Exploring the impact of open innovation on firm performances

Structured Abstract

Purpose - The paper explores the relationships between the openness of firms and their innovation and financial performances.

Design/methodology/approach - In order to investigate such relationships, data on inbound and outbound open innovation (OI) processes and performances of 110 worldwide top R&D spending bio-pharmaceutical companies are collected via the consolidated annual reports and the PATSTAT database. The time period of the analysis is 2008-2012.

Findings - Regarding innovation performances, R&D productivity and revenues to patents ratio decrease with openness, whilst patents growth is not influenced by OI adoption. As to financial performances, sales growth exhibits a positive trend with openness, while operating profit and turnover decrease with OI adoption. Particularly, an inverted-U relationship with inbound and a U-shape one with outbound are observed as of operating profit.

Research implications - The study adds to the knowledge about the effect of openness on firms' performances, a topic of increasing interest to academics, managers and policy-makers. Both inbound and outbound facets of the phenomenon are taken into account.

Practical implications - Understanding how openness affects performances enables more informed decision making by managers, leading to a more effective use of OI activities.

Originality/value - The work provides new insights as to what "being open" means for a company, gauging both inbound and outbound transactions after a pecuniary perspective. Employing objective and continuous measures, the relevance of OI for the whole business of firms can be identified.

Keywords: Open innovation, Inbound, Outbound, Innovation performances, Financial performances, Bio-pharmaceutical.

Article Classification: Research paper

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1. Introduction

This paper explores the relationships between the openness of firms and their innovation and financial performances. Actually, a growing propensity towards openness has recently characterised innovation processes, with companies increasingly relying on outside information and research collaborations to develop new products, services and processes. At the same time, they have become more active in licensing-out and selling internally developed technology to external parties (Spithoven et al., 2013). Essentially, open innovation (OI) has become an integral part of the business model of firms. The growth of this phenomenon is due to a number of circumstances such as the reduction of the life cycle of products, the intensification of global competition and the rising costs of research and development (R&D). In this context, the relationships between openness and organisational performances have emerged as features of principal interest (Schroll and Mild, 2012). However, owing to the complexity and heterogeneity of OI, it is not easy to investigate its effects on companies' performance (Ahn et al., 2015). Although practice and theory seem to indicate that the OI approach is beneficial for organisations, empirical results are not unanimous in their judgement. Though the majority of contributions has found that the implementation of OI has a positive effect on performances, others have discussed inverted U-shaped relationships or even a negative effect (Greco et al., 2015). Moreover, external knowledge acquisition - i.e. inbound OI - has attracted more attention by researchers than internal knowledge exploitation, i.e. outbound OI (West and Bogers, 2014) and, consequently, the linkage between outbound OI and firm performance has received insufficient attention to date (Lichtenthaler, 2015).

Based on this premise, the work aims to deepen the understanding of the impact of OI adoption on companies' innovation and financial performances, taking into account both inbound and outbound modes. In order to do so, a pecuniary definition of openness is suggested, based on

the operational and financial flows that OI transactions generate (Michelino et al., 2015). The hypotheses are tested on a sample of 110 worldwide top R&D spending bio-pharmaceutical companies for the five-year period 2008-2012. For these firms, data were collected via the consolidated annual reports and the PATSTAT database.

The remainder of this paper comprises five sections. First, the theoretical background is introduced and the hypotheses about the topic under investigation are developed. Then, in section 3, data and methods are described, and results presented in section 4. Section 5 covers discussion and the work concludes with implications, limitations and directions for future research.

2. Theory and hypotheses

The question of how openness influences the capacity of firms to innovate and obtain higher economic returns is at the heart of OI research (Dahlander and Gann, 2010; Gassmann et al., 2010). In this section, a literature review is provided in order to 1) delineate the theoretical contributions concerning the relationships between openness and performances and 2) lay the foundations for the theory development and the reasoning of the hypotheses.

2.1 OI and innovation performances

Our first key concern is the linkage between OI and innovation performances. Table 1 presents the analysed studies, reporting for each contribution the direction of the impact.

