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A BIBLIOMETRIC STUDY ON THE EVOLUTION OF CONJOINT ANALYSIS IN 1998-2017

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Abstract *When a technique or a research issue has reached a certain maturity, it is essential for the scientific community to assess its state of the art. Conjoint Analysis (CA), although defined as a market research technique, has been widely used in several domains. The most significant reviews on CA offered partial outlines about its use and its theoretical developments. In this paper, we aim at providing an overall framework of the past two decades of CA through a bibliometric analysis of the reference literature.*

Keywords: *Conjoint Analysis, Bibliometrics, Science Mapping.*

1. INTRODUCTION

Conjoint analysis (CA) is often defined as a market research technique, even if its origins lie in the psychrometers' theoretical debate on measurement scales of the early '60s, starting from the work of Luce and Tukey (1964). It is interesting to note that in a research report of F.W. Young dating 1969, *Polynomial Conjoint Analysis of Similarities: a Model for Constructing Polynomial Conjoint Measurement Algorithms*, a computational model was provided even before delineating CA as a proper methodology. In the same year, J.D. Carroll presented a contribution called *Categorical Conjoint Measurement*, at the Meeting of Mathematical Psychology in Ann Arbor (Michigan, USA). CA appears officially in 1971, with the publication of *Conjoint measurement for quantifying judgment data* by P.E. Green and V.R. Rao in the Journal of Marketing Research. In this paper, the authors drew upon the conjoint measurement theory adapting it to the solution of marketing problems. A publication by Green and Rao followed in 1972, and two more by Green with F.J. Carmone and Y. Wind appeared in 1972 and 1973, making together the history of CA. In these papers, the interest from a statistical point of view was related to the study of proximity data and mainly addressed in the context of multidimensional scaling techniques.

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Marketing studies represented the first and most important applicative field. In this framework, the contribution of CA in decomposing consumer preferences into partial contributions of product features can be considered extremely innovative, not only for explaining the preferences of existing products but also for simulating the preferences of new products. CA can be seen as one of many tools useful to handle situations in which a decision maker has to deal with options that simultaneously vary across two or more attributes. It was necessary to wait mid-'70s to see CA in other application areas, ranging from trading to health, from agriculture to food industry. CA methods were useful to quantify preferences for non-market goods and services, or where market choices were severely constrained by regulatory and institutional factors. This is particularly true in the healthcare sphere, where the contribution of CA became strategic during the years for quantifying patients' relative preferences concerning costs, risk of complications, and healthcare service locations. Since the introduction of a classical metric CA model, a lot of new models and parameter estimation procedures were proposed (for a recent review of the developments in CA see Agarwal et al., 2015). In the '80s, choice-based and hybrid conjoint were introduced, including the adaptive conjoint models. A proposal of re-estimating the part-worths with hierarchical Bayesian models and latent class approaches dating back to the '90s. A factorial approach to CA was developed starting from the end of '90s (Lauro et al., 1998).

When a technique or a research topic has reached a certain maturity, it is essential for the scientific community to assess its state of the art. The evaluation of research issues and streams helps scientists to highlight the trends in the reference literature and the still open challenges. The most significant reviews on CA offered partial outlines about its use and its theoretical developments, by specifically focusing on a given research area (e.g. Alriksson and Öberg, 2008; Moskowitz and Silcher, 2006). In this paper, we aim at providing an overall framework of the last 20 years of literature about CA and its applicative domains. In particular, we decided to follow a bibliometric approach.

2. A BRIEF REVIEW ON BIBLIOMETRICS

Bibliometrics allows investigating the written scientific production of a given domain from a statistical point of view. Considerable interest has been devoted in last years to the quantitative study of the literature, thanks to the availability of online databases and resources (e.g. Web of Science, Scopus, Google Scholar), together with the development of effective techniques for performing automatic analyses. The key procedures commonly implemented in bibliometric studies are

the *performance analysis* (Peters and van Raan, 1991; White and McCain, 1998) and the *science mapping* (Börner et al., 2003; Noyons et al., 1999). The first one aims at evaluating the literature on the basis of bibliographic data, by measuring institutions and authors productivity and estimating the impact of the different actors in the given domain. The second one, science mapping, tries to highlight the structural and cognitive patterns of the domain, by visualising topics and findings with a synchronic (Callon et al., 1983; Noyons and van Raan, 1998) or a diachronic perspective (Cobo et al., 2011; Garfield, 1994). Mapping techniques frequently refer to textual data analysis. Each domain or topic can be characterised by a set of keywords, assigned by the authors of the publications or by the citation indexes. Starting from this keyword set, it is possible to build a co-occurrence matrix to represent the collection of publications. Network tools can be then used to visualise and analyse the knowledge base.

