A bibliometric review of the innovation adoption literature

ABSTRACT

Innovation adoption is of utmost importance for company survival. That is why it is important to develop a thorough understanding of this research domain and the themes it encapsulates. Since the early work of Everett Rogers, the adoption of innovation literature has attracted considerable attention and has continued to grow rapidly, resulting in a large but fragmented body of literature. The goal of this study is to provide a coherent overview of the theoretical cornerstones as well as recent research trends in the innovation adoption literature. To this end, we conducted a bibliometric review and performed bibliographic coupling and co-citation analysis. First, based on co-citation analysis, we illustrate that innovation adoption research is built on four theoretical cornerstones including: institutional theory; theory of reasoned action; theory concerning the determinants of adoption, and; diffusion theory. Second, bibliographic coupling was used to assess the current research trends. This review is the first to identify thematic areas in an exhaustive manner revealing five clusters of thematic related publications or "research trends": determinants of IT adoption; adoption of technological standards; organizational rationales associated with adoption; modelling diffusion, and; adoption of agricultural innovations. We conclude this review with the limitations and future research orientations in the field of innovation adoption.

Keywords:
Innovation adoption; Literature Review; Bibliographic Coupling; Co-citation Analysis

Highlights:

- Adoption and diffusion research is highly segregated
- Innovation adoption research builds upon 4 theoretical cornerstones
- Current innovation adoption research can be linked to 5 "research trends"
- Theoretical cornerstones and trends frame the relevance of future adoption research

1. INTRODUCTION

Many scientific publications in the field of innovation research start from the premise that innovation contributes to a firm's competitive advantage and is considered a necessity for firm survival.

Adoption-diffusion literature can be traced to the work of Gabriel Tarde, a French sociologist, who introduced the *Laws of Imitation* at the beginning of the 1900s [1]. However, not until Everett Rogers [2] introduced the *Diffusion of Innovations Theory (DOI)* did adoption and diffusion research gain widespread recognition. Rogers conceptualized innovation adoption as a communication process whereby adoption reflects a pattern of information flow about an innovation. We start from the semantic work of Rogers [3] to assess the innovation adoption literature.

A number of arguments speak for the theoretical and practical relevance of producing a review on the adoption of innovation. First, the innovation adoption literature has continued to grow rapidly since these early works which resulted in a large but also fragmented body of literature [4-6]. Second, as have been addressed by Gupta et al. [4] and Keupp et al. [6], innovation literature is organised in specific domains. While adoption research entered a wide variety of sectors within the economy [3], the understanding of innovation adoption has grown considerably building on theoretical insights from innovation, organizational and behavioural centred theories. It has been suggested that a "schools of thought" approach might be a prominent path bringing together existing knowledge and theories [11]. Third, as have been emphasized in previous reviews [6, 7], innovation research in the past decades has failed to deliver clear and consistent findings, coherent advice to managers, and convincing "best practice" solutions so far.

The aim of this article is to present a bibliometric review of the innovation adoption literature. In particular, we aim to 1) identify the theoretical foundations of innovation

adoption, 2) pinpoint current themes in adoption of innovation research, and 3) identify avenues for future research. By helping innovation adoption scholars to understand better the key cornerstones of this field of research, the direction in which it is developing and by pointing to potential research gaps, our study is intended to provide a guideline for scholars in positioning their future research efforts. Therefore, we focused on two questions. First, what are the key theoretical cornerstones of innovation adoption research? Second, what are the current research trends within the field of innovation adoption? The first research question involves a classification of scientific articles which revealed four theoretical cornerstones including: A) Institutional Theory and the legitimization of innovative behaviour; B) Theory of Reasoned Action and the Technology Acceptance Model; C) The determinants of innovation adoption through an econometric perspective; and D) Diffusion Theory. For the second research question we assessed the same cited references and identified five trending research directions including: 1) Drivers and impediments of information technology adoption; 2) The adoption of technology standards; 3) Organizational rationales associated with innovation adoption; 4) Modelling the diffusion process; and 5) Adoption of agricultural innovations.

The most recent influential innovation adoption review dates from the 2003 review by Greenhalgh et al [8]. Since then, novel bibliometric methods have been developed to review the literature. Bibliometric studies have already shown their usefulness in a broad array of management research, including innovation [9, 10]. Bibliometric reviews differ from highly cited reviews in this field [13,19,20,21,22], on the aspects data, analysis and coverage [11]. A key benefit of bibliometric methods is their ability to help reduce reviewers' subjectivity and bias, which are inherent to conventional qualitative reviews [12]. In contrast to respected and highly cited reviews in the field, our bibliographic study of the innovation adoption field is based on quantitative data rather than qualitative interpretations which tend to reflect the

subjective views of the authors [10, 11, 13]. This article presents a bibliometric review of the innovation adoption research over the period 2003-2016.

In combining two techniques, co-citation analysis and bibliographic coupling, we visualize the network of publications on innovation adoption and arrive at distinct clusters of thematically related publications. This quantitative review allowed us to create a more systematic and encompassing picture of the adoption innovation research agenda, especially in terms of theoretical foundations and avenues for future research.

This article is structured in the following way. In the section that follows, Section 2, we discuss the method we applied to this review and present the articles included. In Section 3, the theoretical cornerstones of innovation adoption research are discussed; in Section 4, we consider recent debates on innovation adoption research. Section 5 discusses the key findings of this review and elaborates about the potential paths for future research.

2. DATA AND METHODS

2.1. Data

For our two bibliometric analyses, we follow the four-step procedure as outlined by Kovacs et al. [14]. First, we developed a search query for the Web of Science (WoS) database (–Core Collection). We included articles using the terms: “innovation [and] adoption”. We restricted our search to articles published between 2003 and 2016. We chose this time span because our preliminary analysis of the available review articles and meta-analysis studies indicated that the most influential literature reviews were at least three years old. A preliminary search resulted in the identification of approximately 6,800 articles. To further narrow down our search, only articles from the WoS Research Area “Business Economics” were included in the review, since our primary interest is in the mechanisms that affect innovation adoption from an innovation economics viewpoint. In-depth analysis of this refinement revealed that

top innovation journals and the most cited articles were not excluded from the review (see Figure 2). Moreover, many of the articles that were excluded by this refinement addressed the status quo of a certain kind of "development" – describing them as innovative is questionable – without contributing to the development of innovation adoption theory itself. As a result, application of these selection criteria resulted in 3,713 articles that could be reviewed in greater depth.

Second, to ensure that each article in this study was relevant to the adoption-innovation domain, the abstract, key words, and introductory section were manually evaluated by the authors. This allowed us to exclude false positives, i.e. articles that include the terms "innovation" and "adoption" in the title, abstract, or keywords but are unrelated to the domain under study (see, for example, [15]). We did not remove articles that were indirectly related to the innovation adoption debate, e.g. articles that focus on implementation and assimilation of innovations. These articles could well enrich the review and in case they are irrelevant to the domain under study they appear in the periphery of the visual map created with the Vos Viewer software. Applying the aforementioned selection criteria resulted in a set of 1,260 articles (with 45,932 references) to be included in the bibliometric review. For each of the 1,260 articles, an output file (tab-delimited) was generated from the WoS database. The cited references are relevant for this bibliographic review and formed the raw input for the VOS Viewer software.

Third, we analysed the WoS data of the remaining 1,260 articles using the VOS Viewer software. Two types of output were generated: a co-citation analysis of cited references and bibliographic coupling of the 1,260 articles identified. The VOS Viewer identified 1,260 articles suitable for bibliographic coupling, that together have 45,932 cited references of which 155 have a minimum of 20 citations. Figures 1 and 2 present descriptive statistics of this dataset.

During the fourth and final step, we interpreted the results of the co-citation analyses and the bibliometric coupling. To interpret and label the theoretical orientations of each cluster, all articles were downloaded from the Web of Science database and all books were accessed via the university library. The co-citation analysis of cited references was used to derive the theoretical cornerstones of innovation adoption research (Clusters A, B,C, and D). The output of the bibliographic coupling analysis allowed us to define the thematic clusters (Clusters 1, 2, 3, 4 and 5). Clusters A-D encompass a limited number of articles; therefore, the assessment of these clusters was relatively straightforward. However, each cluster, 1 to 5, holds up to 300 articles, making interpretation and labelling a less straightforward process. Therefore, for each cluster, the fifteen most cited articles were identified. However, since these articles could be situated on the periphery of a specific cluster, the 15 articles that are most closely related to each other were identified based on a cluster's density plot. The density view corresponds with the label view (figure 6) with the difference that the labels are now expressed by a colour scheme. The colour scheme (blue-green-red) depends on the density of items at that point, i.e. the colour at a certain point is calculated by the number of items in the vicinity of that point as well as on the importance of the neighbouring items [13]. The authors independently labelled the clusters after which the results were discussed to find an agreed label for each cluster. The theoretical cornerstones and current research trends identified will be discussed in Sections 3 and 4 respectively.

The validity of any bibliometric review depends in part on the selection of publications that form the input of the analyses. Although the journals included in WoS Core Collection meet the highest standards regarding impact factor and number of citations [10, 16], we decided to further evaluate the robustness of our bibliometric review by using the Scopus database. This

allowed us to verify if we omitted relevant studies that could have affected our core findings.[1] Our search queries in the WoS and Scopus database resulted in 2,216 and 2,706 articles respectively. This difference is in part explained by a difference in the search queries used. In WoS the query was limited to the research area of 'business economics'. In Scopus this filter is not available and therefore we included articles linked to the two Scopus categories 'business management' and 'economics'. By comparing the search results we observe that 1,088 articles are included in both output files, i.e. a 49% and 40% overlap with the WoS and Scopus data set respectively. As a next step we ran a separate co-citation analysis using the Scopus output file with VOS Viewer software. Examination of the two bibliometric maps revealed that both maps can be linked to the same theoretical cornerstones. From this we conclude that our findings are robust and not specific to the WoS database.

Table 1: Most cited review, overview and meta-analysis articles on adoption of innovation (based on the Web of Science citations linked to Google Scholar search results).

Nr	Authors	Title	Citations	Type	Field
1	Venkatesh et al. (2003) [17]	User acceptance of information technology: Toward a unified view	3,925	Survey	ICT innovation
2	Damanpour (1991) [18]	Organizational innovation - A meta-analysis of effects of determinants and moderators	1,706	Meta-analysis	Organizational innovation
3	Greenhalgh et al. (2003) [8]	Diffusion of innovation in service organizations: Systematic review and recommendations	1,724	Review	Health care innovation
4	Legris et al. (2003) [19]	Why do people use information technology? A critical review of the technology acceptance model	713	Review	ICT innovation
5	Tornatzky and Klein (1982) [20]	Innovation characteristics and innovation adoption-implementation – a meta-analysis of findings	709	Meta-analysis	Not sector specific
6	Feder et al. (1985) [21]	Adoption of agricultural innovations in developing countries	604	Survey	Agricultural innovation
7	Geroski (2000) [22]	Models of technology diffusion	386	Survey	Not sector specific
8	Gatignon and Robertson (1985) [23]	A propositional inventory for new diffusion research	360	Review	Not sector specific
9	Wolfe (1994) [24]	Organizational innovation – review, critique and suggested research directions	343	Review	Organizational innovation
10	Frambach and Schillewaert (2002) [25]	Organizational innovation adoption – a multi-level framework of determinants and opportunities for future research	247	Review	Organizational innovation

[1] The EBSCO Academic Search Complete database deemed not suitable for this purpose as it excludes relevant innovation journals and includes grey literature that we did not want include in our analyses. Furthermore this database did not permit us to limit our search query to our focus area of 'business economics'.

