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Exploring the scope of open innovation: A bibliometric review of a decade of research

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Exploring the Scope of Open Innovation:

A Bibliometric Review of a Decade of Research[1]

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ABSTRACT

The concept of open innovation has attracted considerable attention since Henry Chesbrough first coined it to capture firms' increasing reliance on external sources of innovation. Although open innovation has developed into a prospering topic in innovation management research, it has also triggered debates pertaining to the coherence of the research endeavors pursued under this umbrella, including its theoretical foundations. In this paper we aim to contribute to these debates by means of a bibliometric review of the first decade of open innovation research. We combine two techniques – bibliographic coupling and co-citation analysis – to visualize the network of publications that explicitly use the label 'open innovation' and to arrive at distinct clusters of thematically related publications. Our findings illustrate that open innovation research mainly builds upon four related streams of prior research, whilst the bibliographic network of open innovation research portrays seven – persistently pursued – thematic clusters. While 'open innovation' is used in a variety of contexts, the research agenda has developed into a coherent field of research which resides mainly in the management (business) literature. As such, there is considerable cross-fertilization potential by embracing concepts and insights from complementary fields (economics, sociology), e.g. transaction cost economics and network analysis.

Keywords; Open Innovation; Openness; Literature Review; Bibliographic Coupling; Co-citation Analysis

[1] Draft Paper (Jan 14, 2014 Version); Please do not circulate without consent of the authors.

INTRODUCTION

Within a mere decade after its first appearance in the scientific literature the concept of open innovation has developed into a prospering area of innovation management research today (a.o. Dahlander & Gann, 2010; 2011; Huizingh, 2011). The increased interest for open innovation is manifested by the fast-growing number of scientific publications referring to the concept as well as the number of special issues in management journals devoted to open innovation (a.o. R&D Management, 36(3):40(3), Technovation 31, Research Policy, forthcoming). Open innovation has been broadly defined as *'…the purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external use of innovation respectively…' (Chesbrough, Vanhaverbeke & West, 2006:1)* and has been marked as *'the new imperative for creating and profiting from technology' (Chesbrough, 2003)* and even as *'the new paradigm for understanding industrial innovation' (Chesbrough, Vanhaverbeke & West, 2006).* Whilst this broad definition has arguably contributed to the proliferation of the concept, it also lies at the heart of critical acclaims that have been expressed towards the concept.

These critical acclaims either relate to the lack of coherence of the body of research surrounding the concept or to the lack of sufficient theoretical grounding of the concept. With regard to the first critique, Dahlander & Gann (2010) note that although '*a variety of definitions and focal points are used [in existing open innovation research]… these do no yet cohere into a usable analytical frame' (Dahlander & Gann, 2010:699).* They stress that the absence of such a coherent analytical frame makes it difficult to compare and validate the findings of studies on the effects of firms' openness. Groen & Linton (2010) go one step further by explicitly posing the question; *'is open innovation a field of study or a communication barrier to theory development?'*. With regard to the second critique, Trott & Hartmann (2009) suggest that open is

simply a repackaging of a heterogeneous set of concepts and findings that have been present in innovation management for decades. They accuse the open innovation community of giving only limited recognition to the prior research on which it builds.

While existing *qualitative* reviews of open innovation research (Dahlander & Gann, 2010; Elmquist, Fredberg & Ollila, 2009; Gassmann, Sandmeier & Wecht, 2006; Gassmann, Enkel & Chesbrough, 2010; Huizingh, 2011; Lichtenthaler, 2011; Van De Vrande, Vanhaverbeke & Gassmann, 2010; West & Bogers, 2013) provide useful insights regarding current themes, definitions, key empirical findings and the identification of avenues for future research, they do not address these critiques systematically. Furthermore, qualitative reviews are inherently characterized by a certain degree of subjectivity and bias, as they rely on – idiosyncratic – views and perspectives of the reviewers involved (Vogel & Güttel, 2013). This might explain why existing reviews differ with regard to the themes of open innovation research that they distinguish as becomes apparent in Table I. This table provides an overview of the themes that the most recent reviews of open innovation research distinguish as well as the avenues for future research that they advance. While Table I reveals some coherence in terms of identified themes, it also illustrates the idiosyncratic nature of these reviews.

Insert Table I about here

In order to create a more systematic and encompassing picture of the 'open innovation' research agenda, especially in terms of coherence and theoretical foundations, we engage in a systematic quantitative review of the existing literature on open innovation. In particular, we aim to (i) identify the theoretical foundations of open innovation research, (ii) identify themes within open innovation research and – based on (i) and (ii) – (iii) identify fertile areas for future research. To

this end, we apply two bibliometric techniques – bibliographic coupling and co-citation analysis – that enable us to assess the thematic similarity between scientific publications based on overlaps between their referencing patterns. Whereas co-citation analysis implies an assessment of the similarity of cited documents, bibliographic coupling is an assessment of the similarity of citing documents. As such, the former technique is well-suited towards identifying the theoretical foundations of a field of research, whereas the second technique is well-suited for identifying current themes and future trends within a field of research. Therefore, combining these techniques enables us to get relevant insights into both the past traditions and current trends that characterize open innovation research.

Our paper is structured as follows; in the next section, we elaborate upon the data that we use and the methods that we apply. We discuss the procedures taken to construct the dataset and describe the application of bibliographic coupling and co-citation analysis in detail. In the third section we present the bibliographic network of the references that are cited by our set of open innovation publications, based on co-citation analysis. We analyze this network in order to highlight the theoretical foundations of open innovation research. In the fourth section we present the bibliographic network of our set of publications themselves, based on bibliographic coupling. This network serves as the basis for our subsequent discussion of clusters that represent thematic areas in open innovation research. In the fifth section, we discuss the implications of our findings and relate them to the findings of existing reviews in order to identify fertile areas for future research.

DATA AND METHODS

Data

We used the 'topic search option' in Thomson Reuters' Web-of-Science database in order to search for scientific publications that contain the terms 'open' and 'innovation' in either the title, keywords or abstract fields of the database. We limited our search to publications published between 2003 and 2013 and included only publications of the document type 'article'[2]. However, the topic search option in the Web-of-Science is conducive to 'false positives' as it not only captures publications that contain the combination term 'open innovation' but also publications that simply contain the terms 'open' and 'innovation' separately from each other (Dahlander & Gann, 2010). Rather than making ex-ante normative judgments with regard to whether publications address the concept of open innovation or not[3], we decided to limit our sample to only those publications that contain the combination term 'open innovation' in either the title, keywords or abstract fields of the Web-of-Science database. Hence, authors who have the intention to contribute to the state-of-the-art of open innovation research, are likely to use the combination term 'open innovation' in these fields. Although our approach implies that we might miss out on a number of 'false negatives' it ensures that we do not capture any 'false positives'.

Our initial search effort resulted in a set of 2013 publications for which we downloaded Web-of-Science-records[4]. These standardized records comprise information about the title, abstract and keywords fields and also contain basic information about authors, sources, publishers and, most relevant to our study, the cited references. We subsequently read through the title, abstract and

[2] In rare cases publications are assigned to multiple document type categories, e.g. 'article/editorial'. We only selected publications that are assigned to the document type 'article' only.

[3] Which is the predominant approach amongst existing reviews of open innovation research.

[4] We downloaded the Web-of-Science-records on October 1st, 2013. A copy of these records will be made available in an online supplement to this article or can be obtained by contacting the corresponding author.

keywords fields of all of these publications and identified all records that contain the combination term ‘open innovation’ in at least one of these fields. Based on this effort we identified 358 publications, which constitute the dataset that we used for further analysis. These publications refer to 11.873 other publications and are referred to by 2372 other publications themselves. Figure I below visualizes the distribution of our set of publications over time whilst Table II contains information regarding their distribution over journal sources and Web-of-Science categories respectively. The most noteworthy observation from Figure I is that although the first publication containing the combination term ‘open innovation’ was published in 2003, the number of publications only started to flourish from 2006 onwards. The information portrayed in Table II suggests that most of the attention for the concept of open innovation in the past decade has come from management- and business-oriented journal sources.

Insert Figure I and Table II about here

Methods

Bibliographic coupling and co-citation analysis.

As aforementioned, we combine two bibliometric techniques that rely on the analysis of the referencing behavior of authors – bibliographic coupling and co-citation analysis. As such, these techniques rely on the fundamental assumption that, to the extent that the cited references of a focal publication provide a background for this publication, they denote at least some degree of relatedness between the citing focal publication and the publication(s) that it refers to. Based on this assumption, citation-based indicators have been widely applied in the field of bibliometrics as a means of mapping the flow of science and the development of fields and communities for decades (see for instance Kessler, 1963; Weinberg, 1974; Vladutz & Cook, 1984). More

recently, citation-based bibliometric methods have also found their way into management research (e.g. Chen, Huang & Chen, 2012; Vogel & Güttel, 2013)[5]. The basic intuition underlying both bibliographic coupling and co-citation analysis is that the greater the extent to which the referencing patterns of a pair of focal publications overlap, the greater the relatedness between both publications is. Simply put, the greater the extent to which focal publications refer to the same set of publications or are referred to by the same set of publications, the greater the relatedness between these publications is.