There is a considerable body of literature proving that opening to external knowledge sources helps to boost innovation performances. Specifically, as to the degree of innovation novelty, Chiang and Hung (2010) and Parida et al. (2012) uncovered that inbound OI activities have a positive and significant effect on incremental and radical innovation performances. Similarly, Ebersberger et al. (2012) argued that OI practices positively impact both on the capacity for novel innovation and on actual innovation performances. When sales of new-to-the-market products are accounted for, Barge-Gil (2013) proved that an open strategy performs better than

a semi-open strategy, which, in turn, performs better than a closed one. Also Garcia Martinez et al. (2014) suggested that a broad and deep openness approach allows companies to gain additional value.

Other contributions do not provide a definite direction of the linkage between OI and innovation performances because the use of different metrics leads either to opposite or to non-significant results. For instance, Huang and Rice (2009) discovered that innovation performances improve with the engagement in networking but decrease as a consequence of technology purchase. Cheng and Shiu (2015) found that the focus on inbound activities enhances radical innovation performances but hinders incremental innovation ones, whereas the focus on outbound processes produces the opposite effects. Remaining on the subject of the degree of innovation novelty, Hwang and Lee (2010) argued that radical innovation performances are neither explained by the breadth nor by the depth of external knowledge search. Yet, only breadth has a significant curvilinear relationship with incremental innovation performances. Lazzarotti et al. (2010) proved that innovativeness is positively linked to the variety of partners with whom the company collaborates, but no significant relation occurs as of the innovation funnel openness. Going more specifically into the types of collaborative partners, Wagner (2013) uncovered that only customers, suppliers, and competitors contribute to innovation performance, whilst the use of universities and consultants as sources of innovation does not seem to have any impact. Analogously, Inauen and Schenker-Wicki (2011) found that openness towards different external players can have positive, negative or non-significant effects on innovation performances.

A different stream of papers supports the idea that “too much” openness may be harmful to the firm, discovering a curvilinear relationship between OI and performances. Substantially, there are moments or tipping points after which openness can negatively affect innovation performances. The balance between the positive effects of companies’ external innovation

linkages and the potential for over-searching led Laursen and Salter (2006) and Berchicci (2013) to expect an inverted U-shaped relationship between the breadth/depth of innovation linkages or the R&D outsourcing and the innovation performances, which has been confirmed by their empirical analyses.

Table 1. Literature contributions on the relationship between OI and innovation performances

Based on the previous arguments, we believe that opening up firms' boundaries enables greater benefits in terms of innovation performance but only up to a certain point, because relying heavily on external technology sourcing significantly increases search, coordinating and monitoring costs. Therefore, this logic suggests the following:

Hypothesis 1: Innovation performances of companies have an inverted-U relationship with open innovation adoption (Hp. 1).

2.2 OI and financial performances

Our second key concern is the relationship between openness and financial performances. Once again, empirical findings do not point out a unified judgment (Table 2). The majority of the contributions demonstrates that it is worthwhile for companies to implement inbound and outbound OI modes in terms of return on sales (Lichtenthaler, 2009), sales growth (Chaston and Scott, 2012; Hung and Chiang, 2010), and evolution of employment (Teirlinck and Poelmans, 2012). In addition, Noh (2015) - by examining the long-term financial performances of firms that announced an OI strategy - discovered that openness is useful not only in terms of profitability, but also for production process improvement and market benefits.

On the contrary to the above studies, Faems et al. (2010) argued that the diversity of technology alliance portfolio negatively affects personnel costs in value added and profit margin. The same result was uncovered by Lazzarotti et al. (2010), who demonstrated that not only partner variety but also innovation funnel openness can negatively influence a company's overall performance.

Other papers do not give a clear direction of the linkage between OI and financial performances, disallowing a general conclusion on this relationship. For example, Hwang and Lee (2010) proved that external search breadth has a U relationship with productivity - calculated as firm's total sales divided by the number of employees - whereas depth shows an inverse-U relationship. Hence, the moderate use of external knowledge sources increases labour productivity, but only a limited number of external sources with innovative importance are effective in improving it. Furthermore, Ahn et al. (2013) found that four OI capacities positively associate with sales, while connective and innovative capacity negatively associate with them. Finally, Du et al. (2014) uncovered that R&D projects with OI partnerships record higher financial returns. Yet, by making a distinction between science-based and market-based partnerships, only the former are related to better financial performances than closed innovation projects.