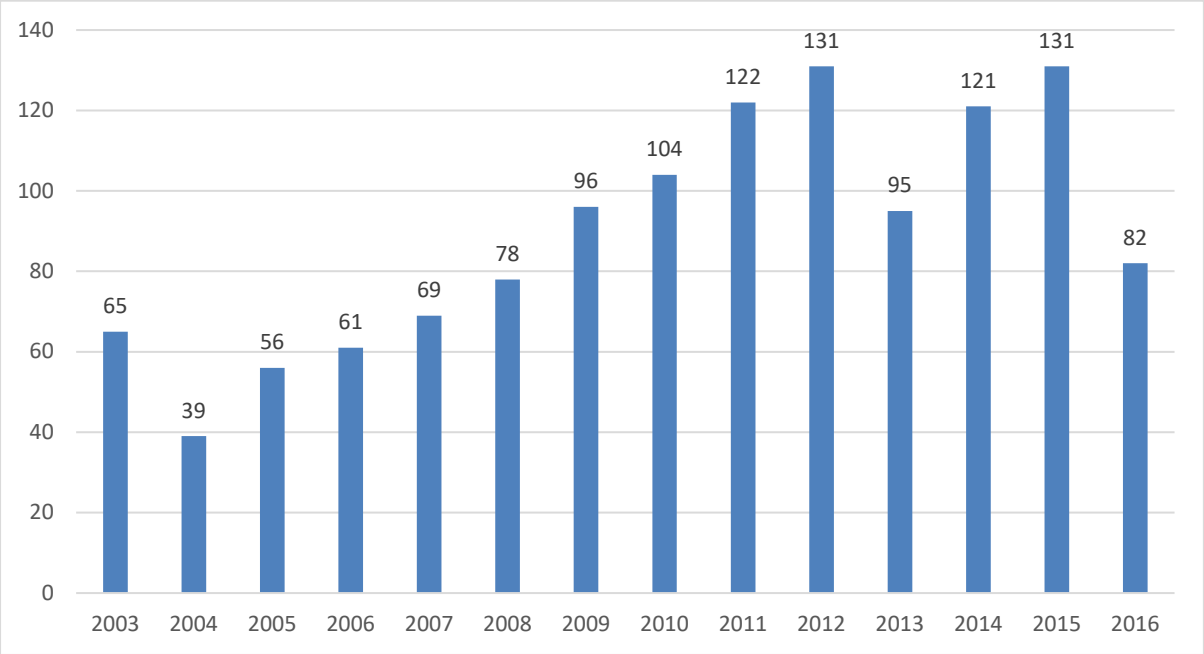


Figure 1: The number of scientific articles about innovation adoption per year included in this review

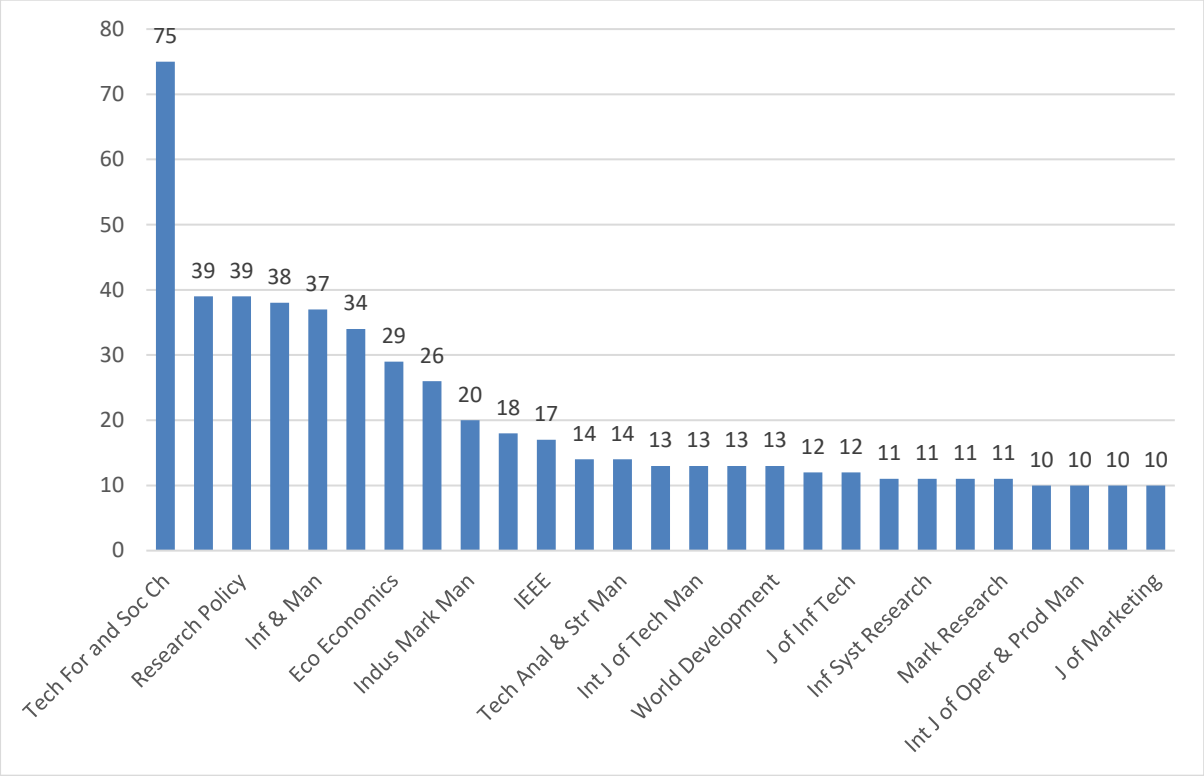


Figure 2: Number of scientific articles about innovation adoption per year per academic journal (560 articles (out of 1260), or 44%, have been published in 27 scientific journals).

2.2. Methods: Bibliographic coupling and co-citation analysis

Many methodological scholars have emphasized the need for a process of systematic reviewing in order to overcome the bias challenge facing scientific literature reviews. The principles of "systematic reviewing" are based on a replicable, scientific and transparent protocol. Such protocols minimize human error and bias in mapping and synthesizing the fragmented empirical studies [26, 27]. To further reduce the reviewer bias, it would be possible to perform a bibliometric analysis that does not depend on the reviewer's knowledge or preferences [28]. In order to identify thematic similarities between articles published in scientific journals on innovation adoption, we rely on two bibliometric analysis techniques based on the overlap between reference patterns: (1) bibliographic coupling and (2) co-citation analysis.

Bibliographic coupling clusters recent articles but fewer old articles: co-citation clustering does the opposite, being unable to cluster the most recent articles that have not yet been cited [29]. Clusters identified by co-citation analysis form the cornerstones of the research front in the literature on innovation adoption while bibliographic coupling helps to identify clusters representing the more recent research themes that do not necessarily match the cornerstones. The methods differ from each other in the direction of referencing: this is visualised in Figures 3 and 4 (adapted from Boyack and Klavans, 2010 [29]). The grey box in Figures 3 and 4 represents the longitudinal dataset of innovation adoption articles that are included in the review. Articles A, B, C, D and E represent the most recent published articles, and papers M, N, O and P are somewhat older, dating from 2003. Articles W, X, Y and Z were published before 2003 and are not part of the longitudinal dataset but, as they are cited by publications in the longitudinal dataset, they are included as external references.

Co-citation analysis allows us to reveal the theoretical foundations of the research field by assessing the similarities among cited articles [29]. Clusters A and B in Figure 3 are

derived from the co-citation analysis and, as is evident, these clusters contain articles that are published prior to the articles included in the dataset.

Bibliographic coupling links documents that reference the same set of cited documents and is used to assess the similarity between citing articles [29]. This is illustrated in Figure 4; Clusters 1 and 2 result from bibliographic coupling of the articles in the dataset. Note that the older articles in the innovation adoption dataset, represented by articles M, N, O and P, could be included in a co-citation cluster as well as a cluster identified by bibliographic coupling.

Following Kovacs et al. [14], we combine these complementary techniques to uncover both past research traditions and current trends in the field of innovation adoption. For a more detailed description of this approach, see Boyack and Klavans [29] and Kovacs et al. [14]. In line with the work of Van Eck and Waltman [13], this review applies their association strength measure to reveal the clustering of innovation adoption articles, i.e. it determines the normalized strength between related papers based on similarities among their reference lists (p531):

$$S_{ij} = \frac{C_{ij}}{W_i W_j}$$

C_{ij} = Number of citations (received by) or references (referred to) that articles i and j have in common; W_i = Total number of citations or references article i; W_j = Total number of citations or references article j.

The relative distance (the higher the values of S_{ij}) between the focal articles A and B based on the reference list depends on the quotient between overlapping references and the number of references that could have been made by both publications. This calculation is made for every pair of publications included in the review, one time based on bibliographic coupling and the other time based on co-citation. We used the Visualization of Similarities (VOS) approach (http://www.vosviewer.com) to identify and visualize thematic clusters based on the

relatedness between our set of publications [13]. VOS software combines optimization and clustering algorithms to visualize the relative distance, which reflect the level of similarity between reference lists, and between articles included in the analysis. For the mathematical details, we refer to Van Eck and Waltman [13]. The software places the most connected articles in the middle of the two-dimensional space and, thus, the least connected articles are printed at relative distance from the centre. Next, articles are presented in clusters based on Newman and Givan's modularity function [30], where the maximization of the modularity function is parameterized by a resolution parameter. In the VOS Viewer, this parameter can be adjusted to alter the (optimal) number of clusters derived. This parameter is particularly useful in identifying small clusters – a weakness of modularity-based clustering techniques. In our study we slightly adjusted the resolution parameter, set at 0.75 in contrast to the default setting of 1.0, which resulted in a clearer distinction between cluster, all other settings were set to default. In figure 5 the size of the title of individual publications and the size of the corresponding circle indicate the importance of the publication within the map, depending on the number of neighbouring articles, the distance between these articles and the number of citations these articles received. The distance between two articles explains the overlap between them, i.e. the closer two articles are positioned to each other the more the overlap between the work cited by these publications. Items positioned at a larger distance are less often cited together. Based on the proximity between all publications, clusters are formed which are highlighted with different colours in the map. As explained earlier, to facilitate interpretation of each cluster we also gave a unique label to each cluster that best matches the content of each cluster of publications. Clusters located next to each other indicate closely related fields. Visa versa, clusters at a relative distance cover more different research fields [13].

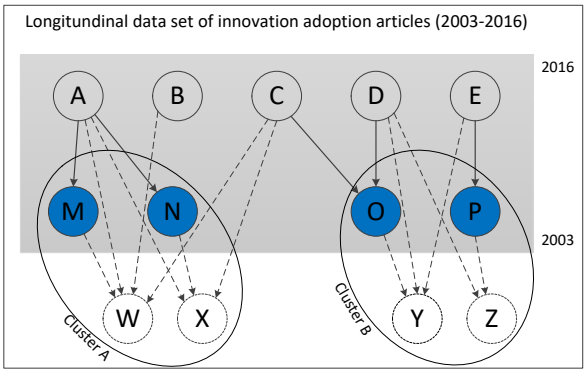


Figure 3: Illustration of co-citation analysis (adapted from Boyack and Klavans, 2010 [29]). The grey box represents the longitudinal dataset of innovation adoption papers included in the review. Articles A-E represent the most recent published articles and papers. M-P are somewhat older going back to 2003. Articles W-Z were published before 2003 and were not included in the review. Clusters A and B result from the formation of co-cited articles and, thus, these clusters contain articles that were published before the articles in the dataset. Clusters A and B are referred to as the theoretical cornerstones of innovation adoption research.

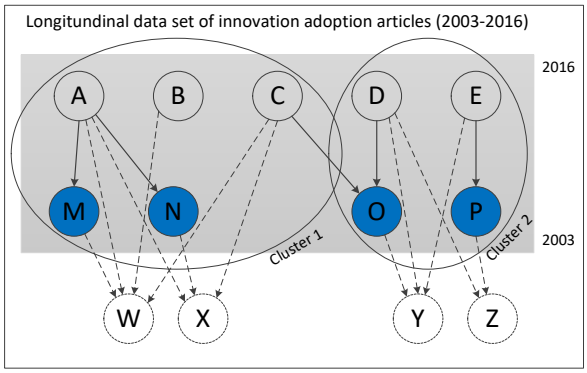


Figure 4: Illustration of bibliographic coupling (adapted from Boyack and Klavans, 2010 [29]). The grey box represents the longitudinal dataset of innovation adoption papers included in the review. Articles A, B, C, D and E represent the most recent published articles, and papers M, N, O and P are somewhat older, going back to 2003. Articles W-Z were published before 2003 and were not included in the review. Clusters 1 and 2 result from bibliographic coupling of the articles in the dataset based on the links between the articles that reference the same set of cited articles.