The key difference between bibliographic coupling and co-citation analysis pertains to the direction of referencing. Whereas bibliographic coupling is a technique used to associate focal publications based on an analysis of the publications that they refer to, co-citation analysis is a technique to associate focal publications based on an analysis of publications that refer to them (see Figure II for an illustration of bibliographic coupling and co-citation analysis). Bibliographic coupling and co-citation analysis are complements in the sense that whilst the former approach is suitable for capturing current trends within a field, the latter approach is suitable for capturing the past traditions of that field (Boyack & Klavans, 2010). Hence, bibliographic coupling associates focal publications based on their references to publications which are by definition older than the focal publications themselves. Co-citation analysis on the other hand associates focal publications based on their future appraisal by publications which are by definition more recent than the focal publications themselves. Therefore we apply co-citation analysis in order to identify the theoretical foundations of existing open innovation research and bibliographic coupling to identify themes within open innovation research itself.

[5] See Vogel and Güttel (2013) for a more elaborate overview of management research that draws upon citation-based bibliometrics methods.

Insert Figure II about here

Relatedness measures.

Several measures have been developed to calculate the relatedness between pairs of bibliographic objects[6]. We apply a measure – known as the *association strength* – that determines the relatedness between a pair of focal publications by normalizing the co-occurrence frequency of the references they make / the references they receive. This measure has been developed by Van Eck & Waltman (2009), who argue that it is more suited towards normalizing co-occurrence data than the more conventional cosine and Jaccard-index-based measures, that are widely applied in the field of bibliometrics. We calculate the association strength between pairs of focal publications by means of the following formula;

$$AS_{ab} = \frac{C_{ab}}{C_a C_b}$$

Hereby C_{ab} relates to the references made / references received that a pair of focal publications *A* and *B* have in common, C_a relates to the total number of references made by / references received by publication *A* and C_b relates to the total number of references made by / references received by publication *B*. This entails that the association strength of publications *A* and *B* is proportional to the ratio between on the one hand the observed number of overlapping references made / references received and on the other hand the expected number of references made / references received by publications *A* and *B*. As such, the higher the value for *AS* is for a given pair of focal publications, the greater the relatedness between these publications is. In the example of Figure II, the association strength between focal publications *A* and *B* equals 0.25

[6] See Van Eck and Waltman (2009) for an overview of the most widely applied measures of similarity in bibliometric studies.

(1/(2*2)) based on bibliographic coupling and 0.11 (1/(3*3)) based on co-citation analysis. We calculated the association strength for all possible pairs of publications that are contained by our dataset based on bibliographic coupling. The resulting association matrix served as the input for the visualization and identification of thematic clusters of open innovation research. We also calculated the association strength for all possible pairs of references cited by the publications within our dataset based on co-citation analysis. The matrix that resulted from this exercise served as input to visualize and identify the theoretical foundations of the concept of open innovation.

Visualization and clustering.

We rely on the Visualization of Similarities (VOS) – approach as described by Van Eck & Waltman (2010) in order to identify and visualize thematic clusters based on the relatedness between our set of publications. Essentially VOS is a unified approach to mapping and clustering bibliometric networks that combines an optimization algorithm with a clustering algorithm in one software package; VOS Viewer[7]. The VOS optimization algorithm ensures that publications are located in a low-dimensional space in such a way that the distance between any two items is a reflection of the relatedness of the items as accurately as possible. More specifically, the algorithm minimizes the weighted sum of the squared distances between all pairs of publications and weighs these by the relatedness of these publications. As such, the greater the association strength between a pair of publications, the smaller the distance between these publications will be in the low-dimensional space. Furthermore, the optimization algorithm ensures that the most

[7] VOS Viewer is a freely available computer program for the visualization of bibliometric networks that can be downloaded from http://www.vosviewer.com/

connected publications will be located near the center of the low-dimensional space whilst the less connected publications will be located in its periphery.

Publications are grouped into clusters on the basis of the VOS clustering algorithm which is based on a weighted version of Newman & Girvan's (2004) modularity function. In this function modularity denotes a measure of the quality of the division of a given network into communities (clusters). Specifically, the algorithm eliminates edges in a network that have the highest betweenness[8] until the modularity function of Newman and Girvan is maximized. In other words, the optimal number of clusters is the one at which the maximum value for the modularity function is reached. However, in the VOS-approach to clustering the maximization of Newman and Girvan's modularity function is parameterized by a resolution parameter. Altering the value of the resolution parameter in VOS Viewer alters the optimal number of clusters derived, with higher values for the resolution parameter imposing a higher optimal number of clusters derived. This resolution parameter is implemented in the VOS-approach to clustering in order to overcome the key weakness of modularity-based clustering techniques – their proneness to failure in identifying small clusters.

RESULTS

The theoretical foundations of open innovation research

The bibliographic network of the references cited by our set of open innovation publications is portrayed in Figure III. The network was created based on the cited references that we filtered from our set of 358 publications. Since the form of cited references tends to differ between journal sources, they need to be converted to a standardized form for further processing.

[8] Hence, the betweenness of an edge is larger, the higher the number of pairs of nodes in between which it lies.

Therefore all cited references were standardized to a string that contains only a maximum of two initials of the author's first name, as well as the author's full surname and the year of publication. After this standardization effort, 11.873 unique references remained for further analysis. In Figure III, however, we only portray references that have been cited a minimum of ten times. This restriction is imposed to capture only the most important references, whilst not overly complicating the interpretation of Figure III. We do not impose restrictions with regard to the publication date of cited references, meaning that we also include references published after 2003. However, we do not take into account cross-citations that occur within our set. This entails that we filter out publications that are both part of our set of 358 publications and receive a minimum of 10 citations from other publications of our set. Hence, our primary interest lies on identifying the foundations of open innovation research that is situated outside the field itself.

Insert Figure III about here

In Figure III each vertice represents a cited reference that is cited at least ten times overall by our set of publications. The greater the size of a vertice, the more often the reference is cited by our set of publications. The distance between a pair of cited references represent the likehihood that these references are cited in combination by our set of publications. Thereby a shorter distance corresponds with a greater likelihood. Lastly, the oval shapes and corresponding latin characters in Figure III indicate clusters of cited references that can be distinguished. The grouping of a reference into a cluster indicates that this references is more likely to be cited in combination with other references that are grouped into this cluster than with references that are grouped into other clusters. It can be observed from Figure III that the clustering resulted in four clusters that are represented by the latin characters *A*, *B*, *C* and *D* respectively. Figure III displays a relatively coherent network in which clusters *A*, *B* and *C* are tied together by cluster *D*, which is located

near the centre of the figure. In order to interpret and label the clusters, we donwloaded the Web-of-Science records of the 123 cited references represented in the figure[9] and listed the most frequent terms in the keywords, title and abstract sections of these references per cluster. In addition we also read the abstracts and introductions of the cited references. Based on this effort we labeled clusters as *'Cluster A – Strategic Partnering and External Sourcing'*, *'Cluster B – User-Centric Innovation'*, *'Cluster C – Technology and Innovation Management'* and *'Cluster D – Resource- and Knowledge Based View of the Firm'*. In what follows, we discuss and relate the cited references captured by each cluster. Although we aim to describe every cluster as elaborately as possible, we acknowledge that our description cannot fully capture the richness of every cluster.

Cluster A – Strategic partnering and external sourcing (37 items).

The thematic orientation of this cluster of references is best captured by the label *'Strategic Partnering And External Sourcing'* as most publications that are grouped into it address different kinds of interorganizational collaboration arrangements. Most of these publications examine the contingencies influencing strategic partnering behavior (Dyer & Singh, 1998; Gulati, 1998; Hagedoorn, 1992:2002, Powell, 1996; Tether, 2002), the effects of strategic partnering on firm performance (Ahuja, 2000; Baum, Calabrese & Silverman, 2000; Belderbos, Carree & Lokshin, 2004; Dittrich & Duysters, 2007; Dyer & Nobeoka, 2000; Faems, Van Looy & Debackere, 2005) and the ways of governing interorganizational collaboration agreements (Van De Vrande, Lemmens & Vanhaverbeke, 2006). Others focus specifically on the external sourcing of knowledge, often referred to as the inbound dimension of open innovation. These studies explore

[9] Hence, we were only able to download Web-of-Science records for 92 of the 123 cited references since the remaining references are books, which are not contained by the Web-of-Science.

the complementarity between internal and external R&D (Cassiman & Veugelers, 2006; Veugelers, 1997) and study the effects of external knowledge sourcing on firm performance (Fey, 2005; Katila & Ahuja, 2002; Laursen & Salter, 2004:2006; Van De Vrande *et. al*., 2006). Taken together, these studies provide empirical evidence for firms' increased reliance upon external sources of knowledge, which is, at least in part, the trend that the open innovation concept aims to address. As such it is not surprising that open innovation research draws upon these studies.

