size positively influences the adoption of OI.

Positive correlation is found between firm size and openness variety (see Table XI), negative correlation with openness intensity (see Table XII), thus confirming the hypothesis when variety is used and disconfirming it by the use of intensity.

Results: Firm size positively influences the variety of OI, while negatively influences its intensity.

The use of variety metrics leads to results similar to those of literature (see e.g., [13], [24]–[26], [28]–[31], and [34]): the larger a company, the wider range of open transactions is performed and more relationships are activated with third parties. Conversely, the proclivity to openness—measured as its intensity—is negatively influenced by the size of the firm, meaning that more transactions do not necessarily imply a higher impact on the business of the company. Actually, the larger a firm, the larger the denominators of the ratios defining intensity, so that even if the total value of open transactions is the same for two companies, the larger one will have a lower intensity. Thus, when we compare companies of different size, intensity metrics are inversely affected by the size itself. As a matter of fact, if we consider the top ten companies[3], the total value of open revenues during the five years amounts to €23 billion, while €21 billion are achieved for the remaining 58 firms. Yet, when such values are compared to the total values of revenues (€1634 billion for the top ten companies, €544 billion for the others) it is clear that the top ten companies have a much smaller intensity.

Hp. 2: Firm age positively influences the adoption of OI.

Also, firm age is positively correlated with openness variety (see Table XI) and negatively correlated to intensity (see Table XII) leading to the same findings as firm size.

Results: Firm age positively influences the variety of OI, whereas negatively influences its intensity.

Hence, the range of different open transactions is positively affected by the age of a company; yet, the younger a firm, the higher its proclivity to open its own business. Given that several literature contributions (see [21], [23], and [34]) did not find any evidence of a negative relation, the result could be considered as industry-specific. As a matter of fact, the industry is characterized by very long development times, which may exceed ten years. Therefore, since 21 companies in the sample had not been established for 20 years by 2012, they might still be in the development phase so that most part of their revenues derived from: profit sharing, milestone achievements, development partners' reimbursements, and research services provided to other pharmaceutical companies, as well as government grants. Actually, OI is the very core business for eight of these firms, with open revenues to total revenues ratio being greater than 70%. Con-

[3]Defined after the average value of employees over the five years.

TABLE XI
DESCRIPTIVE STATISTICS AND SPEARMAN CORRELATION COEFFICIENTS (** THE CORRELATION IS SIGNIFICANT AT 0.01 LEVEL, * THE CORRELATION IS SIGNIFICANT AT 0.05 LEVEL)

Variable	Mean	SD/mean	1.	2.	3.	7.	8.	9.	10.
1. Openness variety	4.27	0.474	1						
2. Inbound variety	2.34	0.669	0.806(**)	1					
3. Outbound variety	1.93	0.599	0.617(**)	0.063	1				
7. Firm size	17 982	1.792	0.384(**)	0.425(**)	0.082	1			
8. Firm age	62 years	0.893	0.215(**)	0.223(**)	0.076	0.620(**)	1		
9. Closed R&D per employee	79 k€	1.295	−0.140(**)	−0.276(**)	0.129(*)	−0.259(**)	−0.264(**)	1	
10. Closed ROA	11.09%	2.222	0.211(**)	0.365(**)	−0.148(**)	0.611(**)	0.396(**)	−0.334(**)	1

TABLE XII
DESCRIPTIVE STATISTICS AND PEARSON CORRELATION COEFFICIENTS (** THE CORRELATION IS SIGNIFICANT AT 0.01 LEVEL, * THE CORRELATION IS SIGNIFICANT AT 0.05 LEVEL)

Variable	Mean	SD/mean	4.	5.	6.	7.	8.	9.	10.
4. Openness intensity	18.30%	0.981	1						
5. Inbound intensity	16.50%	1.154	0.656(**)	1					
6. Outbound intensity	13.14%	1.715	0.771(**)	0.065	1				
7. Firm size	17,982	1.792	−0.275(**)	−0.106	−0.283(**)	1			
8. Firm age	62 years	0.893	−0.376(**)	−0.138(*)	−0.388(**)	0.406(**)	1		
9. Closed R&D per employee	79 k€	1.295	0.367(**)	−0.186(**)	0.582(**)	−0.145(**)	−0.294(**)	1	
10. Closed ROA	11.09%	2.222	−0.559(**)	0.04	−0.795(**)	0.300(**)	0.353(**)	−0.538(**)	1