Table 2. Literature contributions on the relationship between OI and financial performances

Even though several studies suggest a positive direction of the impact, we believe that not only OI benefits, but also the costs associated with its adoption, have to be considered. In fact, beyond a certain value of openness degree, it is reasonable to expect that the benefits deriving from leveraging external technologies may be exceeded by the costs resulting from the complexity of managing different external relationships. Accordingly, the following hypothesis is assumed:

Hypothesis 2: Financial performances of companies have an inverted-U relationship with open innovation adoption (Hp. 2).

The research hypotheses formulated in this section form the basis of Figure 1. The underlying logic in this model is that OI adoption curvilinearly influences both types of performances.

Figure 1. Illustration of the proposed hypotheses

3. Methodology

The hypotheses are tested by analysing a sample of bio-pharmaceutical companies, given the high relevance OI has in such an industry. The sector is, in fact, an early pioneer of OI (Chesbrough and Crowther, 2006; Cooke, 2005; Fetterhoff and Voelkel, 2006; Khanna, 2012; Kleyn et al., 2007) because of the high relevance of R&D and the distributed nature of knowledge (Powell et al., 2005). A broad spectrum of OI models have already become a standard in this industry (Gassmann et al., 2008).

A sample of 110 worldwide top R&D spending bio-pharmaceutical companies, ranked by *The EU Industrial R&D Investment Scoreboard*, was considered (see Appendix). Consolidated annual reports from 2008 to 2012 were downloaded from the internet and patents published in the same period were gathered from PATSTAT database. The sample consists of 67 European companies and 43 non-European: the most represented country is USA with 37 firms, followed by Germany (13), UK and Denmark (10 each). According to the four-digit ICB codes disclosed in the Scoreboard, 51 biotech and 59 pharmaceutical companies are examined.

The data are used after a cross-section perspective, as five years are not enough for a longitudinal study, especially in an industry where the development time horizon can be longer than ten years. Thus, 550 statistical units are considered.

Table 3 illustrates the description of the variables employed in this work with the authors supporting them.

Table 3. Summary of the variables

3.1 Independent variables

The paper is based on a pecuniary approach to the measurement of the openness degree of companies, by examining all the OI transactions of firms: costs, revenues, new investments (i.e. additions) and divestments (i.e. disposals) linked to innovation in all its components.

According to literature (Chesbrough and Crowther, 2006), OI is typified by two different dimensions: inbound and outbound; a further distinction between operational and financial transactions is introduced, so that four dimensions of OI can be identified:

- costs, i.e. operational inbound transactions;
- revenues, i.e. operational outbound transactions;
- additions, i.e. financial inbound transactions;
- disposals, i.e. financial outbound transactions.

Actually, the analysis of costs and revenues is quite symmetrical, since every OI activity typically generates revenues for a company and costs for another one. Thus, the operational transactions of OI can be defined as costs and revenues deriving 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, which pertain to a more spot behaviour 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, as to the financial transactions, the analysis of new investments and divestments of intangibles is symmetrical enclosing additions and disposals of:

1. in-process R&D and development costs;
2. licenses, patents, intellectual property (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.

The first four categories have a clear connotation within innovation, whilst the innovative nature of goodwill can be questionable. Yet, 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 organisational expertise 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 arising from a business combination can be considered as a black box containing a bundle of intangible assets (Brännström et al., 2009), and that a significant part of goodwill contains intellectual capital (Boekestein, 2009).

In order to understand how pervasive OI is within the business of a company, all the aforementioned items have to be compared to the total business of firms by adopting homogeneous measures: *total R&D and IP costs* for OI costs, *total revenues* for OI revenues and *total intangibles* for additions and disposals.