Whereas most of the aforementioned publications indicate that firms can benefit significantly from external knowledge sourcing, the cluster also contains publications which stress that the realization of these benefits should not be taken for granted. Cohen & Levinthal's (1990) seminal contribution on the concept of absorptive capacity is the most prominent of these publications and is the second most-cited reference by our set of open innovation publications. Additional references to contemporary works on the concept (Lane & Lubatkin, 1998; Lane, Koka & Pathak, 2006; Szulanski, 1996; Tsai, 2001, Zahra & George, 2002) highlight its recognition as a necessary condition for external knowledge sourcing to succeed within open innovation research. In similar vein, the presence of Katz & Allen's (1982) well-known contribution on the not-invented-here syndrome, arguably indicates that the concept is often regarded within open innovation research as a potential obstacle to successful knowledge sourcing.

Cluster B – User-centric innovation (34 items).

This cluster is labeled as *'User-Centric Innovation'*, since the majority of the references that it comprises focus explictly on the role of end-users within firms' innovation processes. It captures Von Hippel's (1988) and (2005) books entitled '*Sources of Innovation'* and '*Democratizing*

Innovation' – the most-cited contributions of the cluster – as well as contemporary works which center around user communities and open source software (OSS) platforms. Most of these contemporary works study the motivations of users to participate in OSS platforms (Harhoff, Henkel & Von Hippel, 2003; Hars & Ou, 2002; Hertel, Niedner & Herrmann, 2003; Jeppesen & Frederiksen, 2006; Lakhani & Von Hippel, 2003; Von Krogh, Spaeth & Lakhani, 2003) and ways to engage users to participate in them (Franke & Shah, 2003; Lee & Cole, 2003; Prugl & Schreier, 2006; Von Hippel & Katz, 2002). Others explore the conditions under which OSS platforms should be preferred over proprietary platforms (Lerner & Tirole, 2002; West, 2003) and the potential implications that this has for organization science and theory (Von Hippel & Von Krogh, 2003). The inclusion of the abovelisted publications among the references most cited by our set of open innovation publications indicates that users are considered as important sources of external knowledge in existing open innovation research.

Next to the contributions on user-centric innovation, the cluster also contains cited references that provide insights with regard to the methodological foundations of open innovation research. Referencing to Glaser & Strauss' (1967) book on grounded theory, Miles & Huberman's (1984) book on qualitative research designs and Eisenhardt's (1989, 2007) and Yin's (1994, 2003) contributions on case study methodology indicate that qualitative research, and especially case studies, play an important role in open innovation research. The fact that these contributions are included in this cluster might indicate that case studies are especially predominant in open innovation research that is also based on user-centered innovation.

Cluster C – Technology and innovation management (34 items).

Compared to the other clusters, this cluster is relatively more heterogenous with respect to the thematic areas that it covers. However, the majority of cited references grouped into this cluster can be put under the umbrella of technology and innovation management and therefore the cluster has been labeled as such. The most-cited references of the cluster are the ones that put forward frameworks for the organization of innovation from a strategic management point of view. To this group of references belong publications on the exploration-exploitation dilemma of organizational learning (March, 1991; Rothaermel & Deeds, 2004), the dynamic capabilities framework (Eisenhardt & Martin, 2000; Teece, Pisano & Shuen, 1997; Teece, 2007) and the recombinative capabilities framework (Kogut & Zander, 1992). In essence, these frameworks describe how organizations can (re-) develop capabilities in order to sustain in the wake of rapid technological change. The fact that they are cited extensively indicates that the insights from these general frameworks are relevant for open innovation research.

Next to the more general frameworks on the organization of innovation, the cluster also contains a subset of publications that focus specifically on external technology commercialization. This subset encompasses Arora, Fosfuri & Gambardella's (2001) seminal contribution on 'markets for technology' as well as a number of contemporary works that explore the implications of these markets for external technology commercialization. These works examine the antecedents and determinants of external technology commercialization (Fosfuri, 2006; Gambardella *et. al.*, 2007; Gans & Stern, 2003; Lichtenthaler, 2005; Nagaoka & Kwon, 2006), the challenges associated with managing external technology commercialization (Grindley & Teece, 1997; Koruna, 2004; Lichtenthaler, 2005) and the ways to capture value from technology commercialization (Teece, 1998). Hence, whereas the publications belonging to the first cluster

address the inbound dimension of open innovation, these publications address its outbound dimension.

Cluster D – Resource- and knowledge based view of the firm (18 items).

This cluster predominantly captures references that relate to the *Resource Based View (RBV)* and *Knowledge Based View of the Firm (KBV)* and is therefore named after these theoretical frameworks. The cluster comprises both the seminal works on the RBV (Barney, 1991; Penrose, 1959; Wernerfelt, 1984) and KBV (Grant, 1996) as well as works that incorporate a resource-based/knowledge-based perspective (Hargadon & Sutton, 1997; Howells, 2006; Nahapiet & Goshal, 1998; Nonaka, 1994; Rosenkopf & Nerkar, 2001). Both the RBV and the KBV are based on the central premise that a focal firm can establish a position of sustainable competitive advantage through the creation and exploitation of idiosyncratic firm attributes (Barney, 1991; Wernerfelt, 1984). The fact that several of the key contributions on both the RBV and KBV are grouped together in this cluster, indicates that a considerable share of open innovation research takes into account this premise.

In addition to the seminal works on the RBV and KBV, the cluster also contains two other highly cited publications – Nelson & Winter's (1982) book entitled *'An Evolutionary Theory of Economic Change'* and Teece's (1986) publication entitled *'Profiting From Technological Innovation – Implications For Integration, Collaboration, Licensing and Public Policy'*. This indicates that our set of open innovation publications builds at least in part on Nelson & Winter's (1982) conceptualization of 'routines' as a framework for understanding technological change as well as Teece's (1986) conceptualization of 'appropriability' as a framework for understanding how to capture value from technological innovation. Lastly, the cluster also contains

Chesbrough's (2003) and Chesbrough, Vanhaverbeke & West's (2006) seminal publications on open innovation. Since both of these publications are books they are not part of our sample and are as such displayed in Figure III. Inherently, these works are amongst the references cited the most by our set of open innovation publications.

The relative importance of clusters of cited references

In order to assess the relevance of each cluster of cited references as foundation of open innovation research, we calculated a number of publication-output and citation-based statistics per cluster. These statistics are presented in Table III below. Column five of the table shows the average number of citations that a reference received from our set of open innovation publications, whilst column six portrays the ratio between this average and the total sample average. From these columns it can be derived that, on average, references belonging to '*Cluster A – Strategic Partnering and External Sourcing'* are cited the most by our set of open innovation publications. An average reference belonging to this cluster is cited 20 times while an average reference belonging to the other clusters is cited 17 or 18 times only. Furthermore, only references belonging to Cluster A are cited more than the average citation (18.57).

In order to put this observation into context we calculated the same statistics for the Web-of-Science as a whole. Column seven shows the average number of citations that a reference received from all Web-of-Science publications between 2003 and 2013, whilst column eight portrays the ratio between this average and the total sample average. It follows from columns seven and eight that the references belonging to *'Cluster D – Resource- and Knowledge Based View of the Firm'* have on average, by far received the most citations from Web-of-Science publications. Interestingly, references belonging to Cluster A have received the least citations

from Web-of-Science publications between 2003 and 2013. Taken together, the information presented in columns five to eight of Table III indicates that open innovation research builds dispropotionally more on references pertaining to strategic partnering and external sourcing than Web-of-Science publications in general.

Insert Table III about here

Thematic areas in open innovation research itself

The bibliographic network of our set of open innovation publications, based on bibliographic coupling is presenten in Figure IV. The principles that apply for the interpretation of Figure IV are largely the same as the ones that apply for the interpretation of Figure III. However, in Figure IV the sizes of nodes are equal and have no particular meaning of significance, whilst clusters are marked by numbers instead of latin characters. It is important to note that Figure IV visualizes the bibliographic-coupling-network for 344 of our 358 publications only. Firstly, we dropped a number of publications because their Web-of-Science records did not contain information with regard to the references cited. We treated these publications as missing observations. Secondly, we dropped a number of publications because they have no cited reference in common with any other publication within our set. We treated these publications as outliers. Although the bibliographic coupling resulted in the identification of ten clusters, we decided to exclude three smaller clusters, representing 29, 8 and 2 publications respectively, from further analysis. These three clusters had the lowest coherence of all clusters and a close examination of the contents of these clusters revealed that they cover miscalleneous applications of open innovation that cannot be linked in a meaningful way as such. By excluding these clusters we remained with 307 publications, that are grouped into seven clusters.

Figure IV displays a relatively coherent bibliographic network in which the seven clusters are each represented by a corresponding number. In order to interpret and label the clusters, we followed the same approach as we did in order to interpret and label clusters of cited references. This means, that we listed the most frequent terms in the keywords, title and abstract sections of these publications per cluster. In addition we also read the abstracts and introductions of the publications. Based on this effort we labeled clusters as *'Cluster 1 – The Core of Open Innovation'*, *'Cluster 2 – User-Centric Innovation'*, *'Cluster 3 – External Knowledge Sourcing'*, *'Cluster 4 – External Technology Commercialization'*, *'Cluster 5 – Implementation Mechanisms and Tools'*, *'Cluster 6 – Open Innovation in Specific Industries'* and *'Cluster 7 – Idea Generation and Idea Competitions'*. In what follows, we discuss our interpretation of the themes that clusters represent. Again, we emphasize that although we attempt to describe every cluster as elaborately as possible, we acknowledge that our description cannot fully capture the richness of each and every cluster.