TABLE XIII
DESCRIPTIVE STATISTICS FOR INBOUND AND OUTBOUND

Average value	Inbound	Outbound
Variety	2.34	1.93
Intensity	16.50%	13.14%

versely, for longer established companies, with a wider product portfolio, revenues deriving from the selling of drugs are obviously prevalent if compared to open revenues.

B. OI Modes

Hp. 3: The adoption of inbound OI is higher than the adoption of outbound OI.

In Table XIII, the comparison of inbound and outbound practices is outlined.

The hypothesis is confirmed, the values of inbound metrics being slightly higher than those of outbound ones.

Results: The adoption of inbound OI is higher than the adoption of outbound OI in both variety and intensity.

The results confirm the findings of those scholars (see [6], [16], [17], [26], [31], [32], and [34]) who use the number of inbound/outbound practices, importing/exporting mechanisms or organizational modes to define OI. In theory, as also remarked by Chesbrough and Crowther [6], any inbound flow for a company should generate an outbound flow for another one so that the two values should be the same. Yet, our sample being limited to only 68 companies, we do not expect a perfect equality of inbound and outbound flows, which is verified only when open transactions of all firms worldwide are analyzed. The higher values of inbound, if compared to outbound, show that the top R&D spending pharmaceutical companies rather behave as innovation seekers.

Hp. 4: The adoption of inbound OI positively influences the adoption of outbound OI.

In Table XIV, one-way ANOVA is performed in order to test the hypothesis. It is not confirmed in variety, given that the mean value of outbound is almost the same for both companies implementing inbound practices and firms not adopting them. On the contrary, a significant reverse relation is found when intensity metrics are employed, since the companies not performing inbound show a significantly higher average outbound intensity.

Results: The adoption of inbound OI does not affect the adoption of outbound OI in variety and negatively influences it in intensity.

Once again, some peculiarities of the specific industry can be outlined: inbound practices are prevailing for larger and longer established companies, while outbound is much more featuring among smaller and younger firms. Therefore, the higher values of outbound intensity within the companies not performing inbound are affected by the higher relevance of OI within the business of the latter (see *Hp. 1* and *Hp. 2*).

C. Internal R&D

Hp. 5: OI is complementary to internal R&D.

Negative correlation is discovered between closed R&D per employee and openness variety (see Table XI), whereas positive correlation is obtained as to intensity (see Table XII).

Results: OI is substitutive to internal R&D when measured in variety, complementary if measured in intensity.

While the range of the open transactions a company performs decreases with its R&D focalization, the proclivity to openness is higher for more R&D focalized firms. Actually, if compared to

TABLE XIV
MEAN COMPARISON FOR OUTBOUND USING THE ADOPTION OF INBOUND PRACTICES AS A PREDICTOR: ONE-WAY ANOVA

	Outbound variety mean					Outbound intensity mean				
Not performing inbound	1.91					41.96%				
Performing inbound	1.93					9.94%				
Total	1.93					13.14%				
	Sum of squares	df	Mean square	F	Sig.	Sum of squares	df	Mean square	F	Sig.
Between groups	0.012	1	0.012	0.009	0.925	3.137	1	3.137	75.303	0.000
Within groups	452.294	338	1.338			14.081	338	0.042		

TABLE XV
QUADRATIC REGRESSIONS OF CLOSED ROA USING OPENNESS AS A PREDICTOR

	Variety				Intensity			
Adjusted R^2	0.055				0.320			
Standard error of the estimate	0.216				0.183			
ANOVA:	Regression		Residual		Regression		Residual	
Sum of squares	1.022		15.754		5.434		11.343	
df	2		337		2		337	
Mean square	0.511		0.047		2.717		0.034	
F	10.935				80.717			
Sig.	0.000				0.000			
Predictors:	B	Standard error	t	Sig.	B	Standard error	t	Sig.
Constant	−0.156	0.047	−3.338	0.001	0.104	0.018	5.678	0.000
Openness	0.051	0.020	2.573	0.011	−0.241	0.194	−1.239	0.215
Openness^2	−0.003	0.002	−1.319	0.188	−0.833	0.003	−2.424	0.016

the top ten companies, smaller and younger firms are, in average, 1.5 times more R&D focalized (83 versus 56 k€/employee).