3. CORNERSTONES OF INNOVATION ADOPTION RESEARCH

Figure 5 shows the bibliographic network based on co-citation analysis and reveals the theoretical cornerstones of innovation adoption research. Figure 5 displays a relatively coherent network in which clusters A, B, C and D are tied together by different editions of Rogers' seminal work positioned in the core of the network [2, 3, 31, 32]. We included externally cited references in the analysis [29]. Taking into account the different citation styles of journals, this resulted in the identification of 45,932 unique references. To facilitate interpretation of the clusters, we restricted our focus to references that were cited 20 times or more. This helped us to focus on the most important publications and facilitated interpretation of the identified clusters in the network. Our network of publications, shown in Figure 5, consists of four clusters. Each cluster consists of vertices that represent the cited references. Publications represented by larger vertices are cited more often by the publications in our longitudinal dataset than those that are represented by smaller vertices. The distance between

vertices corresponds to the likelihood of co-citation, i.e. the closer two vertices are located together in the network, the more likely these references will be cited together. In this respect, publications in a cluster are more likely to be cited together than any combination of publications from separate clusters.

It should be noted that the four clusters are tied together by four (out of five) editions of Everett Rogers' Diffusion of Innovations [2, 3, 31, 32]. As the latest version of Rogers' book, Diffusion of Innovations [3], has been used for the development of the search query "innovation adoption", it will not be considered in detail in order to derive a meaningful and distinctive description of each cluster. For the same reason, methodological publications are not considered any further. The relatively empty centre of the structure indicates that clusters are clearly separated from each other (Van Eck and Waltman, 2010, p.535). A more detailed analysis in Figure 5 indicates that Clusters C and D are relatively coherent where "gaps" or relative empty spaces can be found between publications in Clusters A and B. Following the protocol discussed in Section 2.1, the following clusters have been identified: A) Institutional Theory and the legitimization of innovative behaviour; B) Theory of Reasoned Action and the Technology Acceptance Model; C) The determinants of innovation adoption, an econometric perspective; and D) Diffusion Theory. In the following sections, 3.1 to 3.4, we assess the theoretical cornerstones of innovation adoption research, i.e. we define each of the four identified clusters and assess the relative importance of the clusters.

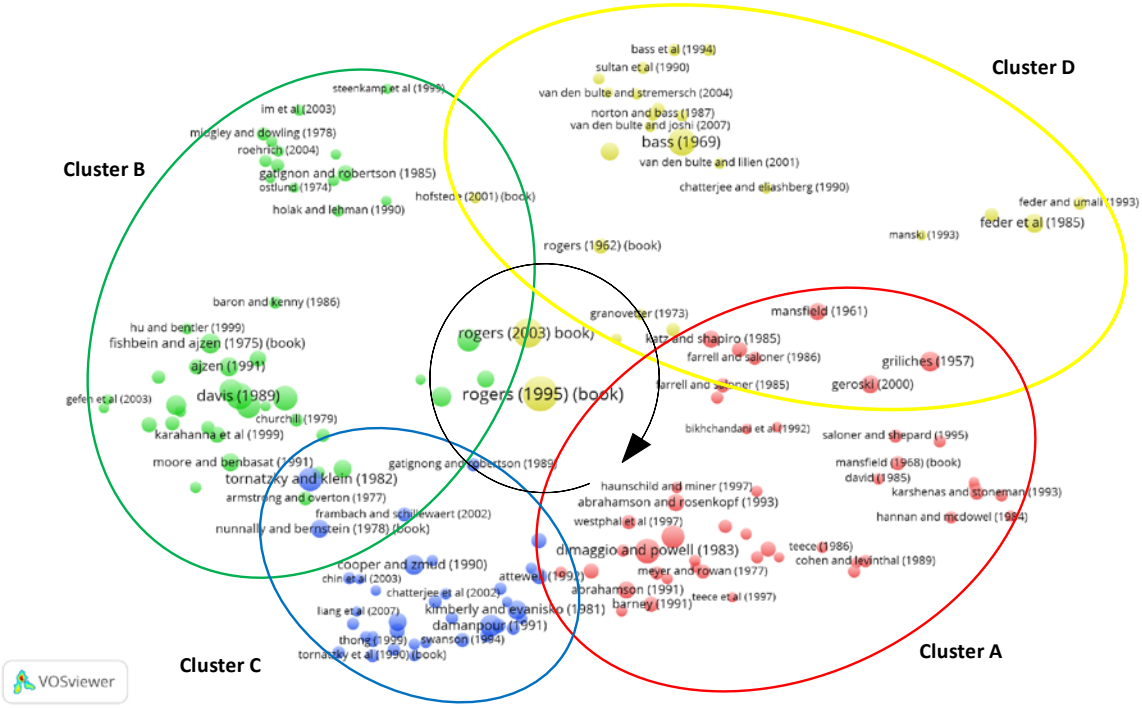


Figure 5: Co-citation network of references cited by innovation adoption publications between 2003 and 2016. The research fields, or theoretical cornerstones, are linked to each other by the seminal work of Rogers on which we base our search query.

3.1. Cluster A: Institutional Theory and the legitimization of innovative behaviour

Cluster A, which includes 37 articles and 7 book publications, can be labelled as "Institutional Theory and the legitimization of innovative behaviour". In common, the publications in this cluster address forces that dictate how firms behave, how they innovate and which innovations they adopt. One of the most important explanations can be found in Institutional Theory. Next, four themes related to firm behaviour with respect to innovation and innovation adoption and diffusion were identified in the periphery of Cluster A. Finally, three methodological publications were dropped while they do not address innovation adoption or diffusion. Table 3 provides an overview of the 44 publications, their theoretical contribution and the implications for innovation adoption-diffusion research. Table 3 makes

clear that most of the publications included in Cluster A address firm behaviour at the aggregate level and do not address innovation adoption in particular. Moreover, the few publications which address adoption and/or diffusion are found in the periphery of Cluster A. Therefore, we have organized the publications according to the theoretical concept upon which they build and have deduced the conceptual adoption mechanism from them as shown in the last column. To grasp this cluster, we drew on the work of Agrote and Greve [33].

In the main, Cluster A encompasses the theoretical background from which scholars derived their conceptualizations in order to explain innovative behaviour and, thus, innovation adoption (as is evident in Section 4). In this respect, Cluster A is considered better "grounded in theory" than the clusters discussed in the next sections. In particular, institutional theory is well covered (table 3). Conceptualizations based on institutional theory build upon the notion that the acceptance of any innovation, or any other form of change challenging an incumbent institution, depends, by and large, on its (regulative, normative and cultural-cognitive) legitimacy. In this regard, it opposes the socio-economic efficiency considerations addressed in Cluster C [34].

Four themes related to firm innovative behaviour can be found in the periphery of Cluster A. Closely related to Cluster D, the first theme addresses adoption-diffusion from an econometric viewpoint. Before the well-known work of Rogers [2] and Bass [35], Griliches [36] and Mansfield [37, 38] published about "*the longer-run aspects [in the economics] of technology change*" (Griliches, 1957, p521) and "*technological change and the differences among innovations in the rate of imitation"* (Mansfield 1961, p741). The work of Griliches (1957) presents a logistic growth function (S-curve) based on parameter origins (availability of a new technique), slopes (rate of acceptance) and ceilings (equilibrium level use). Mansfield [37] introduced an imitation model based on the hypothesis that: "*the probability that a firm will introduce a new technique is an increasing function of firms already using it*

and the profitability of doing so, but a decreasing function of the size of the investment require" (pp.762-763) [2]. The publication of Geroski (2000) studied several alternative technology diffusion models [22]. In contrast to the dominant S-curve diffusion model or epidemic model, two alternative approaches are emphasized (probit models and models of density dependence).

Next, the second theme embodies the Network Externalities Theory, which studies the implications of network effects on innovation adoption-diffusion [39-41]. "Direct network externalities" refers to the notion that the level of user value depends on the size of the installed base, i.e. the number of other adopters of the innovation. In contrast, indirect network externalities increase utility through the availability of complementarities; for example, the availability of DVDs (complementarities) increases the utility of DVD players (installed base).

A third topic addresses the relation between complementary organizational capabilities and innovation [42]. In this respect, Cohen and Levinthal [43, 44] introduced the concept of Absorptive Capacity. Moreover, Teece et al. [45] introduced the concept of Dynamic Capabilities. Dynamic Capabilities encompass specific capabilities and resources which constitute a firms' competitive advantage. This framework has been applied by scholars to assess how a set of competences and resources are developed, deployed, and protected by a specific firm within changing and competitive economic environments. In contrast to research projects that study the adoption of innovation in isolation, Bresnahan et al. [46] analysed the effect of the complementary adoption of three related innovations.

Finally, the publications which do assess the adoption and diffusion of innovation are found in the periphery of Cluster A. Jensen [47] and Karshenas and Stoneman [48] for example attempted to bridge the gap between the work of Griliches and Mansfield and the

[2] Rogers made the terms "adoption" and "diffusion" popular among scholars. However, the early work in this field dates back to Gabriel [de] Tarde who introduced the "Laws of Imitation" around 1900 and, therefore, these terms are used in early publications.

work of Rogers by addressing the gap between understanding adoption-diffusion behaviour at the aggregate industry level and individual firm's adoption behaviour taking into account both economic and information communication factors. Thus, these publications take into account market structure and organizational innovation behaviour [49-53].

Table 3: Overview of the 44 publications in Cluster A. The publications included address, how firms innovate, and which innovations they adopt from a behavioural point of view.

Reference:	**Theory:**	**Conceptual adoption mechanisms deduced from theory*:**
Cyert and March, 1963 [54]	Behavioural Theory of the Firm	Adoption behaviour (the adoption of innovation) depends on several mechanisms which related to: bounded rationality of the firm; firm"s problematic search; the dominant coalition; standard operating procedures within the firm, and firms slack search – subsequently, these mechanisms can be found in a number of related organizational theories.
Nelson and Winter, 1982 [55]; Tushman and Anderson, 1986 [56]	Evolutionary Economic Theory	Longitudinal perspective on technological change; technologies evolve through periods of incremental change punctuated by breakthroughs that affect firm (adoption) behaviour (prompted by uncertainty).
Meyer and Rowan, 1977 [57]; Tolbert and Zucker, 1983 [58]; DiMaggio and Powell, 1983 [59]; Abrahamson, 1991 [34]; Bikhchandani et al., 1992 [60]; Abrahamson and Rosenkopf, 1993; 1997 [61, 62]; Suchman, 1995 [63]; Westphal, Gulati and Shortell, 1997 [64]; Haunschild and Miner, 1997 [65]; Abrahamson and Fairchild, 1999 [66];	Institutional Theory	The acceptance of any innovation, or any other form of change challenging an incumbent institution, mainly depends on its (regulative, normative and cultural-cognitive) legitimacy (in contrast to economic efficiency considerations).
Cohen and Levinthal, 1989; 1990 [43, 44]; Milgrom and Roberts, 1990 [42]; Teece, 1986 [67]; Teece et al., 1997 [45]; Bresnahan et al.,, 2002 [46]	Absorptive Capacity, dynamic capabilities and complementarities	The ability of a firm to recognize the value of new, external information; the ability to assimilate this information; and the capability to apply this information during adoption (decision making). In addition, often complementary organizational capabilities are required to adopt innovation.
Schumpeter, 1934; 1942 [68, 69]; Porter, 1980 [70]; Henderson and Clark, 1990 [71]	Schumpeterian (economic) theory of "creative destruction"	In its essence, firms' innovative behaviour and, thus, innovation adoption behaviour, is motivated by firm survival considerations.
Barney, 1991 [72]; Pfeffer and Salancik, 1978 [73]	Resource-based view	Adoption depends on a firm's belief that the innovation is a future strategic resource that must be obtained in order to sustain a competitive advantage.
Farrell and Saloner, 1985; 1986 [40, 41]; Katz and Shapiro, 1985; 1986 [39, 74]; Saloner and Shepard, 1992 [75]	Network externalities Theory	The adoption of innovation with network effects depends on the availability of direct and indirect network externalities (for example, the availability of DVDs increases the utility of DVD players).
Griliches, 1957 [36]; Mansfield, 1961; 1969 [37, 38]; Geroski, 2000 [22]	Diffusion econometrics	Modelling the longer run aspects of technology change and the differences among innovation in the rate of imitation (following a S-curve).
Reinganum, 1981 [49]; Jensen, 1982 [47]; Hannan and McDowell, 1984 [50];	Market structure and organizational innovation adoption behaviour	Bridges the gap between the work of Griliches and Mansfield and the work of Rogers by addressing the gap between understanding adoption-diffusion behaviour at the

Fudenberg and Tirole, 1985 [51]; Milliman and Prince, 1989 [53]; Karshenas and Stoneman, 1993 [48]		aggregate industry level and individual firm's adoption behaviour (taking into account market structure (economics, governmental policy, information communication) and firm determinants).