In an unpublished study of Giordano and Infante (2002), a lexical correspondence analysis on the 1970-2004 publications listed in the University of Naples Federico II and University of Salerno library catalogues was performed. Teichert and Shehu (2010), carried on a bibliometric analysis on a more extended temporal interval (1960-2006) but considering only a factorial co-citation analysis of the most cited publications listed in the ISI Social Science Citation Index. Here in the following a performance analysis and a thematic analysis over the past 20 years of literature about CA is presented and discussed.

3. TWENTY YEARS OF CONJOINT ANALYSIS

To collect the publications about CA of the past 20 years, on April 18^{th} 2018 we queried the *Web of Science* (WoS) indexing database[1], founded by the Institute for Scientific Information and now maintained by Clarivate Analytics. We searched for the term "conjoint analysis", obtaining 3522 entries. Limiting the study to the period 1998–2017, we excluded the entries published before 1998. It is important to say, however, that WoS indices only the publications that appeared after 1985. We selected original articles, review articles, book chapters and proceedings published in English. In this way, our collection reduced to 2963 entries. To consider only the most important domains, we decided to analyse only the publications belonging to the first 15 research areas in terms of number of entries (Table 1). It is important to note that the research area category in WoS is not exclusive, hence a publication may belong to more than one category at the same time.

[1] `http://www.wokinfo.com`

Tab.1: Top fifteen Research Areas

Research Areas	Publications
BUSINESS ECONOMICS	972
ENGINEERING	400
HEALTH CARE SCIENCES SERVICES	337
COMPUTER SCIENCE	252
FOOD SCIENCE TECHNOLOGY	237
OPERATIONS RESEARCH MANAGEMENT SCIENCE	202
AGRICULTURE	190
ENVIRONMENTAL SCIENCES ECOLOGY	185
PUBLIC ENVIRONMENTAL OCCUPATIONAL HEALTH	130
SOCIAL SCIENCES – OTHER TOPICS	112
PSYCHOLOGY	90
GENERAL INTERNAL MEDICINE	84
MATHEMATICS	81
SCIENCE TECHNOLOGY – OTHER TOPICS	69
TRANSPORTATION	60

The resulting collection included 2459 publications. The performance analysis was carried out with the R package *bibliometrix* (Aria and Cuccurullo, 2017), whereas the thematic analysis was performed with the free software *SciMat* (Cobo et al., 2012). In Table 2, the main descriptive information and statistics about the collection are reported.

Tab. 2: Main information about the collection

Period	1998–2017
Documents	2459
Sources (Journals, Books, etc.)	991
Authors' Keywords (DE)	5437
WoS Keywords (ID)	4159
Average citations per documents	17.43
Authors	5737
Author Appearances	8397
Authors of single authored documents	111
Authors of multi authored documents	5626
Documents per Author	0.43
Authors per Document	2.33
Co-Authors per Documents	3.41
Collaboration Index	2.50

The publications showed an average citation of 17.43 in the period from 1998 to 2017, and were written by about 5737 authors with a mean of 0.43 publication per author, in 991 different sources. It is interesting to note that only the 4.5% of the

publications was written by a single author. The annual percentage growth rate was 11.48, showing a linear growth rate (Figure 1).