In line with the studies by Lichtenthaler and Ernst [31] and Schroll and Mild [34], the hypothesis is also tested by separating inbound and outbound practices: negative correlation is found with inbound variety and intensity, positive correlation with both outbound measures (see Tables XI and XII).

Results: Inbound OI is substitutive and outbound OI is complementary to internal R&D as to both variety and intensity.

The findings suggest that inbound practices are substitutive to internal R&D, while outbound can be considered as complementary. Actually, inbound activities and internal R&D both represent efforts that a company puts in its innovation process, while outbound practices can be regarded as a result of such process. Thus, if the two typologies of input—external versus internal resources—can be viewed as substitutive, it is not surprising that a higher level of internal R&D generates more innovation outputs that can be exploited through outbound practices.

D. Financial Performances

Hp. 6: Financial performances of companies have an inverted-U relationship with OI adoption.

In order to test the inverted-U shape relationship, quadratic regressions were performed (see Table XV). As to variety, the regression is not significant, disconfirming the hypothesis; furthermore, the positive correlation of closed ROA with openness variety (see Table XI) defines an increasing trend of the performance. On the contrary, as of intensity, the first-order coefficient is not significant but the second order one is significantly negative leading to the following equation:

$$Closed\ ROA = 0.104 - 0.833 * openness\ intensity^2 + \varepsilon$$

where ε is the regression error.

Results: Financial performances increase with openness variety and have a quadratic decreasing trend with openness intensity.

The specific contributions of inbound and outbound activities to financial performances are also investigated using both variety and intensity metrics (see Table XVI). In both cases, as to inbound, the first-power term has a positive coefficient and the second-power term a negative one, whereas the coefficients of outbound have the opposite signs. Noteworthy, in both instances, the coefficient of the inbound $*$ outbound term is not significant, proving that there is no synergy between the two different adoption modalities of OI.

Results: Financial performances have an inverted-U shape relationship with inbound and a U shape relationship with outbound.

The trends of closed ROA versus inbound (outbound) for different values of outbound (inbound) are reported in Fig. 6.

It is possible to observe that, for any fixed value of outbound, closed ROA increases with the value of inbound until a maximum is reached and then begins to decrease. Such a trend is more manifest with variety rather than with intensity for which closed ROA is almost constant. The inverse-U shape of performances versus inbound confirms that a slight recourse to inbound

TABLE XVI
QUADRATIC REGRESSIONS OF CLOSED ROA USING INBOUND AND OUTBOUND AS PREDICTORS

	Variety				Intensity			
Adjusted R^2	0.205				0.655			
Standard error of the estimate	0.198				0.131			
ANOVA:	Regression		Residual		Regression		Residual	
Sum of squares	3.638		13.139		11.072		5.705	
df	5		334		5		334	
Mean square	0.728		0.039		2.214		0.017	
F	18.498				129.634			
Sig.	0.000				0.000			
Predictors:	B	Standard error	t	Sig.	B	Standard error	t	Sig.
Constant	−0.091	0.044	−2.075	0.039	0.096	0.013	7.395	0.000
Inbound	0.128	0.021	6.005	0.000	0.286	0.104	2.756	0.006
Outbound	−0.097	0.030	−3.266	0.001	−1.369	0.155	−8.831	0.000
$Inbound^2$	−0.013	0.003	−3.812	0.000	−0.335	0.152	−2.207	0.028
$Outbound^2$	0.019	0.006	2.948	0.003	0.825	0.225	3.661	0.000
Inbound * Outbound	−0.001	0.006	−0.215	0.830	0.296	0.155	1.907	0.057