*conceptual because the mechanisms are relatively abstract compared to the mechanisms identified in Cluster 3.

3.2. Cluster B: Theory of Reasoned Action and the Technological Acceptance Model

Cluster B is labelled as: "Theory of Reasoned Action and the Technology Acceptance Model". Cluster B encompasses 30 publications, including 2 book publications, that can be subdivided into two groups of closely related publications, B1 and B2 respectively. About 11 methodological publications were dropped as were three versions of Rogers' Diffusion of Innovations book. Next, we discuss the two subsets in more detail.

The 16 articles of Subset B1 build upon the concept of technology acceptance. The Technology Acceptance Model is grounded in the Theory of Reasoned Action (TRA) developed by Fishbein and Ajzen [76] from which, later on, the "(Decomposed) Theory of Planned Behavior" ((D)TPB) has been developed [77-79]. The TRA has been developed to predict and explain social behaviour in general. The Technology Acceptance Model (TAM) was introduced by Davis [80] and was developed to specifically explain computer usage intention and actual usage behaviour. Later studies refined the original TAM [81-83], which resulted in several versions of the model such as TAM2 [83] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [17]. The basic assumptions of TAM encompass the causal relation between Perceived Usefulness, Perceived Ease of Use, and the decision makers' attitudes, intentions and actual innovation usage. In general, this research stream demonstrates that the intention to use an innovation is the only accurate predictor of the actual adoption and use of the innovation [84].

How are the innovation adoption-diffusion and the innovation acceptance line of debate positioned alongside each other? Four articles in this cluster focus on complementarities between both lines of debate [85-88]. Criticizing the adoption-diffusion

theory, these scholars claim that the adopters' perception of the innovation does not itself explain its diffusion but rather their perception of applying the innovation. This critique has been stimulated by Rogers' definitions of the five perceived innovation characteristics (i.e. relative advantage, compatibility, complexity, observability and trialability) [3]. Addressing this critique, the innovation acceptance line of debate is based on the assumption that innovation behaviour (usage) is preceded by the intention to use the innovation. In contrast, the innovation acceptance line of debate has been criticized for its lack of a comprehensive set of attributes explaining technology acceptance outcomes as found in innovation adoption-diffusion research. As a result, several attempts have been made to include these attributes in the TAM (see Cluster 1, Section 4.1).

Fourteen articles form a subset in Cluster B, referred to as B2, although these articles are closely related to the technology acceptance line of debate [23, 89, 90]. Their relative distance from the rest of the articles can be explained by the origins of these papers; the core publications were published just prior to the introduction of the concept of technology acceptance. The publications within subset B2 explore consumer innovativeness in more detail [89, 91]. The review of Roehrich (2004) revealed that the concept of innovativeness is still under debate and lacks clear conceptualizations and measures (even after decades of research since its introduction in the early seventies) [91].

3.3. Cluster C: Determinants of innovation adoption, an econometric perspective

This cluster is labelled "The determinants of innovation adoption, an econometric perspective" and includes 35 publications. Cluster C encompasses subsequently 33 scientific papers and 2 book publications. Two publications were dropped as these references o0nly include research methodology issues. Compared to Clusters A, B and D, Cluster C is relatively coherent. As can be seen in Figure 5, Cluster C is closely related to Cluster D and,

therefore, publications assigned to Cluster C are more often cited in combination with publications from Cluster D in contrast to Clusters A and B. From the publications constituting Cluster C it was derived that these publications apply a variance based approach as the dominant research strategy. More specifically, Cluster C publications apply unidirectional causations to assess the impact of determinants on the adoption of specific innovations within various contexts (see table 4).

The articles in this cluster all address the Downs and Mohr critique [92] on the generalizability of research findings on innovation adoption. In their article, they argued that innovation adoption models lacked a rigorous theoretical foundation and were too simplistic since they failed to take into account contextual differences, i.e. contingency variables. Most of the publications in this cluster examine the contingencies influencing the adoption of different types of innovation in different contexts [93, 94].

In contrast, Tornatzky and Klein's [20] meta-analysis addresses the question of whether "*across an heterogeneous array of innovations, actors, and organizations, the innovation characteristic-adoption relationship vary widely or reverse itself*" (p.29). These scholars oppose, to some degree, the argument in Downs and Mohr's critique. Instead, Tornatzky and Klein propose that "*perceived innovation characteristics can predict the adoption and implementation of various innovations, and with some degree of consistence across various settings.* [They] *assume that the literature fails, to a considerable extent, to exploit this possibility because of methodological and conceptual problems in many of the innovation characteristic studies*"(p.29). Meyer and Goes [95] and Cooper and Zmud [96] also presented several methodological and conceptual shortcomings regarding adoption research.

Furthermore, Damanpour [18] has levelled the criticism that researchers have overemphasized sub-theories of organizational innovation adoption. According to

Damanpour, the purpose of those studies, such as Kimberly and Evanisko [93] and Dewar and Dutton [94], was to further explore several specific dimensions of innovation and their determinants. However, the sub-theories have not been evaluated in different contexts (p.556). In contrast, several researchers claim that an unified adoption theory does not exist at all because the variations in innovations and the adoption context in which the innovations will be applied are unique, and that the contingencies of every situation must be taken into account [97, 98]. A recent meta-analysis conducted by Jeyaraj et al. (2006) shed some new light on this debate [99]). These authors assessed the determinants which affect IT adoption at the individual and organizational level. They found that, at the aggregate level, innovation and organizational determinants are both predictors of individual and organizational adoption. These scholars conclude that both categories of determinants are strong predictors of IT adoption at the individual and organizational level.

Taken together, this cluster addresses the different conceptualizations of the adoption of distinct innovations affected by a specific set of contingency variables. The two most frequently applied frameworks to study innovation adoption in its context, including innovation, organizational and contextual determinants, have been developed by Tornatzky and Fleisher (1990) and Iacovou et al. (1995) [100, 101]. Moreover, Cluster C can be considered as the birthplace of middle-range theories of adoption.

Table 4: Determinants of innovation adoption; an econometric perspective on middle-range theories of adoption

Reference	Determinants affecting adoption	Innovation	Framework	Cross reference within Cluster C
Attewell, 1992 [102]	Organizational learning	Business computing	Tornatzky and Fleisher's Technology-Organization-Environment framework	Kimberley and Evanisko, 1981 [93]; Rogers, 1983 [31]; Tornatzky and Fleisher, 1990 [100]
Chatterjee et al., 2002 [103]	Top Management Support, strategic investment rationale, extent of coordination	Web technologies		Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]; Meyer and Goes, 1988 [95]; Cooper and Zmud, 1990 [96]; Fichman and Kemerer, 1999 [104]
Chau and Tam, 1997 [105]	Firms tend to focus more on their "ability to adopt" than on the "benefits from adoption"; firms take a reactive rather than "proactive" attitude in adopting open systems technology	Open systems	Tornatzky and Fleisher's Technology-Organization-Environment framework	Zaltman et al., 1973 [106]; **Downs and Mohr, 1976 [92]**; Rogers, 1983 [31]; Tornatzky and Fleisher, 1990 [100]; Attewel, 1992 [102]
Chwelos et al., 2001 [107]	Readiness, perceived benefits, external pressure	Electronic data interchange (EDI)	Iacovou, Benbasat and Dexter framework	Tornatzky and Klein, 1982 [20]; Damanpour, 1992 [108]; Premkumar et al., 1994 [109]; Premkumar and Ramamurthy, 1995 [110]; Iacovou et al., 1995 [101]; Rogers, 1995 [32]
Cooper and Zmud, 1990 [96]	Compatibility, Technology complexity	Material requirements planning: MRP (IT)		**Downs and Mohr, 1976 [92]**; Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]
Damanpour, 1991 [18]	Organizational determinants: specialization, functional differentiation, professionalism, centralization, managerial attitude toward change, technical knowledge resources, administrative intensity, slack resources, and external and internal communication	*Meta-analysis*	*Meta-analyses*	Zaltman et al., 1973 [106]; **Downs and Mohr, 1976 [92]**; Dewar and Dutton, 1986 [94]; Kimberly and Evanisko, 1981 [93]; Tornatzky and Klein, 1982 [20]; Meyer and Goes, 1988 [95]
Damanpour, 1992 [108]	Organizational size			
Damanpour and Schneider, 2006 [111]	Environmental, organizational and top managers' characteristics	Administrative programmes	Tornatzky and Fleisher's Technology-Organization-Environment framework	Zaltman et al., 1973 [106]; Dewar and Dutton, 1986 [94]; Kimberly and Evanisko, 1981 [93]; Meyer and Goes, 1988 [95]; Tornatzky and Fleisher, 1990 [100]; Damanpour, 1991; 1992 [18, 108]; Rogers, 1995 [32]; Hofstede, 2001 [112]; Wejnert, 2002 [113]
Dewar and Dutton, 1986 [94]	(Levels of) knowledge [no effect of decentralized decision making, managerial attitudes toward change, and exposure to external information]	Technical process innovation		Zaltman et al., 1973 [106]; **Downs and Mohr, 1976 [92]**; Kimberley and Evanisko, 1981 [93]
Fichman and Kemerer, 1997 [114]	Organizational learning [knowledge barriers]: learning costs; related knowledge, knowledge diversity	Software process innovation	Tornatzky and Fleisher's Technology-Organization-Environment framework	**Downs and Mohr, 1976 [92]**; Rogers, 1983 [31]; Tornatzky and Fleisher, 1990 [100]; Damanpour, 1991 [18]; Attewell, 1992 [102]
Fichman and Kemerer, 1999 [104]	Knowledge barriers, increasing returns to adoption	Software process innovation	Tornatzky and Fleisher's Technology-Organization-Environment framework	Cooper and Zmud, 1990 [96]; Tornatzky and Fleisher, 1990 [100]; Attewel, 1992 [102]; Rogers, 1995 [32]; Fichman and Kemerer, 1997 [114]