After this perspective, OI can be regarded as a four-dimensional phenomenon represented in the $\mathbb{R}^4$ space. If costs, revenues, additions and disposals are used as the four Cartesian axes, each company can be represented as a four-dimensional point whose openness is the Euclidean distance from the point of the origin of the axes:

$$Openness = \sqrt{\frac{1}{4}\left[\left(\frac{open\ costs}{R\&D + IP\ costs}\right)^2 + \left(\frac{additions}{intangibles}\right)^2 + \left(\frac{open\ revenues}{revenues}\right)^2 + \left(\frac{disposals}{intangibles}\right)^2\right]}$$

The projections of openness on the two planes "costs-additions" and "revenues-disposals" respectively provide a synthetic measure of inbound and outbound:

$$Inbound = \sqrt{\frac{1}{2}\left[\left(\frac{open\ costs}{R\&D + IP\ costs}\right)^2 + \left(\frac{additions}{intangibles}\right)^2\right]}$$

$$Outbound = \sqrt{\frac{1}{2}\left[\left(\frac{open\ revenues}{revenues}\right)^2 + \left(\frac{disposals}{intangibles}\right)^2\right]}$$

The factors ¼ and ½ are used to normalize the values of the metrics to the range [0, 1] where the thresholds correspond to a completely closed and a completely open behaviour.

3.2 Dependent variables

Innovation and financial performances of companies are defined as dependent variables of the model. As of the former, three indicators are employed:

- *R&D productivity*, representing the propensity to patent of a firm, measured as the ratio of patents published by the company in a year divided by R&D and IP costs sustained in the same year;
- *patents marketability*, evaluated as revenues to patents ratio. Such a measure presumes that the innovativeness, usefulness and value of companies' patents are reflected in revenues;
- *patents growth*, calculated as the percentage annual increase in the number of published patents.

Financial performances are assessed in terms of:

- *closed EBIT per employee*, where closed EBIT is measured as operating profit net of open revenues less open costs;
- *asset turnover ratio*, calculated as revenues on assets;
- *sales growth*, defined as the percentage annual increase of revenues.

3.3 Control variables

Prior studies suggest that there are specific factors influencing innovation and financial performances of firms, which need to be controlled (Table 3). For this reason, the control variables utilised are:

- *biotech*, as a dummy variable assuming value 1 when the firm belongs to the biotechnological segment, 0 when it is a pharmaceutical company;
- *firm age*, assessed in number of years from the date of establishment;

- *firm size*, measured as the natural logarithm of the number of employees;
- *R&D intensity*, as the ratio of R&D and IP costs divided by revenues.

4. Findings

Table 4 exhibits descriptive statistics and correlations between all the measures under study: variables failed Shapiro-Wilk test for normality and, therefore, Spearman's correlation is used.

Table 4. Descriptive statistics and Spearman's correlations for the period 2008-2012 (N = 550)

A positive correlation is uncovered between *openness* and the belongingness to the biotech segment, as well as with *R&D intensity*. Conversely, negative relations are observed as to *firm age* and *size*. More specifically, *outbound* shows the same behaviour as *openness*, while no significant linkage occurs for *inbound*. This means that the most open companies in the sample, strongly relying on outbound activities, belong to the biotech sector, mainly focus their efforts on R&D processes and tend to be young and small.

4.1 OI and innovation performances

Hp. 1: Innovation performances of companies have an inverted-U relationship with open innovation adoption.

Both *R&D productivity* and *patents marketability* are negatively correlated to openness, whereas *patents growth* shows no significant correlation (Table 4).

In order to test the inverted U-shape, quadratic regressions are performed. For all the three performance indicators, by using *openness* as a predictor, the regressions are not statistically significant (Adjusted R-square < 1%), disconfirming the inverse U-shape relationship. Further, even using linear regressions no significant result is found. Therefore - as to *R&D productivity* and *patents marketability* - a negative trend of the two indicators with *openness* is discovered, but it is neither quadratic nor linear. On the contrary, no support is given as to any kind of relation between *openness* and *patents growth*.

As for the specific contributions of *inbound* and *outbound*, a negative correlation is obtained between *patents marketability* and *outbound* (Table 4). Once again, quadratic regressions are performed to test the inverted U-shape, utilising the two indicators as predictors. The only significant regression is obtained when *patents marketability* is examined (Table 5).