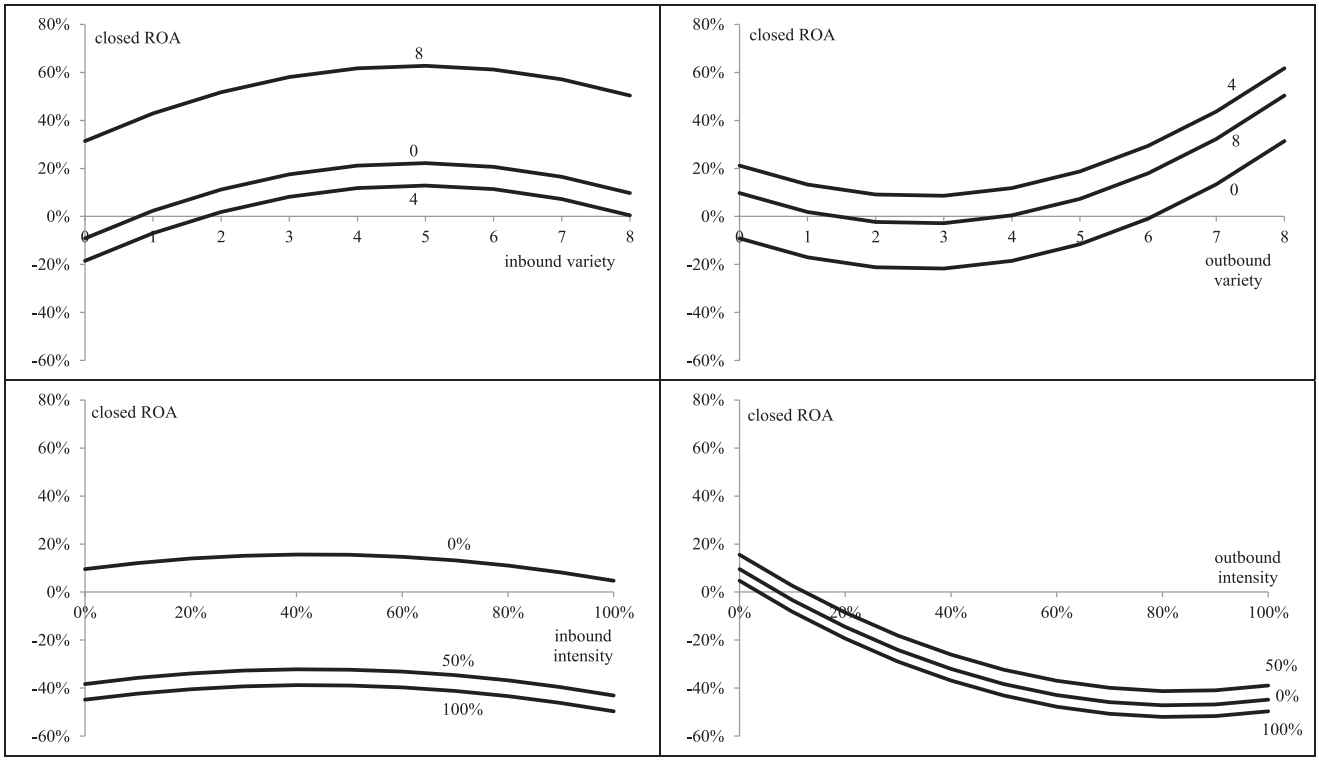

Fig. 6. Iso-outbound and iso-inbound curves for closed ROA.

practices provides benefits in terms of costs reduction, companies can access external resources at a lower cost than the one they would incur if only internal resources were used. Yet, when the recourse to external resources increases, the management complexity of such resources becomes higher than the benefits.

With regard to outbound, the regressions suggest a U-shaped relationship but, as to variety, the trend is mostly increasing, while in the range of existence of intensity, almost only the decreasing part of the trend is observed. This result is no doubt industry-specific; actually, high values of outbound intensity are typical of smaller and younger companies, which are mostly focused on the R&D process and only seldom commercialize products. Such firms are typically in loss, and survive only from private investments and government contributions.

V. DISCUSSION

In Table XVII, a summary of the findings is provided.