Insert Figure IV about here

Cluster 1 – The core of open innovation (94 items).

This cluster is both the largest – in terms of the number of publications that it contains – as well as the most centrally placed cluster and has therefore been labeled as the 'core of open innovation'. The cluster comprises Chesbrough's (2003) seminal contribution *'The Era of Open Innovation'* which introduces the concept of open innovation as well as a number of literature reviews that address the concept's basic dimensions (Dahlander & Gann, 2010; Van De Vrande *et. al.*, 2010). It furthermore comprises a set of publications that address the implications of open innovation on the systemic level. These publications tend to highlight the relevance of open

innovation for public policy (Clausen & Rasmussen, 2011; Karo & Kattel, 2011), provide frameworks that describe how policy makers should respond to open innovation (De Jong, Calvet & Vanhaverbeke, 2010; Herstad, Bloch, Ebersberger & Van De Velde, 2010) and examine the policy initiatives that are currently in place for addressing open innovation (Mayer, 2010; Lee, Wang & Choi, 2012; Wang, Vanhaverbeke & Roijakkers, 2012; Zhao & Zheng, 2011). But there are also publications that explore the implications of open innovation for regional innovation systems specifically (Belussi, Sammara & Sedita, 2010; Cooke, 2005; Halbert, 2012; Isaksen & Onsager, 2010; Todtling, Van Reine & Dorhofer, 2011).

Although publications that focus on the concept of open innovation constitute the main part of the cluster, it also contains publications that explore the concept of open business models. These publications explore how firms can create and capture value from an open innovation approach. Some publications outline how firms should develop and implement open business models in general (Chesbrough, 2004; Chesbrough & Schwartz, 2007; Munch, 2009; Sandulli & Chesbrough, 2009). Others focus more on the viability of open business models in specific industry (Davey, Brennan, Meenan & McAdam, 2011), economic (Di Minin, Frattini & Piccaluga, 2010), product (Jaspers & Van Den Ende, 2010) and geographic (Li & Kozhikode, 2009) settings. Finally, a small subset of studies explores the link between business models and corporate venturing initiatives (Anokhin, Ortqvist, Thorgen & Wincent, 2011a; Napp & Minshall, 2011; Van De Vrande, Vanhaverbeke & Duysters, 2011).

Cluster 2 – User-centric innovation (78 items).

This cluster captures contributions pertaining to user communities, user platforms, crowdsourcing and open source software (OSS) development. Out of these topics, publications

on OSS comprise the largest part of the cluster. Most of these publications describe the business models and strategies that firms should adopt in order to create and capture value from OSS development in general (Dahlander & Wallin, 2006; Deodhar, Saxena, Gupta & Ruohonen, 2012; Gruber & Henkel, 2006; Haefliger, Jager & Von Krogh, 2010; Harison & Koski; 2010; Morgan & Finnegan, 2010; Perr, Appleyard & Sullivan, 2010; Rajala, Westerlund & Moller, 2012; Rolandsson, Bergquist & Ljunberg, 2011; Stam, 2009; West & Gallagher, 2006). Others focus specifically on a key part of OSS development; the involvement of experienced and qualified users. These studies explain the conditions under which users are motivated to freely contribute their knowledge to OSS projects (Henkel, 2006:2009) and the modes through which this contribution actually takes place (Martinez-Torres, Toral, Barrero & Cortes, 2010; Toral, , Torres & Barrero, 2009a:2009b). A final segment of OSS-related studies explores the applicability of the principles of open source in non-software-related areas (Muller-Seitz & Reger, 2009:2010a:2010b; Penin & Wack, 2008; Raasch, Herstatt & Balka, 2009).

Although the remaining publications that are grouped into this cluster do not focus on OSS development, the key topics addressed by these publications are very similar to the ones address by the publications on OSS. Many contributions focus on the motivations of users to participate in communities/platforms (Battistella & Nonino, 2012; Frey, Luhtje & Haag, 2011; Fuller. Hutter & Faullant, 2011, Fuller, Matzler, Hutter & Hautz, 2012; Spaeth, Stuermer & Von Krogh, 2010), the identification of key participants (Fichter, 2009; Fleming & Waguespack, 2007) and the effects of users' contributions on contemporary platform development (Boudreau, 2012). Other contributions present concrete cases to illustrate the frameworks and business models that have proven to be successful for benefitting from the contributions of users (Anghern, Luccini & Maxwell, 2009; Basole & Karla, 2011; Bullinger, Rass, Adamczyk, Moeslein & Sohn, 2012; De

Couvreur & Goossens, 2011; Ebner, Leimeister & Kcmar, 2009; Faraj, Jarvenpaa & Majchrzak, 2011; Feller, Finnegan, Hayes & O'Reilly, 2012; Hildrum, 2009; Hutter, Hautz, Fuller, Mueller & Matzler, 2011; Kohler, Matzler & Fuller, 2009:2011; Leimeister, Huber, Bretschneider & Krcmar, 2009; Lohman, Niesenhaus, Heim & Ziegler, 2009; Parjanen, Hennala & Konsti-Laakso, 2012; Shu & Chuang, 2012; Tickle, Adenbanjo & Michaelides, 2011; Toral *et. al.*, 2009; Ye, Xu, Jia & Jiang, 2012). Finally, remaining publications clarify the meaning of user communities (West & Lakhani, 2008) and crowdsourcing (Marjanovic, Fry & Chataway, 2012), and position these concepts within the broader frame of collaborative innovation (Baldwin & Von Hippel, 2011) and the private-collective model of innovation (Garriga, Aksuyek, Hacklin & Von Krogh, 2012; Von Hippel & Von Krogh, 2006).

Cluster 3 – External knowledge sourcing (42 items).

The common denominator of the majority of publications captured by this cluster is that they focus their attention on the inbound dimension of open innovation; the external sourcing of knowledge. As such the majority of publications focus either on (i) the determinants/antecedents of firms' openness to external sources of knowledge or (ii) the effects of external knowledge sourcing on firm performance. The determinants-oriented publications link the openness of firms' external knowledge sourcing strategies to a number of firm characteristics such as firm size (Barge-Gil, 2010; Moon, 2011), firm age (Moon, 2011), firms' R&D intensity (Barge-Gil, 2010, Segarra-Cipres, Bou-Llusar & Roca-Puig, 2012), the severity of firms'internal weaknesses (Keupp & Gassman, 2009), firms' appropriability strategy (Moon, 2011), firms' absorptive capacity (Bogers & Lhuillery, 2011), the type of knowledge concerned (Bonesso, Comacchio & Pizzi, 2011) and the complementarity between firms' external and internal R&D (Cassiman & Valentini, 2009; Choi, Lee & Kim, 2012).

The performance-oriented publications examine the relationship between external knowledge sourcing and firm performance, although there is considerable variation with regard to the type of knowledge sourcing studied and the type of performance metrics used. Most studies examine the relationship between external knowledge sourcing and firms' innovative performance, without going into the specific dimensions of external sourcing behavior (Bae & Chang, 2012; Czarnitzki & Thorwarth, 2012; Parida, Westerberg & Frishammar, 2012; Spithoven, Clarysse & Knockaert, 2010). Others examine the link between specific dimensions of firms' search behavior – most notably search scope and depth (Chen, Chen & Vanhaverbeke, 2011) and search diversity (Ebersberger & Herstad, 2011) – on firms' innovative performance. Still others study the performance effects of knowledge sourcing in conjuction with the performance effects of other outings of open innovation (Faems, De Visser, Andries & Van Looy, 2010; Love, Roper & Bryson, 2011; Neyens, Faems & Sels, 2010). Interestingly, only few studies (Faems *et. al.*, 2010; Kafouros & Forsans, 2012) examine the effects of external knowledge sourcing on financial performance.

Lastly, the cluster also contains contributions that specifically address the implications of open innovation for small- and medium-sized enterprises (SMEs). These contributions tend to either provide accounts of SMEs' open innovation initiatives (Van de Vrande, De Jong, Vanhaverbeke & De Rochemont, 2009) and examine the effects of these initiatives on SMEs' innovative performance (Parida *et. al.*, 2012; Pullen, De Weerd-Nederhof, Groen & Fisscher, 2012) or financial performance (Lee, Park, Yoon & Park, 2010). Other contributions focus on more specific issues, such as the role of absorptive capacity in SMEs (Spithoven *et. al.*, 2010) and the utilization of innovation intermediaries by SMEs (Lee, Park & Song, 2009).