Frambach and Schillewaert, 2002 [25]	Innovation, organizational and individual (within firm context) determinants	*Model development*		Zaltman et al., 1973 [106]; Kimberly and Evanisko, 1981 [93]; Tornatzky and Klein, 1982 [20]; Gatignon and Robertson, 1989 [115]; Damanpour, 1991 [18]; Rogers, 1995 [32]
Gatignon and Robertson, 1989 [115]	Effect of competition on adoption behaviour as well as the effect of organization/taks characteristics and DMU information-processing characteristics (all including several determinants)	High-tech innovation		Zaltman et al., 1973 [106]; Kimberly and Evanisko, 1981 [93]; Rogers, 1983 [31];
Grandon and Pearson, 2004 [116]	Perception strategic value: operational support, managerial productivity, and strategic; decision aids; From TAM: organizational readiness, external pressure, perceived ease of use, and perceived usefulness	E-commerce	Iacovou, Benbasat and Dexter framework	Iacovou et al., 1995 [101]; Premkumar and Roberts, 1999 [117]
Grover, 1993 [118]	Organizational, policy, environmental, support and innovation (IT) factors	Customer based inter-organizational systems (IT)		Zaltman et al., 1973 [106]; Kimberly and Evanisko, 1981 [93]; Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]; Dewar and Dutton, 1986 [94]; Cooper and Zmud, 1990 [96]
Iacovou et al., 1995 [101]	organizational readiness (because of the low levels of IT sophistication and resource availability of small firms), external pressures to adopt(because of the weak market positions of small firms and the network nature of the technology), and perceived benefits (because of the limited impact that IT has on small firms due to under-utilization and lack of integration	EDI	Iacovou, Benbasat and Dexter framework	Rogers, 1983 [31]
Jeyara et al., 2006 [99]	Predictors of individual IT adoption: Perceived Usefulness, Top Management Support, Computer Experience, Behavioral Intention, and User Support. Predictors of IT adoption by organizations: Top Management Support, External Pressure, Professionalism of the IS Unit, and External Information Sources. Independent variables: Top Management Support stands as the main linkage between individual and organizational IT adoption; At an aggregate level, two collections of independent variables were good predictors of both individual and organizational IT adoption: innovation characteristics and organizational characteristics. Thus, generic characteristics of the innovation and characteristics of the organization are strong predictors of IT adoption by both individuals and organizations.	*Meta-analysis*	*Meta-analyses*	Grover, 1993 [118]; Swanson, 1994 [119]; Iacovou et al., 1995 [101]; Fichman and Kemerer, 1999 [104]
Kimberley and Evanisko, 1981 [93]	Individual, organizational, and contextual variables were found to be much better predictors of hospital adoption of technological innovations than of administrative innovations. The two different types of innovation were found to be influenced by different variables. Organizational level variables, size in particular, were clearly the best predictors of both types of innovation	Technological versus administrative innovation (by hospital)		Zaltman et al., 1973 [106]; **Downs and Mohr, 1976 [92]**
Kuan and Chau, 2001 [120]	Perception-based model using TOE framework (including Technology, Organizational and Environmental determinants) is a useful approach for examining factors affecting adoption	Electronic data interchange (EDI)	Tornatzky and Fleisher's Technology-Organization-Environment framework	**Downs and Mohr, 1976 [92]**; Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]; Tornatzky and Fleisher, 1990 [100]; Iacovou et al., 1995 [101];

				Premkumar et al., 1994 [109]; Premkumar and Ramamurthy, 1995 [110]
Liang et al., 2007 [121]	Importance of top management in mediating the effect of institutional pressures on IT assimilation: Mimetic pressures positively affect top management beliefs, which positively affects top management participation in the post-adoption process and continued usage. Next, coercive pressures positively affect top management participation (without the mediation of top management beliefs). No support for the hypothesis that top management participation mediates the effect of normative pressures on usage, in contrast normative pressures directly affect usage.	Enterprise resource planning (ERP)	Iacovou, Benbasat and Dexter framework	Rogers, 1983 [31]; Damanpour, 1991 [18]; Iacovou et al., 1995 [101]; Chatterjee et al., 2002 [103]; Teo et al., 2003 [122]; Swanson and Ramiller, 2004 [119]
Meyer and Goes, 1988 [95]	Contextual attributes, innovation attributes, and attributes arising from the interaction of contexts and innovations	Technological innovations		Zaltman et al., 1973 [106]; **Downs and Mohr, 1976 [92]**; Kimberly and Evanisko, 1981 [93]; Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]; Dewar and Dutton, 1986 [94]
Premkumar et al., 1994 [109]	The results of the multivariate regression analyses revealed that relative advantage, costs, and technical compatibility were the major predictors of adaptation. While relative advantage and duration were important predictors of intemal diffusion, technical compatibility and duration were found to be important predictors of extemal diffusion. Both forms of compatibility (technical and organizational) and costs were found to be important predictors of implementation success.	Electronic Data Interchange		Zaltman et al., 1973 [106]; Kimberly and Evanisko, 1981 [93]; Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]; Gatignon and Robertson, 1989 [115]; Cooper and Zmud, 1990 [96]; Damanpour, 1991 [18]
Premkumar and Roberts, 1999 [117]	Innovation, organizational and environmental characteristics: relative advantage, top management support, organizational size, external pressure and competitive pressure	Communication technology		Gatignon and Robertson, 1989 [115]; Cooper and Zmud, 1990 [96]; Attewel, 1992 [102]; Grover, 1993 [118]; Rogers, 1995 [32]; Premkumar et al., 1994 [109]; Premkumar and Ramamurthy, 1995 [110]
Thong, 1999 [98]	CEO characteristics (innovativeness, level of IS knowledge); innovation characteristics (RA, compatibility, complexity); organizational characteristics (business size, level of employees' knowledge)	IT	Tornatzky and Fleisher's Technology-Organization-Environment framework	Zaltman et al., 1973 [106]; **Downs and Mohr, 1976 [92]**; Kimberly and Evanisko, 1981 [93]; Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]; Dewar and Dutton, 1986 [94]; Tornatzky and Fleisher, 1990 [100]; Attewel, 1992 [102]; Fichman and Kemerer, 1993 [97]
Zhu and Kraemer, 2005 (i.e Zhu et al., 2003; 2006) [123-125]	The model links technological, organizational, and environmental factors (TOE framework): technology competence, firm size, financial commitment, competitive pressure, and regulatory support are important antecedents of e-business use.	E-business	Tornatzky and Fleisher's Technology-Organization-Environment framework	Tornatzky and Klein, 1982 [20]; Rogers, 1983 [31]; Cooper and Zmud, 1990 [96]; Tornatzky and Fleisher, 1990 [100]; Damanpour, 1992 [108]; Iacovou et al., 1995 [101]; Fichman and Kemerer, 1997 [114]; Teo et al., 2003 [122]; Zhu and Kraemer, 2003 [123]

3.4. Cluster D: Diffusion Theory

Cluster D is labelled as “Diffusion Theory” since most references in this cluster focus on the mathematical modelling of diffusion processes. Cluster D encompasses 23 publications, including 2 book publications, and mainly includes elaborations on the modelling of diffusion processes building upon the Bass model. Similar to Cluster B, three publications of Rogers’ Diffusion of Innovation were excluded. Next, a small subset within Cluster D specifically focuses on the diffusion of agricultural innovations, the effect of policy intervention on diffusion, and the effect of diffusion on economic development.

Most of the articles in Cluster D can be related to the work of Frank M. Bass, after which the Bass Model has been named [35, 126, 127]. This research is closely related to early work of Griliches [36] and Mansfield [37] which can be found in Cluster A. Bass devised his model in 1969 in order to develop a theory of timing concerning the initial purchase of new consumer products. The Bass model is based on the assumption that “*the probability of purchase at any time is related linearly to the number of previous buyers. [..] The model implies exponential growth of initial purchases to a peak and then exponential decay”* (1969, p. 226). The model finds its theoretical background in mathematical models concerned with the social contagion of news. Since the early work of Bass several researchers have extensively explored which mechanisms constitute social contagion [128-130]. The strength of the Bass model lies in the forecasting opportunities based on predictions about timing and magnitude sales and, in particular, the sales peak (1969, p.226). In contrast to the spread of innovations in homogeneous social systems as assumed by the early ‘diffusionists’, Chatterjee and Eliashberg [131] were among the first to model the diffusion of innovation in a heterogeneous population (which had previously been suggested by Gatignon and Robertson [23]). Specific attention have been devoted to international (spatial) diffusion

models taking into account country characteristics including cultural determinants [112, 115, 132].

Although the Bass model has often been criticized, today's diffusion scholars continue to use the model; the renewed attention has been encouraged by several reviews and will be addressed in greater detail in Section 4.4 (Cluster 4) [113, 126, 133-136]. As a result diffusion models have been modified over time to improve their explanatory power (these modifications include the introduction of marketing variables in the parameterization of the models; generalizing the models to consider innovations at different stages of diffusion in different countries; and building models to consider the diffusion of successive generations of technology – particularly related to the diffusion of durables and communication technology) [135]. Nevertheless, diffusion scholars face several challenges regarding anticipating on market trends such as opening up of markets in developing countries, Web-based services, virtual social networks, and complex product-service structure [136]. In their review Meade and Islam (2006) suggest that future research should focus on forecasting new product diffusion with little or no data, forecasting with multinational models, and forecasting with multi-generation models [135]. In addition Peres et al. (2010) suggest that in order for diffusion to remain a state-of-the-art modelling framework, research should be devoted to include additional growth drivers (in addition to interpersonal communications as a parameter); re-examine the metrics to describe both the level and variety of usage; and extend the range of data sources [136].

Two small subsets of articles were identified within Cluster D. The first subset addresses the diffusion of agricultural innovations (often from a policy-making perspective) [137, 138]. In their article, Feder et al. [21] surveyed the adoption of agricultural innovation

in developing countries. As demonstrated in Cluster 5 (see Section 4.5), this subset secured renewed interest by specifically addressing Feder et al. [21] notion of “diffusion dynamics”.

A second subset builds upon the effect of network ties with respect to social contagion and diffusion of innovation [139, 140]. It has been suggested that the tie strength between adopters (or non-adopters) being “structural equivalents” (i.e. very similar) is a predictor of innovation adoption. In this respect, Burt (1987) distincts between two types of diffusion models suggesting a debate between cohesion and structural equivalence models. Cohesion models build upon the notion that adopters resolve the uncertainty problem through conversations with peers in contrast to structural equivalence models which suggests that uncertainty of adoption is resolved through the perception of appropriate behaviour related to the social network position [140].

3.5. Relative importance of the theoretical cornerstones

The relative importance of the four cornerstones of innovation adoption have been assessed using citation-based statistics. Table 5 reveals that Cluster A (“Institutional theory and the legitimization of innovative behaviour “) and Cluster B (“Theory of Reasoned Action; Technology Acceptance Model”) received, on average, the most citations from the 1260 articles included in the innovation adoption dataset. On average, the references in Cluster A and Cluster B have both been cited 44 times while Clusters C and Cluster D obtain substantially less citations, 41 and 37 respectively. Only Cluster A and Cluster B have been cited more than the average citation number (42,07).

However, the Web of Science database consists of articles where all clusters also include some highly cited book publications, and the citation statistics from 2003 to 2016 cannot be derived from this database [2, 3, 31, 32, 54, 68, 70, 73, 76, 77]. Books are therefore excluded from the citation impact analysis.

Table 5: Indicators of publication output and citation impact (cited by the 1260 articles included in the dataset) per cluster of cited references

Cluster	Label	Number of publications (including books)	Top 3 most-cited articles	Average number of citations / article*	Ratio to average (sample) *
A	Institutional theory and the legitimization of innovative behaviour	44	Dimaggio and Powell (1983) [59]: 105; Cohen (1990) [44]: 92; Griliches (1957) [36]: 67	44,37	1482,57
B	Theory of Reasoned Action and the Technology Acceptance Model	30	Davis (1989) [81]: 122; Venkatesh et al. (2003) [17]: 99; Davis et al. (1989) [82]: 90	44,36	1444,77
C	Determinants of innovation adoption, an econometric perspective	35	Tornatzky and Klein (1982) [20]: 97; Damanpour (1991) [18]: 87; Cooper and Zmud (1990) [96]: 70	41,03	326,60
D	Diffusion Theory	23	Bass (1969) [35]: 134; Feder et al. (1985) [21]: 66; Mahajan et al. (1990) [126]: 57	36,67	739,78
	Total	132		42,07	12 01,95

4. ANALYSIS OF INNOVATION ADOPTION RESEARCH TRENDS BASED ON BIBLIOGRAPHIC COUPLING

In this section, we will unravel the current trends in the innovation adoption research by studying bibliographic coupling among the publications in our longitudinal dataset. Figure 6 illustrates a relatively coherent bibliographic network with five clusters of references cited by the 919 publications on innovation adoption published between 2003 and 2016. Clusters 1 to 4 are structured around a relative empty centre, which indicates that fields are more strongly tied than others [13]. Cluster 5, however, can be found in the periphery of the map with strong ties to Clusters 2 and 4. In this respect, Cluster 5 is clearly separated from Clusters 1 and 3. The identified clusters are labelled as follows: Cluster 1 –drivers and impediments of information technology adoption; Cluster 2 – the adoption of technology

standards; Cluster 3 – organizational rationales associated with innovation adoption; Cluster 4 – modelling the diffusion process; and Cluster 5 – adoption of agricultural innovations.