Table 5. Quadratic regression of patents marketability using inbound and outbound as predictors

Only the constant and the linear coefficient of *outbound* have statistically significant values, suggesting a decreasing linear trend of *patents marketability* with *outbound* (Figure 2), following the equation:

$$patents\ marketability = 6.0\text{E}{+}05 - 2.7\text{E}{+}06 * outbound + \varepsilon$$

where ε is the regression error.

Figure 2. Regression curve of patents marketability using outbound as a predictor

Results: R&D productivity and patents marketability decrease with openness, without following either a linear or a quadratic trend. Yet, a linear decrement of patents marketability is observed with outbound. Patents growth is not influenced by either openness or its components.

4.2 OI and financial performances

Hp. 2: Financial performances of companies have an inverted-U relationship with open innovation adoption.

Closed EBIT per employee and *asset turnover ratio* are negatively correlated to *openness* whereas *sales growth* is weakly positively correlated to it (Table 4).

In order to test the inverted U-shape, quadratic regressions are performed (Tables 6 to 8): model 1 is obtained by using only *openness* as a predictor, whereas in models 2 to 5 one control variable at a time is added.

Table 6. Quadratic regressions of closed EBIT per employee using openness as a predictor

As to *closed EBIT per employee* (Table 6), given that the first order coefficient is negative but the second order term is not significant, it tends to decrease when openness increases (Figure 3), leading to the following equation:

$$closed\ EBIT\ per\ employee = 80.81 - 553.2 * openness + \varepsilon$$

where ε is the regression error.

All control variables except *R&D intensity* show a significant contribution: the negative coefficient of *biotech* suggests that performances are higher for pharmaceutical companies, whereas both *firm age* and *firm size* positively influence *closed EBIT per employee*.

Figure 3. Regression curve of closed EBIT per employee using openness as a predictor

Table 7. Quadratic regressions of asset turnover ratio using openness as a predictor

Similar findings are uncovered for *asset turnover ratio* (Table 7), which exhibits a linear decreasing trend versus *openness* (Figure 4), following the equation:

$$asset\ turnover\ ratio = 0.618 - 0.618 * openness + \varepsilon$$

where ε is the regression error.

All control variables give a significant contribution: higher values of *asset turnover ratio* are obtained for larger, longer-established and less R&D intense pharmaceutical companies.

Figure 4. Regression curve of asset turnover ratio using openness as a predictor

Table 8. Quadratic regressions of sales growth using openness as a predictor

Sales growth (Table 8) has a completely different behaviour if compared to the previous two performance indicators. Actually, in this case, only the second order coefficient is significant and positive, proving a quadratic increase of *sales growth* with *openness* (Figure 5), defined by the equation:

$$sales\ growth = 2.394 * openness^2 + \varepsilon$$

where ε is the regression error.

In this instance, no control variable shows a significant contribution.

Figure 5. Regression curve of sales growth using openness as a predictor

Inbound is positively correlated to both *closed EBIT per employee* and *sales growth*, whereas *outbound* shows negative relations with closed *EBIT per employee* and *asset turnover ratio* (Table 4). Results of quadratic regressions using the two indicators as predictors are reported in Table 9.

Table 9. Quadratic regressions of financial performances using inbound and outbound as predictors

As to *closed EBIT per employee*, the linear coefficient of *inbound* is positive and the quadratic coefficient negative, while the coefficients of *outbound* have the opposite signs, suggesting an inverted U-shape trend with *inbound* and a U-shape relationship with *outbound*.

It is possible to observe that, for any fixed value of *outbound* (Figure 6), *closed EBIT per employee* increases with the value of *inbound* until a maximum is reached and, then, begins to decrease: the performance indicator reaches its maximum for values of *inbound* ranging from 50% to 70%. It is noteworthy that only the curve corresponding to no *outbound* shows positive values of the ratio, so that for any value of *outbound* greater than 20% a negative EBIT should be expected, which is also confirmed by Figure 7.