Cluster 4 – External technology commercialization (33 items).[10]

Whereas publications belonging to the previous cluster concentrate on the inbound dimension of open innovation, the publications within this cluster address the outbound dimension of open innovation – external technology commercialization. The publications within this cluster tend to (1) describe best practices for managing external technology commercialization, (2) investigate its determinants/drivers, (3) examine its performance effects and (4) explore its complementarity with external technology sourcing. Best pratices for managing external technology commercialization relate to the integration of product and technology roadmaps (Lichtenthaler, 2008c:2008e:2008f:2010a); the development of 'desorptive capacity' (Lichtenthaler & Lichtenthaler, 2009; Lichtenthaler & Muethel, 2012). The determinants of firms' strategic approaches towards external technology commercialization relate to environmental characteristics concerning appropriability and technology markets (Lichtenthaler, 2010b*), the level of integration of product marketing and licensing (Lichtenthaler, 2007) and the personal characteristics of licensing managers (Bianchi, Chiaroni, Chiesa & Frattini, 2011b).

The contributions that focus on the performance effects of external technology commercialization tend to report a positive effect of an integrated technology commercialization strategy on firm performance (Lichtenthaler, 2008b*; Lichtenthaler, Lichtenthaler & Frishammar, 2009*). This effect is positively mediated by the degree of technological turbulence, the transaction frequency in technology markets and the level of competition in technology markets (Lichtenthaler, 2009; Lichtenthaler & Frishammar, 2011*), whereas studies are inconclusive with regard to the effect of the level of patent protection (Lichtenthaler, 2009;

[10] Citations denoted with a * in this section indicate references to publications that have been retracted during the course of our research. However, we choose to include these citations as they were contained by the Web-of-Science records at the time that we retrieved our data.

Lichtenthaler & Frishammar, 2011*). Finally, the contributions that aim to integrate the outbound dimension of external technology commercialization with the inbound dimension of technology sourcing discuss the implications of such an integrative perspective for the management of external technology commercialization in general (Lichtenthaler, 2008b; 2010d) or describe implications for the governance of knowledge flows (Lichtenthaler & Ernst, 2006; Lichtenthaler, 2008d:2009:2011a; Tukel, Kremic, Rom & Miller, 2011) and the management of intellectual property (Alexy, Criscuolo & Salter, 2009; Chesbrough, 2003) in particular.

Cluster 5 – Implementation mechanisms and tools (33 items).

This cluster mainly captures publications that describe the challenges associated with implementing open innovation in different organizational contexts and put forward a variety of mechanims, best practices and tools that could be applied to overcome these challenges. A first branch of publications describes the determinants of successful implementation mechanisms, best practices and tools in general (Hopkins, Tidd, Nightingale & Miller, 2011; Hsieh & Tidd, 2012; Mortara & Minshall, 2011; Remneland-Wikhamn & Wikhamn, 2011; Traitler & Saguy, 2009). These publications denote the novelty of projects, the nature of existing resources, the timing of implementation and the existing organizational culture as the most important determinants. A second branch of publications focuses specifically on the managerial challenges associated with implementing open innovation in SMEs (Albors-Garrigos, Etxebarria, Hervas-Oliver & Epelde, 2011; Bianchi, Campodall”Orto, Frattini & Vercesi, 2010; Caetano & Amaral, 2011; Igartua, Garrigos & Hervas-Oliver, 2010; Minshall, Mortara, Valli & Probert, 2010). These publications highlight the idiosynchrasies of SMEs – most notably focused business portfolios, specialized knowledge and limited resources – that impose unique challenges with respect to the implementation of open innovation initiatives (Bianchi *et. al.*, 2010; Minshall *et.*

al., 2010). Whereas the first two branches of publications present implementation tools and mechanisms for open innovation in general, the third and final branch of publications presents implementation tools and mechanisms for specific facets of the open innovation process. These publications tend to focus specifically on the inbound perspective (Ford, Mortara & Probert, 2012; Jeon, Lee & Park, 2012; Robertson, Casali & Jacobson, 2012; Sjodin, Eriksson & Frishammar, 2011; Schiele, 2010:2012; Wang, 2012) or outbound perspective of open innovation respectively (Bianchi *et. al.*, 2010:2011; Lichtenthaler, 2011).

Cluster 6 – Industry-specific open innovation initiatives (19 items).

This cluster distinguishes itself from other clusters as it is the cluster that is least connected to the other clusters. This is explained by the fact that the publications belonging to this cluster study outings of open innovation in specific industries, with most publications exploring open innovation in the biopharmaceutical context. These publications either explore the trend towards open innovation on the industry-level (Barnes, 2012; Carrascosa, Massaguer & Mestres, 2012; Ghauri & Rao, 2009; Robertson & Mayr, 2011; Rusu, Kuokkanen & Heier, 2011; Zdrazil, 2012) or describe tools and best practices for managing open innovation on the level of biopharmaceutical firms/institutes (Allarakhia & Walsh, 2011; Calderon *et. al*., 2011; Lee *et. al*., 2010; Nakagaki, Aber & Fetterhof, 2012; Seldon, 2011; Simiyu, Masum, Chakma & Singer, 2010). In addition to the contributions that focus on biopharmaceuticals, the cluster also encompasses studies that focus on open innovation initiatives in the oil and gas industry (Gronlund, Sjodin & Frishammar, 2010) and space industry (Holmes, 2009) respectively. The cluster is connected to the rest of the bibliographic network by a number of publications that are situated at its borderline with *'Cluster 5 – Implementation Mechanisms and Tools'*. These publications describe best practices for managing open innovation in general (Slowinski,

Hummel, Gupta & Gilomnt, 2009; Slowinski & Sagal, 2010) and the management of intellectual property within the frame of open innovation in particular (Mehlman *et. al.*, 2010; Slowinski & Zerby, 2008).

Cluster 7 – Idea generation and idea competitions (8 items).

This cluster captures publications that focus on how to manage ideas that originate from users. The focus lies specifically on ideas that are developed within the frame of idea competitions that aim to generate solutions to problems from a crowd of external actors. As such the publications that are grouped into this cluster are very much related to the publications grouped into Cluster 2. However, the fact that publications on idea generation and idea competitions are grouped into a separate cluster, indicates that this topic is sufficiently distinctive from the topics covered by Cluster 2. Most of the publications describe how to manage idea competitions and the resulting ideas effectively (Alexy, Criscuolo & Salter, 2012; Erat & Krishnan, 2012; Lampel, Jha & Balla, 2012; Wagner, 2011). They investigate a broad spectrum of issues pertaining to the design of idea competitions, ranging from the specification of the problem to be solved to the number and type of rewards that should be offered. The remaining publications address the contingencies under which idea competitions are beneficial to firms (Terwiesch & Xu, 2008), examine the characteristics of the winners of these competitions (Jeppesen & Lakhani, 2010) or investigate the influence of social ties on the market efficacy of online knowledge market places (Dushnitsky & Klueter, 2011).

The impact and development of clusters over time

In order to assess the relative importance of the identified themes, we calculated a number of citation-based statistics per cluster. These statistics are presented in Table IV below. Firtsly, it

can be observed from column 4 of the table that publications belonging to clusters 1, 2 and 4 capture the 'oldest' publications on open innovation on average. The publications that belong to these clusters have an average age of 4.79, 4.12 and 4.05 years respectively, which is higher than the sample average of 3.86 years. Clusters 1, 2 and 4 are also the ones that have received the most citations of all clusters in total (see column 5). This also holds if we control for the number of publications per cluster (see column 6), as well as the average age of publications (see column 7). However, in the latter case also publications belonging to cluster 7 score above the sample average. In fact if we control for the age of publications, publications of cluster 7 are cited the most with an average of 3.20 citations received per year. The publications of cluster 1, 2 and 4 also receive more citations per year than the sample average of 2.32. However, publications belonging to clusters 3, 6 and 5 have a below average citation rate per year. Taken together, the figures in Table IV indicate that publications that focus on the themes of idea generation and idea competitions, external technology commercialization, the basics of open innovation and user-centric innovation have the highest citation impact on average of all publications that comprise our dataset.

We also plotted the distributions of the number of publications per year per cluster in order to assess the thematic development of research on open innovation over time. This plot is presented in Figure V below. It can be observed from the figure that the distribution of publications on open innovation, follows a 'double boom' pattern, with peaks in terms of publication output arising in both 2006 and 2011. It also follows from the figure that all seven themes that we have identified followed a similar pattern of growth in terms of publication output from 2008 onwards. As such, no notable fluctuations in the relative importance of themes can be observed from Figure V, with the possible exception of clusters 3 and 4, which seem to have gained in

importance in recent years. In other words, no significant shifts in the thematic orientation of open innovation research can be observed during the past decade.

Insert Table IV and Figure V about here

DISCUSSION

In the previous section we presented the results of our thematic review of the first decade of open innovation research. We complement the existing reviews of open innovation research in two ways. First, whereas many of the existing reviews express the need for a more explicit theoretical grounding of open innovation research (Dahlander & Gann, 2010; Elmquist *et. al.*, 2009; Huizingh, 2011; Lichtenthaler, 2011; Van De Vrande *et. al*., 2010; West & Bogers, 2013), our review is the first to present a systematic quantitatively-oriented account of the foundations of open innovation research. Based on a co-citation analysis of the references cited by open innovation publications, we illustrated that open innovation research builds on four clusters of prior publications. More specifically, the bibliographic network of cited references comprises three innovation-management oriented clusters (*'Strategic Partnering and External Sourcing'*, *'User-Centric Innovation'* and *'Technology and Innovation Management'*) which are complemented by a fourth more theoretically oriented cluster (*'Resource- and Knowledge Based View of the* Firm'. Our comparative analysis based on the number of citations reveals that the *'Strategic Partnering and External Sourcing'* cluster has been the most prominent building block for open innovation research during its first decade of existence.