Table 6 presents an overview of the research trends reflected in Clusters 1 to 5. We found that the research trends of the five clusters can be linked to a particular empirical field – Cluster 1 focuses on Information Technology, Cluster 2 focuses on technological standards, Cluster 3 focuses on management innovations, Cluster 4 on consumer durables and product innovations and Cluster 5 captures publications concerned with the adoption of agricultural economic innovations in developing nations. Column 4 highlights the theory on which it builds, with particular relevance to the theoretical cornerstones identified in Section 3. Cluster 1 builds upon Clusters B and C and specifically explores the determinants affecting the adoption and diffusion of IT innovations. Cluster 2 does not build upon a particular cluster identified in the previous section but explores the adoption of new and/or emerging technological standards related to sustainable technology. Theory development is principally related to technology trajectories; dominant designs and technology standards and the battle for dominance related to diffusion and change within a sector. Cluster 4 mainly takes into account the diffusion of consumer durables and product innovation; it focuses on the Bass Model that has been studied in many different fields. The “appendix”, Cluster 5, addresses the dynamics of innovation adoption and diffusion. In the following section, we discuss the five clusters in greater depth adopting two perspectives: a representation of the field in which adoption has been studied, and the theoretical focus of the cluster.

Table 6: Overview of the 5 identified bibliographic coupled clusters

Cluster	Builds upon cluster:	Field under study	Theory
1	B & C	Information technology	Diffusion of Innovations (DOI); Technology Acceptance Model (TAM)
2	*None in particular*	Technology standards (sustainable technologies)	Diffusion of Innovations (DOI); Technology trajectories; dominant design and technology standards; complementarities and organizational capabilities
3	A	Management innovations	Behavioural Theory of the Firm; Institutional Logic
4	D	Consumer durables and product innovation	Bass Model
5	D	Agriculture innovation (in developing countries)	Duration Analysis

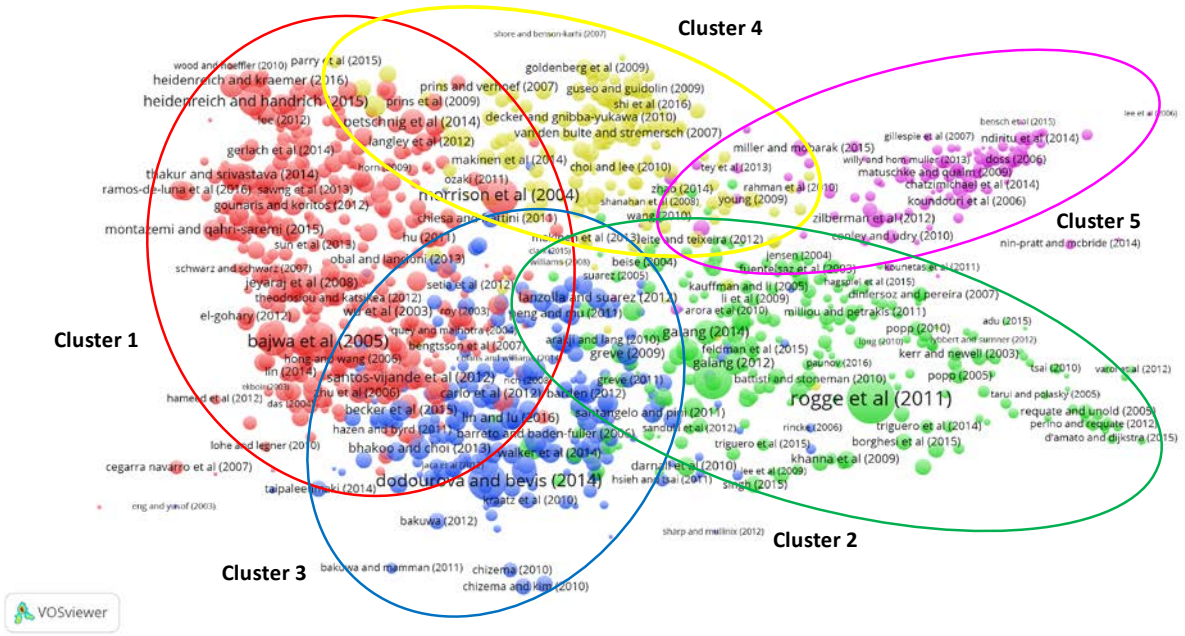


Figure 6: Bibliographic network of innovation adoption publications published between 2003 and 2016

4.1. Cluster 1: Drivers and impediments of information technology adoption

Cluster 1 includes 433 articles and captures research that we labelled: "Drivers and impediments of information technology adoption". This cluster focuses mainly on the adoption of information technology and the determinants that impede or stimulate adoption. Cluster 1 builds upon Clusters A and C, which were important theoretical cornerstones in Section 3. Moreover, the articles included in this cluster focus predominantly on the

contextual drivers and impediments of IT adoption, while Clusters A and C provide uniform models to explore the determinants of technology acceptance and adoption. Recurring IT technologies of interest include: education and E-learning; computer technology and Internet; supply chain management technology and RFID; E-commerce, mobile IT and E-business. Based on the density view it was found that Cluster 1 contains the most important part of the bibliographic network. Based on the density view two research themes were identified that are related to the drivers and impediments of IT adoption. The first theme address the an individual's intention to accept and adopt an IT innovation. In contrast, the second theme studies the acceptance and adoption of IT innovations at the organizational level.

The articles in Cluster 1 focus chiefly on the evaluation of drivers and impediments of IT adoption, which corresponds to the characteristics of Cluster C (see Section 3.3). The adoption determinants related to IT adoption can be assigned to three well-established categories of variables: technology determinants; organizational determinants, and environmental determinants [141-144]. In this respect, some refer to Tornatzky and Fleisher's [100] Technology-Organization-Environment framework [145, 146].

In contrast to Cluster C, a common feature of the articles in this cluster is that they specifically take into account the drivers and impediments of adoption associated with the distinct stages of adoption or the specific adoption context. More specifically, several publications in this cluster study the effects of a firm's environment or supply chain on subsequent stages of IT innovation adoption, including the effect of network externalities [125, 141, 147, 148]. Thus, Cluster 1 connects to the Downs and Mohr critique as discussed in section 3.3 (cluster C).

We also found a group of articles that draws on an established framework, the Technology Acceptance Model, as found in Cluster A (see Section 3.2) [149-151]. The Technology Acceptance Model and insights from the Theory of Planned Behaviour and the

Theory of Reasoned Action have been applied to research both the adoption of IT by individuals and organizations. Several authors have tried to extend or even alter the model while others have "borrowed" several adoption mechanisms from the Diffusion of Innovations, the Reasoned Action and Firm Behaviour line of debate in order to develop a more integrated model. As a result these authors integrated several innovation characteristics (compatibility, cost and perceived risk) from the Diffusion of Innovation Theory and determinants from Firm Behavioural Theory into the Technology Acceptance Model [152-155].

4.2. Cluster 2: The adoption of technological standards

Cluster 2 includes 267 articles and the research trend it represents is labelled as: "The adoption of technological standards". This cluster deals with technological change that overturns existing technological standards of which some are considered as General Purpose Technology, i.e. innovation relevant to a wide range of industries and subsequently changes modes of production and operation [156-158]. Subsequently, the key question is how these newer technological standards will be adopted as well as to what extend (depth of adoption). Cluster 2 does not build upon a particular cluster identified as a theoretical cornerstone in Section 3. The articles within this cluster primarily studied adoption (timing) of new technological standards from an econometric point of view and expressed in mathematical representations. Surprisingly, the most cited articles were located in the periphery of the cluster and, with a few exceptions, focus on technology change instruments (i.e. policies) that sustain the transition of standards.

The common thread in the first research stream derived from the articles is that they assume that technology adoption involves three decisions including [159]: 1) whether to adopt or not, 2) extend of exploiting the innovation (depth of adoption), and 3) replacement

speed of old by the new technology. Subsequently, different models have been developed to address these research questions (see Table7). Next, attempts have been made to develop a diffusion model which includes both inter-firm diffusion concerning the adoption decision as well as the intra-firm diffusion with respect to the depth of adoption and includes determinants related to rank, epidemic, stock and order effects [48, 159-163]. More precisely, these determinants include firm characteristics (including technical prerequisites and absorptive capacity), environment and industry characteristics, epidemic or learning effects and the cost and benefits of usage. It is assumed that these determinants reflect both inter and intra-firm diffusion [163].

Some scholars have assessed some of the previous aspects more specifically related to innovation diffusion. Building upon the work of Milgorm and Roberts [164, 165], Bocquet [166] emphasized that the adoption is not merely affected by traditional adoption variables but also by complementarities between organizational characteristics concerning strategies, organization and information technologies. The complementarity or supermodularity view assumes that the adoption of a new technology only contributes to organizational performance if it matches with other organizational practices. In this line of reasoning similar findings have been reported by Fabiani [157] who claims that adoption is just one comport of a complex process of change. Furthermore, it has been emphasized that complementarities between multiple technologies should be taken into account while it could affect the adoption decision of (multiple) technologies when it complements or substitutes a technology [167-169]. Next, to enable adoption, to develop complementary assets and capabilities and to benefit from innovation, organizations need to learn to adjust the organization to the innovation which it intends to adopt [170].

Table 7: Articles of Cluster 2 address the battle for dominance between two technology standards and focus on one of the five research questions.

Research question	**Model**
Whether and when to adopt?	*Real Options Model* [171, 172]
When to adopt a new network externalities technology? How to break through technology standards and speed up the diffusion of new technology standards?	*Discrete Choice Model* [173, 174]
What is the effect of time-related variables on adoption during a) the subsequent stages of individual decision making, or b) the subsequent stages of diffusion?	*Duration Analysis Model* [175, 176]
Whether and when to invest in adoption?	*Dynamic Investment Game Model* [177]
Which thresholds have to be taken into account during the diffusion of a new standard and when?	*Threshold Model* [178]

Second, with respect to the adoption of technology standards, the most cited articles in Cluster 2 focus on the effect of policy instruments on adoption and, more specifically, on the context of environmentally friendly technology. In particular, policies that stimulate the development and adoption of environmentally beneficial technology has earned considerable attention. Scholars have applied integral conceptualizations to study the effect of governmental policies on adoption by focusing on the nexus between technology and environmental policies [179-182] and on the nexus between incentive- and prescriptive-oriented policy instruments [183, 184]. Several articles address the adoption of environmental innovation at the global level, where environmental innovations diffuse internationally [185-187].

4.3. Cluster 3: Organizational rationales associated with innovation adoption

Cluster 3 includes 258 articles: the research trend it represents has been labelled as: "Organizational rationales associated with innovation adoption". Cluster 3 has a common focus on the institutionalization of management systems such as the adoption of Management Control Systems (MCS) [188], High Performance Work Organizations [189] including Lean management techniques [190] and Performance Management among sub-units within a

multinational [191]. Cluster 3 is nestled between cluster 1 and 2 in the map. From this it can be derived that while management innovations are often adopted together with or complementary to IT and technology innovation (subsequently cluster 1 and 2), these research fields are closely positioned next to each other.

Why do organizations innovate? More specifically, why do organizations decide to (or intent to) adopt and subsequently implement innovations? The articles included in cluster 3 build upon the Schumpeterian law that innovation is deemed necessary with respect to competitive advantage and economic growth. Cluster 3 in particular links organizational practices to adoption emphasizing that traditional economic factors only explain a limited proportion of the variability of innovation adoption across firms. This notion has led to the suggestion that it is necessary to consider alternative explanations building upon the organizational rationality and routines as can be found in theory about evolutionary economics and institutional change [192, 193]. Moreover, recently the work of Birkinshaw, Hamel and Mol [194] made scholars consider that management innovations enable the adoption of technological innovation as organizations need to build capabilities to do so [195, 196].