A positive coefficient is obtained for the *inbound* * *outbound* term, suggesting a synergistic effect of OI modes.

Figure 6. Iso-outbound regression curves of closed EBIT per employee using inbound as a predictor

Figure 7. Iso-inbound regression curves of closed EBIT per employee using outbound as a predictor

As regards to *asset turnover ratio*, the first order coefficient of *inbound* is not significant, the second order term is negative, whereas the linear coefficient of *outbound* is negative and the quadratic term is positive. Therefore, a quadratic decreasing trend is obtained for the performance indicator with *inbound* (Figure 8) and a U-shape with *outbound* (Figure 9). In

particular, for very high values of *inbound* (greater than 80%), negative performances are obtained unless *outbound* is null. The coefficient of *inbound* * *outbound* is not significant, therefore no synergy is shown between the two OI sides.

Figure 8. Iso-outbound regression curves of asset turnover ratio using inbound as a predictor

Figure 9. Iso-inbound regression curves of asset turnover ratio using outbound as a predictor

Lastly, with reference to *sales growth*, only the first and second order coefficients of *outbound* are significant, with the performance showing a quadratic increase with outbound (Figure 10), following the equation:

$$sales\ growth = -\ 0.825 * outbound + 1.065 * outbound^2 + \varepsilon$$

where ε is the regression error.

Figure 10. Regression curve of sales growth using outbound as a predictor

Results: Closed EBIT per employee and asset turnover ratio linearly decrease with openness. Particularly, as to closed EBIT per employee, an inverted-U relationship with inbound and a U-shape relationship with outbound are observed. Regarding asset turnover ratio, a decreasing quadratic relationship with inbound and a U-shape relationship with outbound are found. Sales growth has a positive quadratic trend with both openness and outbound.

5. Discussion

In Table 10 a summary of the results is provided.

Table 10. Summary of the results

Hypothesis 1 is disconfirmed, since no inverse-U relationship is found, whereas Hp. 2 is corroborated only when *inbound* is used as a predictor for *closed EBIT per employee*.

Results prove that opening innovation processes outside company's boundaries is not beneficial for innovation performances. In particular, both *R&D productivity* and *patents marketability* exhibit a negative correlation with *openness*.

R&D productivity - being defined as the number of patents published per euro spent in R&D - should show firms' ability to capitalise on R&D efforts, patenting new molecules. Yet, the negative relation of such an indicator with *openness* can be regarded as an industry-specific finding. In fact, the performance is negatively related to the dummy variable defining biotech companies and to *R&D intensity*. This can be explained considering that some biotech companies - which strongly rely on OI - despite having produced significant efforts in R&D, have not yet achieved significant results in terms of patenting, because of the long development periods in the industry. A limitation of such findings is provided by the contemporaneity of the periods investigated for R&D investments and patent publication. However, the bias is not really significant, considering that R&D costs incurred by companies are fairly constant over time.

On the other side, *patents marketability* - being calculated as the revenues per patent ratio - should represent a quality index for patents, capable of becoming products welcomed by the market. Once again, the negative relation uncovered with OI, and in particular with its outbound dimension, can be explained as industry-specific. The performance indicator is not only negatively linked to *biotech* and *R&D intensity*, but also positively associated with *firm size* and *firm age*. Actually, the large majority of biotech companies in the sample is quite small and young if compared to pharmaceutical firms. Furthermore, they are mostly focused on development processes and only seldom commercialise products. Indeed, a consistent part of their revenues derives from OI activities such as the selling of R&D services or the licensing of their IP: 14 companies out of 110 in the sample gained 100% of their revenues from OI. Such firms are typically in loss and survive only from private investments and government contributions.

As for financial performances, both *closed EBIT per employee* and *asset turnover ratio* are negatively influenced by OI, whereas *sales growth* increases quadratically with *openness*. For

the first two indicators a deeper understanding can be obtained if the two dimensions of OI are investigated separately.