Second, although existing reviews identify different strands of open innovation research, our review is the first to identify thematic areas in an exhaustive manner. On the basis of bibliographic coupling, we showed that the first decade of open innovation research is

represented by a relatively coherent network of publications. At the heart of this network lies a core cluster of open innovation research – labeled as *'The Core of Open Innovation'*, that interconnects the remaining clusters – *'User-Centric Innovation'*, *'External Knowledge Sourcing'*, *'External Technology Commercialization'*, *'Implementation Mechanisms and Tools'*, *'Industry-Specific Open Innovation Initiatives'* and *'Idea Generation and Idea Competitions'*. A subsequent comparative analysis of the publication output and citation impact of clusters, suggests that publications that focus on the themes of idea generation and idea competitions and external technology commercialization, are cited the most by contemporary works. Lastly, an analysis of the distribution of publication output per cluster over time reveals that the identified themes are consistently being pursued during the last decade.

Our findings have have clear implications with regard to the future directions of open innovation research. Firstly, as already noted above, existing reviews of open innovation research emphasize the need for future research to address the theoretical foundations underlying open innovation research by integrating it with prior research in existing fields. In this respect, Van De Vrande *et. al.* (2010) are the most explicit by suggesting literature streams to which future open innovation research could be connected. They suggest that future open innovation research should be linked to transaction cost and value theory (Williamson, 1975; Zajac & Olsen, 1993), the resource based view of the firm (Barney, 1991; Grant & Baden-Fuller, 2004; Wernerfelt, 1984;), the dynamic capabilities approach (Eisenhardt & Martin, 2000; Teece *et. al.*, 1997; Teece, 2007;), the relational view of the firm (Dyer & Singh, 1998), organizational learning theory (Levinthal & March, 1993) and the real options theory (Folta, 1998). The results of our co-citation analysis clearly indicate that existing open innovation research to a large extent already builds on these (strategic) management theories. At the same time our analysis reveals a lack of reliance on

theories outside the management and business domain. Only 5% of existing open innovation research appears in economic oriented journals while sociology[11] as a discpline is even absent (see Table II).

Secondly, existing reviews argue that there is a need for a holistic perspective that integrates the inbound and outbound perspectives of open innovation into a single framework (Gassmann *et. al.*, 2010; Huizingh, 2011; Bogers & West, 2013). Not only do scholars claim that open innovation research often addresses only one of these perspectives, they also claim that there is a bias in favor of the inbound perspective (see a.o. Lichtenthaler, 2009; Lichtenthaler & Lichtenthaler, 2010). Our findings confirm that the inbound and outbound perspectives are often discussed seperately in open innovation research. However, at the same time, they also suggest that the imbalance between research on the inbound and outbound perspective is not that severe. There is considerable attention for the outbound perspective, although this attention mostly originates from one scholar – Ulrich Lichtenthaler – whose work has come under some scrutiny recently. Nonetheless, studies attempting to integrate the inbound and outbound perspectives of open innovation within a single framework are scarce, although there are some notable exceptions (Lichtenthaler, 2008a, Lichtenthaler & Ernst, 2009). In light of recent arguments that the main theoretical contribution of open innovation is the assumed complementarity between inbound and outbound activites (Cassiman & Valentini, 2013), there is clearly a need for future research to integrate both perspectives.

Thirdly, open innovation is claimed to rely mainly on case studies and qualitative research methods. As such, existing reviews tend to call for large-scale quantitative studies as a complement to existing case study research on open innovation (Huizingh, 2011; Lichtenthaler,

[11] While for instance network analysis seems to be a relevant theoretical frame to enrich open innovation.

2011). Our findings confirm that qualitative research, and case studies in particular, have been explicitly present in open innovation research in the past decade. References to contributions on qualitative research methodologies (Glaser &Strauss, 1967; Miles & Huberman, 1994) and especially case study methodology (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Yin, 1994:2003) are amongst the references cited most by our set of open innovation publications. However, our review also suggests that quantitative studies are also present within our sample, although they are mainly in the *'External Knowledge Sourcing'* and *'External Technology Commercialization'* clusters. This suggests that research on some thematic areas might be more conducive towards the application of large-scale quantitative approaches than others.

Lastly, Gassman *et. al.* (2010) and Van De Vrande *et. al.* (2010) argue that there is lack of attention for SMEs in existing open innovation research. Our review indeed shows that there is considerably less attention for SMEs than for large established firms within our set of open innovation papers. This does not mean, however, that SMEs have been neglected by existing research. Publications that focus specifically on SMEs are certainly present within our sample. However, these publications are mainly concentrated in the *'External Knowledge Sourcing'* and *'Implementation Mechanisms and Tools'* clusters only. In light of existing research suggesting that SMEs are specialist suppliers of knowledge and technology on technology markets (see for instance Arora *et. al.*; 2001), studies on the external commercialization initiatives of SMEs may constitute a particularly fertile avenue for future research.

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[12] In this reference list we only include those references that are not part of our set of 358 open innovation publications or their 123 top-cited references on which or review is based. We disclose the full list of these publications in the appendix to our paper.

TABLES

Table I. An overview of existing qualitative reviews of open innovation research.

Authors	Identified Themes	Avenues for Future Research
Gassman (2006)	Identifies Four Literature Streams On Which Open Innovation Research Builds (1) The Internationalization of Innovation Stream, (2) The Early Supplier Integration Stream, (3) The User Innovation Stream and (4) The External Commercialization of Technology Stream.	• There is a need for a contingency approach with respect to the management of innovation; Which of the factors that drive higher performance are preferred by open and which by closed innovation models?
Elmquist *et. al.* (2009)	Identify Seven Common Themes Within Open Innovation Research (1) The Notion of Open Innovation, (2) Business Models, (3) Organizational Design and Boundaries of the Firm, (4) Leadership and Culture, (5) Tools and Technology, (6) Intellectual Property, Patenting and Appropriation and (7) Industrial Dynamics and Manufacturing.	• Open innovation research need to be 'reconceptualized' in order to further develop the existing body of knowledge as well as underlying theoretical models. 'The human side' and 'the organizational side' of open innovation are important avenues for future research. • There is a need for critical discussions of the concept of open innovation which should highlight both its strengths and weaknesses, whilst also elaborating upon its contribution to managerial practice.
Gassman *et. al.* (2010)	Identify Nine Perspectives That Are Represented By Open Innovation Research (1) The Spatial Perspective, (2) The Structural Perspective, (3) The User Perspective, (4) The Supplier Perspective, (5) The Leveraging Perspective, (6) The Process Perspective, (7) The Tool Perspective, (8) The Institutional Perspective and (9) The Cultural Perspective.	• There is a need for a 'holistic' model of open innovation that simultaneously takes into account the determinants of the process and industry specifics, as well as the limits to opening up. • Intellectual property plays a key role in open innovation, yet important questions with respect to intellectual property remain unexplored. • The 'spatial aspect' of open innovation deserves more profound research attention. • There is insufficient attention for SMEs in existing open innovation research, whilst most firms in an economy are SMEs.
Lichtenthaler (2011)	Identifies Four Tentative Streams of Open Innovation Research (1) The Technology Transactions Stream, (2) The Users Stream, (3) The Business Models Stream and (4) The Innovation Markets Stream.	• There is a need for a clearer understanding of the characteristics of open innovation as well as the practices and tools for managing it. • Future research should address the link between approaches towards open innovation and firms' corporate strategy and organizational culture. • Future research should address the impact of opening up the innovation process on firms' innovative and financial performance. Thereby the determinants of successful open innovation deserve special attention. • There is a need for a better theoretical foundation of open innovation research. Future open innovation research should be grounded in prior research into both open innovation and related fields.