Traditional adoption research has tended to emphasize the importance of innovation characteristics, in terms of economic efficiency, on the decision-making process leading to adoption, referred to as the "pro-innovation bias" [3, 197]. Moreover, following the theoretical cornerstone of Cluster D, articles in this cluster have contributed to several "sub-theories" related to the Behavioural Theory of the Firm [33] including neo-institutional theory and the Resource-Based View. Neo-institutional scholars Barreto and Baden-Fuller [198] identified the following lacunas in the literature with respect to innovative firm behaviour: 1) who imitates whom? 2) do imitating firms distinguish between "good" and "bad" options? and 3) what is the effect of mimic isomorphism on firm performance? Barreto

and Baden-Fuller suggest that organizations apply a legitimacy-driven framework when imitating legitimacy providers, which act as “reference points” or “guides” in a complex and hostile firm environment [198]. Thus, gaining legitimacy has a substantial effect on organizational decision making. Moreover, a dualism between “pressure to conform” and “pressure to perform” can be noted, according to these authors.

Several articles build upon theoretical concepts embedded in Neo-institutional theory and have assessed the *habits* [199]; *memetics* [200]; *logic* [201]; *meaning* [202], *vision* [203], *analogies* [204], and *rationales* [205] related to innovation adoption. In addition, as witnessed in Cluster D, Abrahamson [34, 206] introduced the concept of “management fashion”, which has been further explored by Baskerville and Myers [207] and Wang [208]. Following Baskerville and Myers, management fashion is defined as *“a relatively transitory belief that a certain management technique leads rational management progress”* (p.647). From the Neo-Institutional perspective, management-setting organisations, which are by definition located outside the group of followers, shape the belief that certain management practices are rational, state-of-the-art and “the right thing to do”, and that subsequently they will be imitated by fashion followers. Addressing the innovation-diffusion perspective and, in particular, the pro-innovation bias, some organizations imitate fashionable innovations under conditions of uncertainty concerning environmental forces, organizational goals and efficiency, even when they have no utility for the imitating organization [34, 206-208].

From a Behavioural Theoretical standpoint, some studies attempted to combine several theoretical perspectives into an integrative framework. Basaglia et al. [209], for example, integrated the institutional-, management fashion-, and efficient-choice perspectives into a single theoretical model. Furthermore, Cheng [201] addressed both institutional and organizational learning theory. Massini, Lewin and Greve [210] attempted to align Behavioural Theory and Institutional Theory. Another group of scholars have drawn upon the

Resource-Based View (RBV) of organizations and considered the effect of organizational resources, social network ties and learning capabilities on adoption [211-213]. Again, these publications build upon the theoretical assumptions in Cluster D.

4.4. Cluster 4: Modelling the diffusion process

Cluster 4 includes 180 articles; the research trend it represents has been labelled as: "Modelling the diffusion process". The articles in Cluster 4 all focus on mathematical representations of the innovation-diffusion process building upon the theoretical assumptions of Cluster B. Compared to the previously discussed clusters, Cluster 4 is not related to any specific field, while the model is applicable to an evaluation of a wide variety of innovations within diverse industries and sectors. Nevertheless it was found that many articles in Cluster 4 researched the diffusion of durables and product innovations.

The bulk of articles included in Cluster 4 deal with revising the Bass Model. The Bass Model has been criticised from the outset by scholars claiming that the model is too simplistic. Adjustments and additions have been suggested such as incorporating price development and marketing indicators [214, 215]. Recent studies have further refined the Bass Model to better forecast and describe diffusion by addressing the dynamics of diffusion including the effects empowered by policies, social network structure and heterogeneity and product evolution. Moreover, research about diffusion dynamics have addressed issues about how dynamic communication networks among adopters affect knowledge distribution and related innovation adoption [216-218] and the effect of incremental improvement or evolutionary innovation [219, 220]. For example, Rahmandad and Sterman [221] discussed when to apply agent-based (AB) models and when to opt for differential equation models (DE) while modelling dynamic diffusion processes, taking into account network structure and heterogeneity (examples of both can be found in Cluster 4).

Building on the Bass Model, the authors of the highest cited articles in this cluster have focused on the effect of social contagion, referred to as "social influence" or "social learning", and the effect of social heterogeneity on diffusion [128, 130, 222-225]. For example, Van den Bulte and Stremersch's (2004, p.530) definition of social contagion refers to actors' adoption as "*a function of their exposure to other actors' knowledge, attitudes, or behaviours concerning the new product*" [130]. Moreover, viral marketing builds on the characteristics of social contagion and especially (electronic) word-of-mouth [226, 227]. De Bruyn and Lilien [227], for example, studied the role that word of mouth and the effect of social tie characteristics plays during each stage of decision making.

Other themes have been studied as well. First, several authors focused on country-specific effects on innovation adoption and on innovation spill over between countries [228-230]. Next, some scholars took into account network externality effects. Fornerino [231], for example, applied the Non-Uniform Influence (NUI) Model developed by Easingwood, Mahajan and Muller [232] to study the diffusion of the Internet in France. The NUI equations differ from the Bass equation in that it takes into account an (exponential) enhanced influence of interpersonal communication.

4.5. Cluster 5: Adoption of agricultural innovations

Cluster 5 includes 112 articles; the research trend it represents have been labelled: "Adoption of agricultural innovations". The cluster can be found in the periphery of the network close to Clusters 2 and 4 and at arm's length from Clusters 1 and 3. More precisely, it is unlikely that Cluster 5 is cited with Clusters 1 and 3. The articles in Cluster 5 address innovation adoption-diffusion from an economic theory perspective. A large set of articles in Cluster 5 consider the effect of technology adoption on economic growth and increased welfare in developing countries. In general, these technologies encompass agricultural

innovations such as fertilizers, intercropping, and the use of new (bio-engineered) seed varieties. Moreover, several articles focus on the impact of technology adoption on efforts to reduce the environmental impact of agricultural practices such as organic farming [233] and conservation tillage [234, 235]. Finally, some studies deal with innovations that reduce environmental impact and increase the economic performance of biotechnology.

An influential review often referenced in articles in Cluster 5 is the article by Feder, Just and Zilberman [21]. Several publications in Cluster 5 address Feder, Just and Zilbermann's notion of "the dynamics of adoption" [234, 236-239]. This review in particular shows how Cluster 5 relates to Cluster 4. In line with this review, a distinction can be made between adoption studies modelling the adoption of an innovation at a specific point in time and diffusion studies that model the cumulative dissemination of an innovation. Following Davies [240], the criticism has been made that many adoption models depend on cross-sectional data and neglect the impact of time-dependent determinants such as price variation over time. To address this critique, several scholars in this cluster used Duration Analysis (historically used to model epidemiological phenomena) including both cross-sectional and time-series determinants [236].

Several dimensions of adoption dynamics have been addressed, such as the importance of learning, information acquisition, and personal perceptions that effect change over time because its inherent value changes [234]. Some authors implicitly address the adoption dynamics bias. For example, Conley and Udry [241], the most cited article in Cluster 5, developed a model that takes into account the role of social learning in the diffusion of new agricultural technology – an approach that is closely related to the social contagion concept (see Cluster 4). Others have focused on the determinants that lead to "disadoption", i.e. discontinuance or abandonment, which is considered to be another dynamic dimension [237-239]. Some methodological issues related to this line of debate have

been addressed by Diagne and Demont [242] and Doss [243]. Diagne and Demond [242] address two types of bias related to commonly used adoption rates estimators, and Doss [243] conducted an extensive literature review suggesting alternative approaches to designing technology adoption studies, referred to as the second generation of agricultural innovation diffusion research.

4.6. Relative importance of bibliographic-coupled clusters

Table 6 presents some citation-based statistics to assess the relative importance of the five clusters identified. Table 8 shows that Cluster 1 received the most citations per article by far, in contrast to Cluster 3 which seems to be a less popular research trend. The conclusion holds if one controls for the number of publications per cluster or for the average number of citations per article per year. Thus, Cluster 1 on the "Drivers and impediments of information technology (IT) adoption" can be pinpointed as the most cited cluster, with Cluster 2 ("The adoption of technological standards") having an average impact.

Figure 7 shows the number of publications per cluster from 2003 to 2016. Cluster 2, 3 and 4 have trend lines with both peaks and saddles. Cluster 5, the smallest cluster with a relative low impact, shows a relatively stable pattern. Cluster 1 shows a steady grow of articles per year up till 2010. After 2010 this research trend seems to lose the interest of scholars with a drop in the number of publications. In general, the total number of articles published per year in the field of innovation adoption dropped in 2013 after which the number publications increased again on a yearly bases (for the year 2016, from January to October about 80 scientific articles have been published).

Table 8: Indicators of publication output and citation impact per thematic cluster

Cluster	Number of articles	Average age	Total number of citations	Average number of citations/ article	Average number of citations/ article/year
1	432	4,88	5028	11,64	2,39
2	267	5,03	2332	8,73	1,74
3	258	3,93	1311	5,08	1,29
4	180	4,68	1405	7,81	1,67
5	113	5,42	860	7,61	1,41
Total	1250	4,70	10936	8,75	1,86

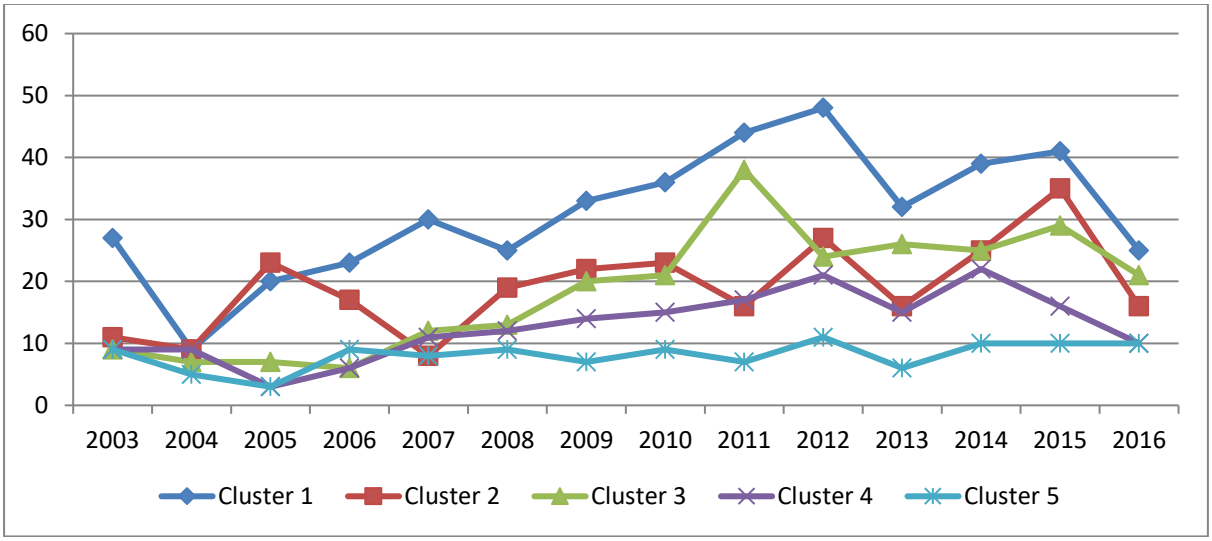


Figure 7: Number of publications per year per cluster.