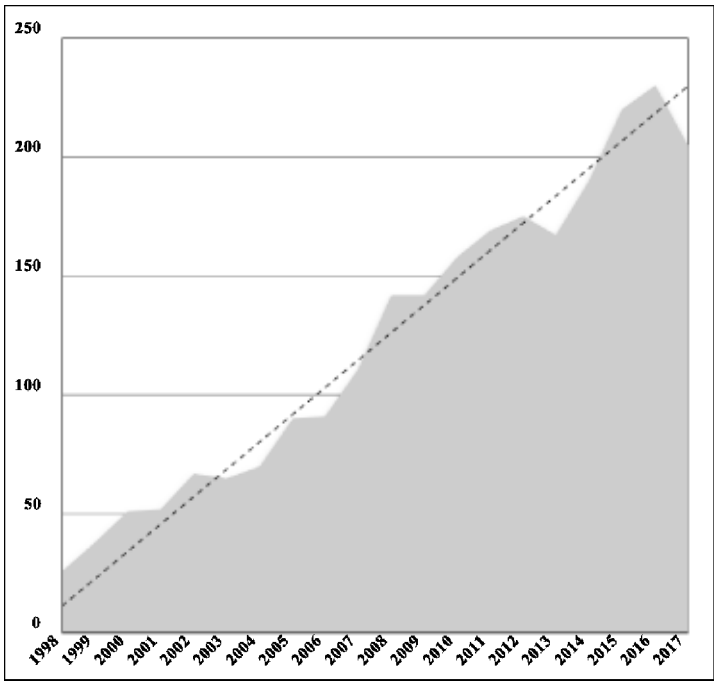

Fig. 1:Year-wise distribution of the 2459 retrieved publications

In Table 3, the most relevant journals in terms of number of published articles are reported. The standard competition ranking (SCR) was considered. If the measurements of bibliometric analysis had the same ranking number, then a gap was left in the subsequent ranking numbers. The first journal was *Food Quality and Preferences*, followed by *Patient-patient centered outcomes Research*, *Value in Health* and *Journal of Sensory Studies*, showing that in the last 20 years there was a large use of CA in the fields of Food industry and Health.

3.1 COUNTRIES / INSTITUTIONS PRODUCTIVITY AND COLLABORATION

The most productive country[2] in the CA research domain was the USA (Table 4). This leadership was reached both in terms of total number of publications (TP) and total number of citations (TC). The most important country in Europe for TP were Germany (SCR=2), the Netherlands (SCR=3) and England (SCR=4).

[2] Note that each country was selected on the basis on the first author of the publications.

Tab. 3: Top ten most relevant journals

SCR	Source	Publications	%
1^{st}	FOOD QUALITY AND PREFERENCE	72	2.93
2^{nd}	PATIENT-PATIENT CENTERED OUTCOMES RESEARCH	50	2.03
3^{rd}	VALUE IN HEALTH	44	1.79
4^{th}	JOURNAL OF SENSORY STUDIES	41	1.67
5^{th}	MARKETING SCIENCE	40	1.63
6^{th}	JOURNAL OF MARKETING RESEARCH	38	1.55
7^{th}	HEALTH ECONOMICS	35	1.42
8^{th}	PHARMACOECONOMICS	27	1.10
9^{th}	EUROPEAN JOURNAL OF OPERATIONAL RESEARCH	25	1.02
9^{th}	PLOS ONE	25	1.02

About the 17% of publications in the analysed collection was produced in these three countries. Interestingly, apart England, all the leading countries showed a higher single-country collaboration (SCC) with respect to a multiple-country collaboration (MCC), revealing that there is a lower propensity in an inter-country scientific collaboration.

Tab. 4: Top ten most productive countries

SCR by TP	Country	TP	%	SCC	MCC	SCR by TC	Country	TC	MCP
1^{st}	USA	757	31.35	591	166	1^{st}	USA	18278	24.14
2^{nd}	GERMANY	173	7.16	142	31	2^{nd}	ENGLAND	3107	28.24
3^{rd}	NETHERLANDS	128	5.30	81	47	3^{rd}	SCOTLAND	2558	63.95
4^{th}	ENGLAND	110	4.55	59	51	4^{th}	NETHERLANDS	1995	15.59
5^{th}	CHINA	106	4.39	78	28	5^{th}	CANADA	1814	22.12
6^{th}	AUSTRALIA	92	3.81	51	41	6^{th}	GERMANY	1533	8.86
7^{th}	KOREA	88	3.64	78	10	7^{th}	AUSTRALIA	1464	15.91
8^{th}	CANADA	82	3.40	51	31	8^{th}	SWITZERLAND	1036	19.55
9^{th}	SPAIN	74	3.06	62	12	9^{th}	SPAIN	987	13.34
10^{th}	JAPAN	71	2.94	66	5	10^{th}	KOREA	955	10.85

A wider overview of collaboration among countries is showed in Figure 2. Looking at the TC, the most productive countries after the USA were England, Scotland and the Netherlands. It is interesting to note that Scotland reported the highest mean citations per publication (MCP), reaching a value of 63.95 citations.