		• Much of the prior work on open innovation is managerially oriented. Therefore there is a need for more rigorous academic studies which employ an empirical research design.
Dahlander & Gann (2010)	Distinguish Four Streams of Open Innovation Research Based on Two Dimensions – Inbound vs. Outbound and Pecuniary vs. Non-pecuniary Open Innovation (1) The Revealing Stream, (2) The Selling Stream, (3) The Sourcing Stream and (4) The Acquiring Stream.	• There is a limited understanding of the costs of openness. Therefore future research should focus on explaining the contingencies under which openness is a fruitful strategy. • Existing research is too focused on studying optimal levels of openness, whilst neglecting how openness has changed in a qualitative sense. • Whilst there is considerable focus on the performance effects of openness, there is a need for research that focuses on the underlying decision processes. • There is a need for future research that elaborates on the conceptual frame of open innovation from the perspective of the product/technology life cycles. • Future research could focus on exploring combinations of different forms of openness and study the conditions under which these different forms are complements or substitutes.
Van De Vrande *et. al*., (2010)	Does not identify themes but addresses trends in open innovation based on three characteristics of the research performed; focus (large-multinationals, SMEs, user communities), type of research (theoretical, qualitative, quantitative) and level of analysis (firms, individuals, dyads, projects, industries, regions).	• Researchers should transcend the closed versus open innovation debate by focusing their attention towards explaining how open innovation strategies enable firms to create a competitive advantage. • There is an urgent need to integrate open innovation in the existing literature about external technology acquisition and cooperation. • Future open innovation research should incorporate different levels of analysis. • Future initiatives should aim to connect open innovation to other disciplines or management areas; e.g. absorptive capacity and corporate venturing. • Future research on open innovation should focus more on SMEs.
Huizingh (2011)	Distinguishes Four Streams of Open Innovation Research Based on The Level of Openness of Two Artefacts – The Process and/or Outcome of Open Innovation (1) Closed Innovation, (2) Private Open Innovation, (3) Public Innovation, (4) Open Source Innovation	• There should be more research on cases in which open innovation initiatives have failed. • There is a need for an integrated framework that helps managers to decide when and how to deploy which open innovation practices. • Existing open innovation research is to a large extent based on descriptive case studies of early adopters. Therefore there is a need for large-scale quantitative studies in various industries and countries that address several practices of open innovation and utilize a diverse set of performance measures. • Many open innovation issues need to be better understood in order to absorb the concept into integrated management theories and existing management toolkits.
Bogers & West (2013)	Identify Four Related Streams of Open Innovation Research (1) Obtaining External Innovations Stream, (2) Integrating External Innovations Stream, (3) Commercializing External Innovations Stream, (4) Interaction Between the Focal Firm and its Collaborators Stream	• Future research on external sourcing should make explicit the role of the business model, should focus more on value capture and should seek opportunities for testing what the most appropriate metrics for assessing sourcing strategies are. • Whereas current research focuses predominantly on obtaining innovations, future research should focus on the entire process of obtaining, integrating and commercializing innovations. • There is considerable disagreement between studies on open innovation with regard to what constitutes an innovation. • Future innovation research should go beyond depictions of innovation as a linear process. • There should be more research on the moderators and limits of external sourcing, thereby the focus should be more on the potential risks and costs associated with external sourcing. There is also a need for more research on the failures of open innovation.

Table II. Top-10 sources and web-of-science categories of open innovation publications.

Top-10 Sources			Top-10 Web-of-Science Categories		
Souce Title	***Number of Items***	***Percentage From Total***	***Web-of-Science Category***	***Number of Items***	***Percentage From Total***
R&D Management	40	11.17%	Management	249	69.55%
Research-Technology Management	29	8.10%	Business	151	42.18%
International Journal of Technology Management	24	6.70%	Engineering-Industrial	61	17.04%
Research Policy	20	5.59%	Operations Research-Management Science	49	13.69%
Technovation	16	4.47%	Planning Development	39	10.89%
Technological Forecasting and Change /	10	2.79%	Engineering-Multidisciplinary	25	6.98%
Technology Analysis Strategic Management	10	2.79%	Information Science-Library Science	21	5.87%
California Management Review	9	2.51%	Computer Science-Information Systems	19	5.31%
Creativity and Innovation Management	8	2.24%	Economics	17	4.75%
Journal of Product Innovation Management	8	2.24%	Multidisciplinary Sciences	10	2.79%

Table III. Indicators of publication output and citation impact per cluster of cited references.

Cluster	Label	Number of Items	Top-3 Most-Cited References (OI Set)	Average Number of Citations Per Item (OI Set)	Ratio to Average (OI Set)	Average Number of Citations Per Item (WoS)	Ratio to Average (WoS)
A	*(A) Strategic Partnering and External Sourcing*	37	Cohen & Levinthal (1990) Laursen & Salter (2006) Powell *et. al.* (1996)	20.03	1.08	605.88	0.72
B	*(B) User-Centric Innovation*	34	Von Hippel (2005) Von Hippel (1988) Eisenhardt (1989)	17.00	0.92	704.76	0.84
C	*(C)Technology and Innovation Management*	34	Chesbrough (2006) Gassman (2006) March (1991)	18.16	0.98	875.64	1.05
D	*(D) Resource-And Knowledge Based View of the Firm*	12	Chesbrough (2003) Chesbrough (2006) Huston & Sakkab (2006)	18.17	0.98	1623.75	1.94
Total		123	-	18.57	1.00	837.03	1.00

Table IV. Indicators of publication output and citation impact per thematic cluster.						
Cluster	**Cluster Label**	**Number of Items**	**Average Age of Items**	**Total Number of Citations**	**Average Number of Citations Per Item**	**Average Number of Citations Per Item Per Year**
1	*The Core of Open Innovation*	94	4.12	1490	15.85	2.57
2	*User-Centric Innovation*	78	4.05	1032	13.23	2.54
3	*External Knowledge Sourcing*	42	3.28	340	8.10	1.93
4	*External Technology Commercialization*	33	4.79	562	17.03	3.09
5	*Implementation Mechanisms & Tools*	33	2.91	107	3.24	1.03
6	*Open Innovation in Specific Industries*	19	3.42	92	4.84	1.47
7	*Idea Generation And Idea Competitions*	8	3.25	114	14.25	3.20
Total		307	3.86	3737	12.17	2.32

FIGURES

Figure I. The cumulative growth of publications on the concept of open innovation over time

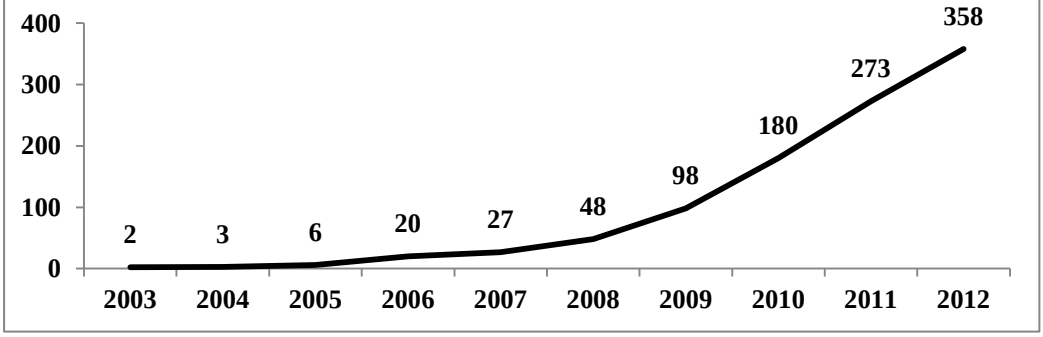
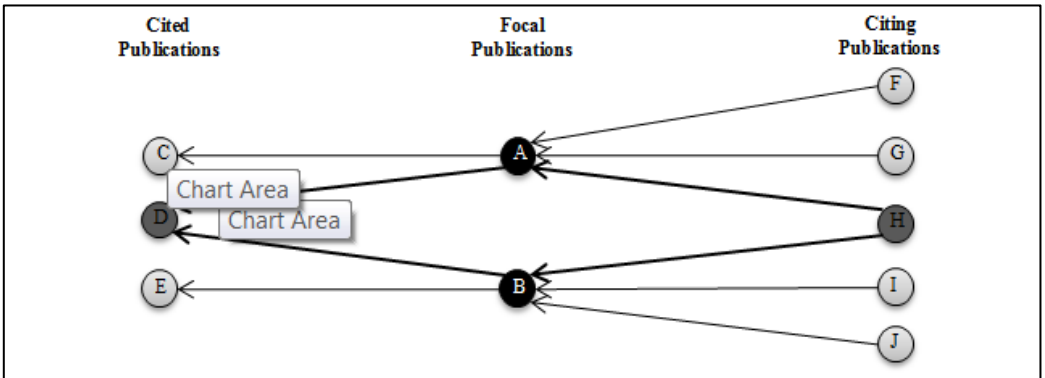


Figure II. An illustration of bibliographic coupling and co-citation analysis.



The figure depicts the citation network of two focal articles A and B which both cite two articles (A cites C and D; B cites D and E) and are both cited by three articles (A is cited by F, G and H; B is cited by H, I and J). A and B have one common backward citation D, which means that A and B can be linked to each other through bibliographic coupling. A and B also have one common forward citation H, meaning that A and B can be linked to each other through co-citation analysis.