The inverse U-shape of operating profit with *inbound* confirms that a slight recourse to inbound 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 is higher than the benefits, thus resulting in an increase of costs. The result is also consistent with literature (Hwang and Lee, 2010). As to outbound practices, the regression suggests a U-shaped relationship but, in the range of existence of outbound (from 0% to 100%), only the decreasing part of the trend is observed. This finding is no doubt industry-specific, linked to the high levels of *outbound* registered for biotech companies, which - as stated before - are usually in loss.

The same goes for the relationship between *asset turnover ratio* and *outbound*, which is influenced by the low levels of revenues achieved by biotech companies. As of *inbound*, the negative trend of the performance seems to indicate that increasing recourse to external sources of innovation hinders the efficiency of companies because of time spent in managing relationships with partners.

Finally, *sales growth* is positively affected by OI, and in particular by outbound practices. This finding is consistent with other contributions (Chaston and Scott, 2012; Hung and Chiang, 2010) and can be explained by taking into account that the highest levels of *outbound* are found for biotech companies. Indeed, despite the fact that these firms currently have low levels of profitability, they show great and still unexpressed potential, linked to the strong technological orientation. Therefore, high levels of dynamism are obtained for small and young biotechnology companies engaged in advanced frontier research.

6. Conclusion

Although the effect of OI activities on firms' performances has received widespread attention in the past decade, empirical results still remain inconclusive. The main purpose of this study is to examine the interplay between openness and innovation and financial performances, considering both inbound and outbound facets of the phenomenon in order to deeply investigate these relationships. In exploring such a topic, the paper sheds light on a number of related questions in the current debate: *is it possible to give hard evidence that OI practices are linked to better performances? which is the role played by the two forms of openness?*

With this premise, two main theoretical implications of the work can be pointed out. Firstly, OI as a field of research needs empirical evidence about the impact of outbound processes on performance. Actually - as emerged by the literature review - only the studies by Lichtenthaler (2009), Hung and Chiang (2010), Ahn et al. (2013) and Cheng and Shiu (2015) enclose, more or less formally, the analysis of internal knowledge exploitation. Hence, the first contribution of the paper pertains to having gauged the effects of both OI sides on performances. Secondly, by proposing a pecuniary model for measuring openness, the study provides new insights as to what "being open" means for a company. While most scholars give a definition of openness in qualitative terms - estimating its adoption through discrete scales - we believe that OI is not an ''on/off'' choice, but it can be implemented with different degrees. In this way, a continuous evaluation approach is suggested enabling the assessment - in quantitative terms - of the pecuniary implications that OI transactions entail and, consequently, of the relevance of openness for the whole business of firms.

As it has been conceived, the study has also some practical implications. Indeed, from a recent Boston Consulting Group's survey (BCG, 2015) the rising importance of innovation emerged, ranked as a top strategic priority by the most innovative companies in the world. This clearly underlines the need for managers of setting and following the "right" metrics to monitor

innovation processes and subsequent performances. Actually, the framework presented in this paper assists managers in doing so, since it is built upon objective data, systematically updated within the information systems of companies and, hence, easily exploitable for monitoring purposes. In particular, the methodology gives useful insights to support decisions on investments in OI. In fact, openness is not costless: it can be time consuming, expensive, and laborious. Hence, not only the potential benefits but also the costs of employing an open strategy should be accounted for. More in detail, the results of this study show that openness does not always lead to benefits, but there are levels of adoption corresponding to maximum performances. At the same time, the findings point to the need of applying a cautious approach towards evaluating the performance implications of OI.

The work has of course some limitations, which open up opportunities for future research. The first issue refers to the generalisability of results, limited by the focus on one industry. Secondly - relying on accounting indicators - the methodology can be used to gauge only the pecuniary dimensions of OI (Dahlander and Gann, 2010) and cannot be applied to industries where sourcing and revealing are widespread (e.g., software). Lastly, the lack of panel data prevented us from assessing how firms' OI activities influence performances over time. Because the implementation of OI requires continuous investment of resources, we are planning to employ a longitudinal analysis, which will help to provide a dynamic perspective on such a topic. Furthermore, we would like to widen our sample of investigation - including other R&D intense sectors (e.g., technology hardware & equipment, automotive) - in order to ensure generalisability of findings.

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