In Table 5 the most productive institutions are showed. According to the previously reported results, it is trivial to note that US institutions leaded the CA research. Surprisingly, the second and third position were reached by a Scottish and a South-Korean University (*University of Aberdeen* and *Seoul National University*, respectively). In Figure 3, it is possible to see the collaboration network among the leading institutions. We noted a singleton community for the *Seoul National University* and three different communities. The prevailing institutions in

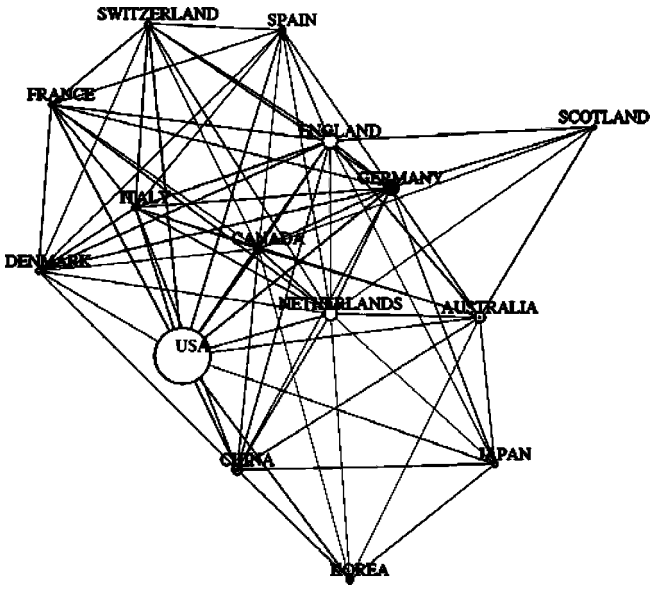

Fig. 2: Countries collaboration network

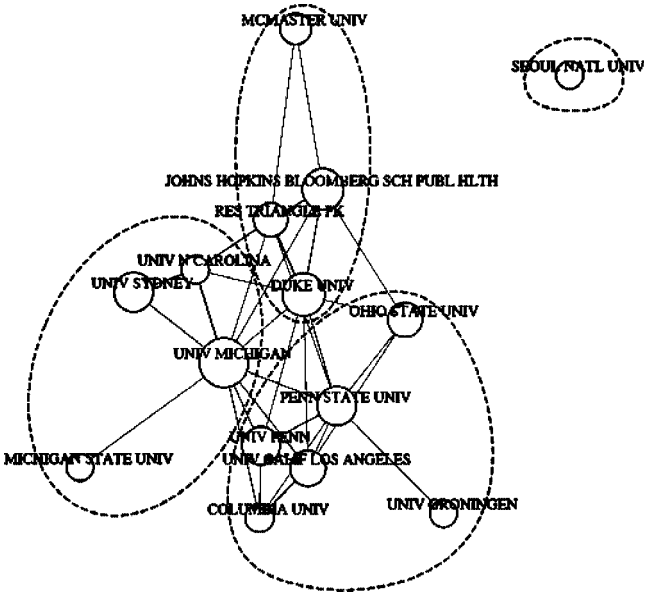

Fig. 3: Institustios collaboration network

Tab. 5: Top ten most productive institutions

SCR	Institution	TP	%	Country
1st	PENNSTATE UNIVERSITY	26	1.04	USA
2nd	UNIVERSITY OF ABERDEEN	23	0.92	SCOTLAND
3rd	SEOUL NATIONAL UNIVERSITY	21	0.84	KOREA
3rd	JOHNS HOPKINS BLOOMBERG SCHOOL OF PUBLIC HEALTH	21	0.84	USA
4th	UNIVERSITY OF MICHIGAN	20	0.80	USA
4th	UNIVERSITY OF ILLINOIS	20	0.80	USA
5th	UNIVERSITY OF SYDNEY	18	0.72	AUSTRALIA
5th	UNIVERSITY OF PENNSYLVANIA	18	0.72	USA
5th	RESEARCH TRIANGLE PARK	18	0.72	USA
5th	CARNEGIE MELLON UNIVERSITY	18	0.72	USA

these communities were from the USA (*Pennstate University*, *University of Michigan* and *Johns Hopkins Bloomberg School of Public Health*). There was mainly a collaboration with other US institutions but also a limited connection with institutions of other countries (*University of Groningen* from the Netherlands, *University of Sidney* from Australia, *McMaster University* from Canada, respectively).

3.2. HIGHLY CONTRIBUTIVE AUTHORS, PUBLICATIONS AND CITATIONS

In Table 6, it is possible to see the most productive authors in 1998–2017.