Figure III. Co-citation network of the references cited by publications on open innovation between 2003 and 2013

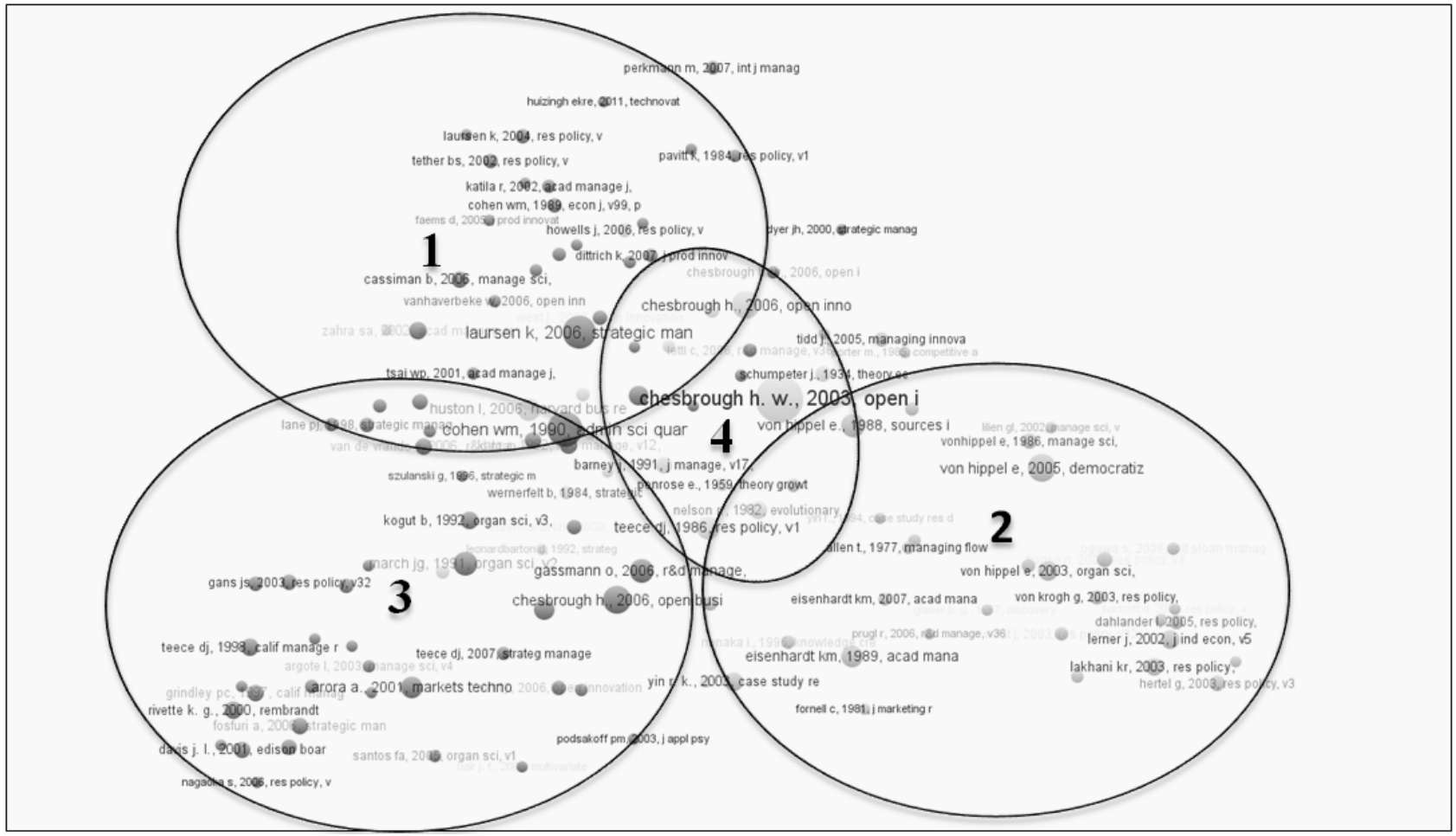


Figure IV. Bibliometric network of open innovation publications published between 2003 and 2013 based on bibliographic coupling

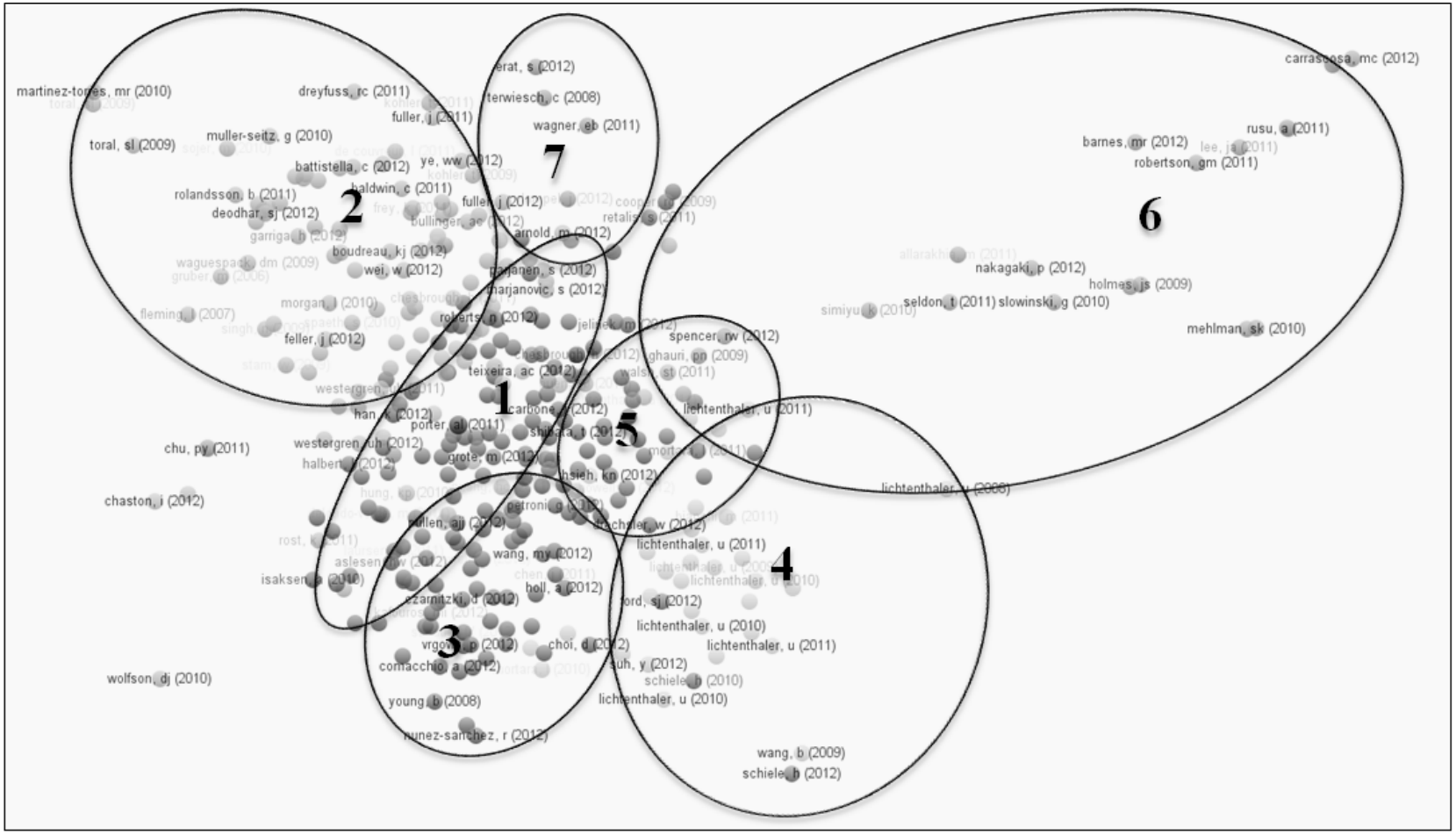
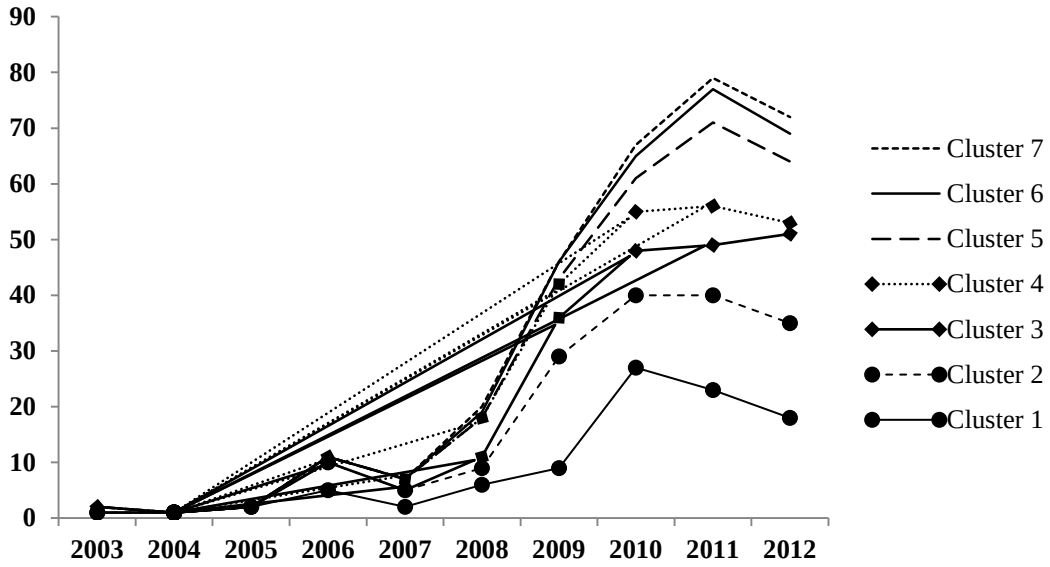


Figure V. The Distribution of The Number of Publications Per Theme Over Time



APPENDICES

Appendix A – List of references included in co-citation analysis

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Appendix B – List of publications included in bibliographic coupling[13].

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[13] Citations denoted with a * in this section indicate references to publications that have been retracted during the course of our research.

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