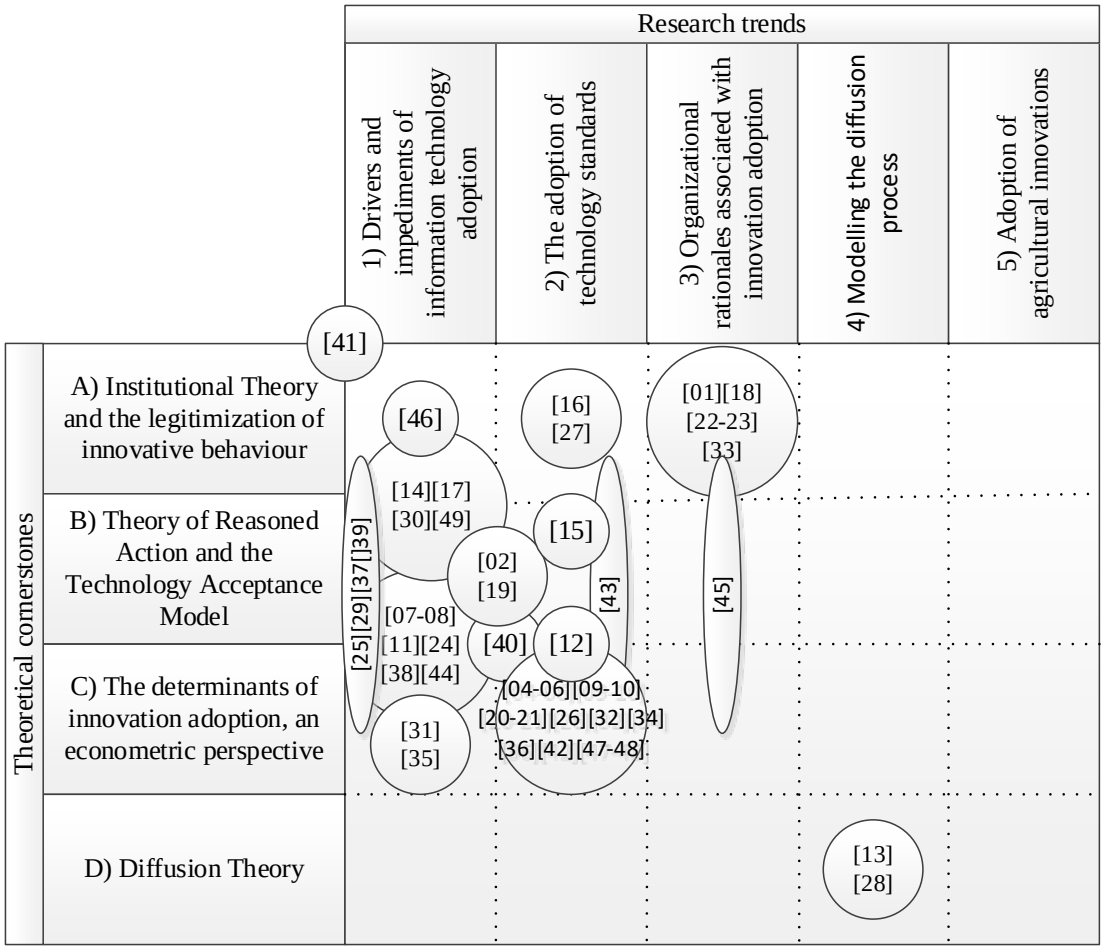
One could wonder how this bibliometric study confirm or dispel from previous reviews of the innovation adoption literature. Therefore we compared the findings with innovation adoption reviews which are published in the period 2013-2017. By consulting the WoS database we identified 1 bibliometric review, 2 scoping reviews, 4 meta-analyses, and 42 systematic, qualitative reviews. After close examination of the theoretical concepts and field of study, three observations were made. First, we found that 13 reviews could not be linked to a particular theoretical framework, i.e. these reviews aim at providing an overview of the variables affecting the adoption-diffusion of innovation. Second, out of these 49 studies, 34 articles include one or several theoretical frameworks linked to the adoption of innovation within a specific field. Finally, 47 reviews could be linked to the adoption of innovation within specific fields: health care (11); eco-innovation and agriculture (16); information and

communication technology (9); business economics and new product introduction (11). In line with Wong et al. (2010) and Wisdom et al. (2014) we consider these reviews as efforts to constitute 'middle-range theories' of innovation adoption [244, 245].

Next, the 2 remaining reviews which we identified could not be linked to a specific research field (i.e.[246, 247]). Kapoor et al. (2014) reviewed Rogers' innovation adoption attributes in order to develop a guideline to the ideal innovation-attribute studies. Sriwannawit and Sandström (2015) conducted a bibliometric analysis of innovation diffusion literature and identified 13 clusters, comprising 6,811 publications over the period of 2002–2011. The main difference with our bibliometric review encompass the distinction between theoretical cornerstones and recent research trends in innovation adoption research, i.e. some of the clusters identified by Sriwannawit and Sandström are considered as theoretical cornerstones in this review rather than current research trends. In our study we applied two distinct bibliometric approaches to distinct between theoretical cornerstones and research trends which are subsequently explicitly linked to each other.

Based on the theoretical concepts and field of study we cross referenced the 48 reviews with the theoretical cornerstones and research trends identified in this bibliometric study. Therefore we constructed the framework as illustrated in figure 7. This analysis shows that the theoretical cornerstones and research trends identified are robust while we were also able to cross reference the review articles with our bibliographic study. While most of the identified reviews are considered middle-range theories of innovation adoption, this framework contributes by organizing the middle-range theories of innovation adoption. A parallel contribution of our bibliometric study is that it confirms that previous, mostly qualitative reviews, contribute to 'disentangle the forest of scientific publications' about innovation adoption. In line with previously conducted bibliometric studies [10, 11], both

type of reviews are valuable and complementary and therefore this bibliometric study may also be used to validate previous interpretations.



[01]	Aarikka-Stenroos et al. (2014) [248]	[18]	Innes et al. (2015) [249]	[35]	Radu (2016) [250]
[02]	Adnan et al. (2017a-b-c) [251-253]	[19]	Kapoor et al. (2014) [246]	[36]	Rahbauer et al. (2016) [254]
[03]	Allen et al. (2017) [255]	[20]	Karakaya & Sriwannawit (2015) [256]	[37]	Rana et al. (2015) [257]
[04]	Bossle et al. (2016) [258]	[21]	Karakaya et al. (2014) [259]	[38]	Rezvani et al. (2015) [260]
[05]	Byambaa et al. (2015) [261]	[22]	Kelly et al. (2017) [262]	[39]	Sanakulov & Karjaluoto (2015) [263]
[06]	Candas et al. (2016) [264]	[23]	Khanassov et al. (2014) [265]	[40]	Sovacool and Hess (2017) [266]
[07]	Cresswell and Sheikh (2013) [267]	[24]	Khong et al. (2015) [268]	[41]	Sriwannawit & Sandström (2015) [247]
[08]	De Grood et al. (2016) [269]	[25]	Kruse et al. (2014) [270]	[42]	Tayouga and Gagne (2016) [271]
[09]	Ellabban & Abu-Rub (2016) [272]	[26]	Lefebvre et al. (2015) [273]	[43]	Varabyova et al. (2017) [274]
[10]	Estem et al. (2016) [275]	[27]	Lyle (2015) [276]	[44]	Williams et al. (2015) [277]
[11]	Gagnon et al. (2015) [278]	[28]	Moglia et al. (2017) [279]	[45]	Wisdom et al. (2014) [245]
[12]	Gangwar et al. (2013) [280]	[29]	Molinillo & Japutra (2017) [281]	[46]	Wu (2016) [282]
[13]	Goodwin et al. (2014) [283]	[30]	Montazemi & Qahri-Saremi (2015) [284]	[47]	Yeatts et al. (2017) [285]
[14]	Hanafizadeh (2013) [286]	[31]	Mwirigi et al. (2014) [287]	[48]	Zanello et al. (2016) [288]
[15]	Hasler et al. (2017) [289]	[32]	Nejad et al. (2014) [290]	[49]	Zhang et al. (2014) [291]
[16]	Hojnik & Ruzzier (2016) [292]	[33]	Novins et al. (2013) [293]		
[17]	Ingebrigtsen et al. (2014) [294]	[34]	Ortiz et al. (2017) [295]		

Figure 7: Cross reference of 49 recently published reviews with the theoretical cornerstones and research trends of innovation adoption research

5. SUMMARY, FUTURE RESEARCH AND LIMITATIONS

5.1. Summary

In the previous sections, we presented a novel, systematic and comprehensive review of the bibliographic literature (including 1260 articles) to identify the theoretical cornerstones and research trends in innovation adoption research. This study complements existing reviews in various ways. First, based on co-citation analysis, we illustrate that innovation adoption research is built on four theoretical cornerstones (or in terms of bibliographic clustering, four clusters of prior publications): A) Institutional Theory and the legitimization of innovative behaviour; B) Theory of Reasoned Action and the Technology Acceptance Model; C) The determinants of innovation adoption, an econometric perspective; and D) Diffusion Theory.

Second, bibliographic coupling was used to assess the current research trends in the innovation adoption literature. This review is the first to identify thematic areas in an exhaustive manner. The bibliographic coupling technique revealed five clusters of thematic related publications or "research trends": 1) Drivers and impediments of information technology adoption; 2) The adoption of technological standards; 3) Organizational rationales associated with innovation adoption; 4) Modelling the diffusion process and; 5) Adoption of agricultural innovations. Within the bibliographic network, one of the clusters, Cluster 5, can be found in the periphery of the structure. It appears that Cluster 5 cannot be regarded as a mainstream thematic area as it is so closely related to Clusters 2 and 4.

Third, we were able to construct a coherent framework to assess the relevance of innovation adoption research by integrating the theoretical cornerstones and the current research trends. As a parallel contribution we found that previous conducted overview studies

contributed to a coherent understanding of innovation adoption in specific fields and are bound together by the present bibliometric study.

5.2. Future research

In this section we present several important areas in the field of innovation adoption and diffusion that merit future research.

The development of more holistic theoretical explanations in the field of innovation adoption and diffusion. This bibliometric review revealed that adoption and diffusion research is highly segregated. Researchers mostly build upon conceptualizations related to a single research stream, which are often applied to explain the adoption of specific innovations within a single context. To create more holistic theoretical explanations of innovation adoption and diffusion, we would encourage future studies to investigate the adoption and diffusion mechanisms related to specific innovations across different contexts.

Detailed investigations of the distinguished research streams. The identified research streams include up to 400 articles, and thus encompass multiple theoretical concepts, which could be subject to fine grained content analysis [296]. Every single research stream encompasses multiple articles which could be assessed by applying bibliometric and text mining techniques as has been demonstrated by Randhawa et al. [9] in their literature review about open innovation and which includes 321 journal articles about open innovation.

Exploration of the explanatory power of psychological and organizational theories.

Despite the maturity of the field of innovation adoption research we suggest to further explore other theoretical perspectives used in e.g. management, marketing and organization behaviour which have not received much attention yet in the field of innovation adoption research. Doing so can help to further advance our understanding of innovation adoption. As a first example, while adoption involves decision-making, we expected that cognitive

processes underlying human thought, knowledge and decision-making would hold a more prominent position in innovation adoption research. Theoretical concepts such as prospect theory [248-250], bounded rationality [252] and stakeholder theory [253] may help to understand which heuristics decision makers apply when considering the adoption of a specific innovation.

A second example of an underused theory concerns the innovation systems theory. This theory emphasizes that innovation systems should be considered as an important determinant of transition and change within an industry sector [297]. Innovation system research builds on the notion that (technological) niche innovations alone are not enough to sustain change but require subsequent innovations in the social domain to pave the way. Innovation and change in the social domain shape user practices, regulation and standards, and industry networks which create technological transition and socio-technical transformation [298].

An empirical lens to identify white spots in innovation adoption literature. Given the growing importance and attention in the last decade for service innovation research, we would also expect an increased stream of research about the potential adoption of service innovations. With a focus on the potential adoption of IT Innovations, Cluster 1 addresses an important, yet only limited subset of potential research in the adoption of service innovations. Also the question how IT as an enabler could stimulate the adoption of new products and services, still remains unanswered. While Cluster 2 and 3 reveal the results of research on the enabling effects of complementary innovations and (organizational) capabilities, research on the enabling effect of IT on the adoption of innovations may still be considered as a white spot in literature. A final suggestion for future research is related to the use of modularity principles and the application of product and process platforms in the industry. While we observe a substantial increase of research in this field, literature about the adoption dynamics

and the mechanisms which drive the adoption and diffusion of module and platforms based innovations are still limited.

5.3. Limitations

Through the use of a bibliometric review methodology, this study reduced the bias that is often associated with expert surveys and traditional reviews [9]. Nevertheless, a limitation of this review is the direct consequence of the application of a bibliometric review methodology. Despite its advantages to overcome bias, bibliometric analyses cannot replace, rather merely complement, extensive reading and fine-grained content analyses [296, 299]. Based on 1260 journal articles referring to almost 46,000 publications, it is hardly possible to extensively discuss all the (middle range) theoretical concepts revealed by all these articles. Therefore, this review is limited to the identification of the theoretical cornerstones and main research trends in the field of innovation adoption, acceptance and diffusion.

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