Hypotheses 1 and 2 are confirmed when variety is employed, while intensity shows the opposite relationship to the one hypothesized. *Hp. 3* is supported as to both variety and intensity. *Hp. 4* is not corroborated by the use of variety metrics and exhibits the opposite direction when intensity is analyzed.

TABLE XVII
CONTEXT FEATURES, OI MODES, INTERNAL R&D, AND FINANCIAL PERFORMANCES: SUMMARY OF THE RESULTS

Hypothesis	Variety	Intensity
Hp. 1	Positive relation with size	Negative relation with size
Hp. 2	Positive relation with age	Negative relation with age
Hp. 3	Inbound higher than outbound	Inbound higher than outbound
Hp. 4	Inbound adoption does not affect outbound adoption	Inbound adoption prevents outbound adoption
Hp. 5	Substitutive to internal R&D (inbound is substitutive and outbound complementary)	Complementary to internal R&D (inbound is substitutive and outbound complementary)
Hp. 6	Positive relation with performances (inbound shows a reverse-U relation, outbound a U-shaped one)	Quadratic negative relation with performances (inbound shows a reverse-U relation, outbound a U shaped one)

Hp. 5 is substantiated by the use of intensity, but manifests the opposite direction with variety. At last, no support is provided to *Hp. 6* when the whole openness of the company is examined, but the reverse-U relationship is uncovered with inbound variety and intensity.

In line with what also emerged from the literature review by adopting different proxies for OI dissimilar results are obtained (see Table XVIII).

By extending Laursen and Salter's [13] concepts of breadth and depth, in most of the literature contributions analyzed, we have 1) the number/diversity of external sources of knowledge, OI practices and mechanisms, collaboration partners, or stakeholders as a measure of open behaviors variety, and 2) the degree of use/importance of them to define the relevance of each behavior. This study proposes a new approach for measuring OI using financial statement data to improve on the ideas of breadth and depth.

1) Variety represents the range of different open transactions the company performs.
1) Intensity indicates how much such transactions are relevant for the firm.

In terms of variety, we obtained similar findings to the prevalent ones from literature contributions as to firm size and financial performances. As to intensity, we confirmed the prevalent view on internal R&D but—in contrast to the dependence relationship found by both Lichtenthaler and Ernst [31] and Schroll and Mild [34]—we discovered that the adoption of inbound hinders that of outbound. Moreover, consistently with the literature, we uncovered higher levels of inbound adoption regardless of the type of metric employed. As to firm size, similarly to the study by Spithoven *et al.* [20], we found opposite results depending on the use of openness variety versus intensity. Finally, as regards to internal R&D, we obtained the same findings by Schroll and Mild [34], since both inbound variety and intensity were discovered to be substitutive to internal R&D efforts.

Noteworthy, the use of different metrics does not only affect the results concerning the relationship of OI with other variables, but also influences the definition itself of openness. As a matter of fact, OI can be viewed as the recourse to different external sources of knowledge [13], rather than the supportive internal climate [38], the use of importing and exporting mechanisms [16], the recourse to collaboration [37], or the adoption of protection methods [27]. Our definition of openness pertains to the use of importing, collaboration, and exporting practices, which have an impact on the business of the company, so that, through the analysis of financial statements, we add a novel methodology to the current debate capturing the breadth and depth of OI.

VI. CONCLUSION

This paper analyses the relationships between the adoption of OI by pharmaceutical companies and their context features, internal R&D, and financial performances.

Our results suggest that being open is a more pervasive behavior among smaller and younger companies, for which OI is the very core business with most part of revenues deriving from openness. Yet, a wider range of open transactions is performed by larger and longer established firms, despite OI is not a core activity for them, more connections are established. Even if the number of companies performing inbound and outbound practices at least in one of the five years is almost the same (respectively, 66 and 65), a slightly higher variety and intensity is found for the former. This means that not only the range of inbound transactions is higher than outbound, but inbound is also a more relevant behavior than outbound in terms of its impact on the business of companies. The financial performances of firms exhibit a positive trend versus openness variety and a negative trend versus intensity. Furthermore, in terms of both variety and intensity, an inverted-U shape trend versus inbound practices and a U shape one versus outbound are uncovered. Beyond a certain value of inbound adoption, the benefits deriving from leveraging external technologies are exceeded by the costs resulting from the management of external relationships. On the other side, the negative relation between performances and outbound intensity can be considered as industry-specific, since high values of outbound are typical of younger companies, which are still in the development phase.

This study contributes to the current debate on OI in three ways. First, by suggesting a measurement system for OI based on its accounting dimension, it provides new insights as to what "being open" means for a company. Actually, most contributions in the literature give a definition of openness in terms of diversity and/or importance of open activities and technological relationships. By using either dummy or ordinal variables, scholars exploit a discrete scale to define openness. Our approach is twofold: from one side, we adopt a *variety* measure, which is very similar to the diversity metrics employed in the literature

TABLE XVIII
CONTEXT FEATURES, OI MODES, INTERNAL R&D, AND FINANCIAL PERFORMANCES: POSITIONING OF OUR RESULTS WITHIN THE LITERATURE CONTRIBUTIONS

Study	Firm size and OI	Firm age and OI	Inbound higher than outbound	If inbound then outbound	Internal R&D and OI	Financial performance and OI
Chesbrough and Crowther [6]			Yes		Complementary	
Laursen and Salter [13]	Positive				Substitution	
van der Meer [16]			Yes			
Chiaroni *et al.* [17]			Yes			
Keupp and Gassmann [21]	Positive	Null			Complementary	
Lichtenthaler [18]			No			Positive
Lichtenthaler and Ernst [31]	Positive		Yes	Yes	Both complementary and null	
van de Vrande *et al.* [26]	Positive		Yes		Complementary	
Barge-Gil [35]	Null				Null	
Faems *et al.* [28]	Positive				Substitution	Negative
Hung and Chiang [40]						Positive
Hwang and Lee [22]						Both U and inverse U
Ili *et al.* [32]			Yes			
Lazzarotti *et al.* [36]					Complementary	Negative
Spithoven *et al.* [20]					Complementary	
Inauen and Schenker-Wicki [37]	Both positive and null				Null	
Podmetina *et al.* [33]	Both positive and negative				Complementary	
Schroll and Mild [34]	Positive	Null	Yes	Yes	Both complementary and substitution	
Chaston and Scott [41]						Positive
Idrissia *et al.* [23]	Positive	Positive			Null	
Salge *et al.* [24]	Positive				Complementary	
Sandulli *et al.* [29]	Positive		Yes		Substitution	
Teirlinck and Poelmans [19]	Null	Both positive and negative			Complementary	Positive
Ahn *et al.* [38]						Both positive and negative
Berchicci [39]	Negative	Negative			Substitution	
Spithoven *et al.* [20]	Both positive and negative				Both complementary and null	
Wagner [30]	Positive					
Laursen and Salter [25]	Positive				Complementary	
Our results-variety	Positive	Positive	Yes	Not supported	Substitutive	Positive
Our results-intensity	Negative	Negative	Yes	Reverse relation	Complementary	Negative

and provides a discrete value of openness; from the other, we introduce an *intensity* proxy, which measures the importance of OI in a continuous way by assessing the impact that open transactions have on the total business of companies. Second, by proposing two alternative ways of measuring the openness of a firm, we outline that different approaches to OI lead to dissimilar results, as also the systematic review of the literature proves. Third, in line with the studies by Lichtenthaler and Ernst [31] and Schroll and Mild [34], the separation of inbound from outbound activities enables a deeper understanding of the whole phenomenon.

Three limits can be outlined for this study. First, the disharmony of accounting standards over countries limited our analysis only to the companies which adopted either IFRS or US GAAP standards resulting in an undercoverage of the sample. Second, being focused on accounting indicators, our methodological approach can be used to investigate only the pecuniary dimension of OI [51] and, thus, it cannot be generalized to such industries as software, where sourcing and revealing are widespread. Third, the paper is based on observations over a five-year period, which is too short—at least in the analyzed industry—to allow a longitudinal analysis.

A future direction of research will be the in-depth analysis of case studies over longer periods of time, in order to describe the different paths to OI within the specific industry and understand how open strategies can be related to the whole innovation process of companies. Furthermore, the widening of the analysis to other industries might lead to the generalization of our results.

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