Tab. 6: Top ten most productive authors

SCR	Author	Publications	SCR	Author	Fractionalised Publications
1st	JOHNSON F.R.	43	**1**st	JOHNSON F.R.	11.27
2nd	BRIDGES J.F.P.	34	**2**nd	RYAN M.	9.35
3rd	HAUBER A.B.	27	**3**rd	SHEPHERD D.A.	7.17
4th	RYAN M.	23	**4**th	BRIDGES J.F.P.	6.59
5th	LEE J.	21	**5**th	BAIER D.	6.25
6th	MOHAMED A.F.	19	**6**th	LEE J.	6.22
7th	NAES T.	18	**7**th	MOSKOWITZ H.R.	5.82
8th	MOSKOWITZ H.R.	17	**8**th	HAUSER J.R.	5.76
9th	BEHE B.K.	16	**9**th	CAGAN J.	5.25
9th	RATCLIFFE J.	16	**10**th	RATCLIFFE J.	5.21

The first was JOHNSON with 43 publications, followed by BRIDGES with 34 publications, and HAUBER with 27 publications. Looking at the fractionalised publications, the ranking of the most productive authors changes. Fractionalise means to give to each author an equal part of one publication: for instance, if a publication has five authors, for each author a 0.2 value is counted for that publication.The first most productive author was again JOHNSON with a value of 11.27, followed by RYAN (9.35) and SHEPHERD (7.17).

In Figure 4, it is possible to see the co-authorship network. We noted three

singleton communities, RYAN, LEE and BEHE, and three closely linked communities with 3,4 and 5 authors respectively. The authors of the three-nodes community including NAES, GRUNERT and SCHNETTLER, comes from Northern-Europe. The four-nodes community, with JOHNSON, HAUBER, BRIDGES and MOHAMED, refers to the most productive authors. The five-nodes community, with CHEN, RATCLIFFE, CUNNINGHAM, RIMAS, and DEAL, represents the Canadian academic community working on CA.

Tab. 7: Top ten most cited publications included in the colletion

Publication	Type	TC	TC per year
Ryan, M. and Farrar, S. (2000). Using conjoint analysis to elicit preferences for health care. In *BMJ: British Medical Journal, 320(7248)*: 1530.	ARTICLE	448	24.9
Hauser, J., Tellis, G.J. and Griffin, A. (2006). Research on innovation: A review and agenda for marketing science. In *Marketing Science*, 25(6): 687–717.	REVIEW	382	31.8
Bridges, J.F., Hauber, A.B., Marshall, D., Lloyd, A., Prosser, L.A., Regier, D.A. and Mauskopf, J. (2011). Conjoint analysis applications in health – a checklist: a report of the ISPOR Good Research Practices for Conjoint Analysis Task Force. In *Value in health*, 14(4), 403–413.	ARTICLE	361	51.6
Lancsar, E. and Louviere, J. (2008). Conducting discrete choice experiments to inform healthcare decision making. In *Pharmacoeconomics*, 26(8): 661–677.	REVIEW	344	34.4
De Pelsmacker, P., Driesen, L. and Rayp, G. (2005). Do consumers care about ethics? Willingness to pay for fair-trade coffee. In *Journal of Consumer Affairs*, 39(2): 363–385.	ARTICLE	341	26.2
Hanley, N., Mourato, S. and Wright, R.E. (2001). Choice modelling approaches: a superior alternative for environmental valuation? In *Journal of Economic Surveys*, 15(3): 435–462.	ARTICLE	337	19.8
Frank, L.D., Saelens, B.E., Powell, K.E. and Chapman, J.E. (2007). Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? In *Social Science & Medicine*, 65(9): 1898–1914.	ARTICLE	303	27.5
de Bekker-Grob, E.W., Ryan, M. and Gerard, K. (2012). Discrete choice experiments in health economics: a review of the literature. In *Health Economics*, 21(2): 145–172.	ARTICLE	296	49.3
Simpson, T.W. (2004). Product platform design and customization: Status and promise. In *Ai Edam*, 18(1): 3–20.	REVIEW	291	20.8
Lusk, J.L. and Schroeder, T.C. (2004). Are choice experiments incentive compatible? A test with quality differentiated beef steaks. In *American Journal of Agricultural Economics*, 86(2): 467–482.	ARTICLE	260	18.6

In Table 7, the most cited publications produced in the period 1998–2017 are shown. It is interesting to note that there were three review and seven original articles in the top ten. The first was Ryan and Farrar (2000) with 448 TC, followed by Hauser et al. (2006) with 382 TC and Bridges et al. (2011) with 361 TC. This latter has the highest number of citation per year in the interval 1998–2017 (51.6), followed by de Bekker-Grob et al. (2012), with 49.3 citations per year.

In Figure 5, it is possible to visualise the historiograph network of the publications listed in the collection (Garfield, 2004). We noted that the milestones in the CA literature of the past 20 years were the publications of Bryan (1998), Ryan (1998; 1999) and Green (2001). The first references concerned the health domain and were used in an applicative perspective, where instead the work of Green were considered in the framework of methodological developments.

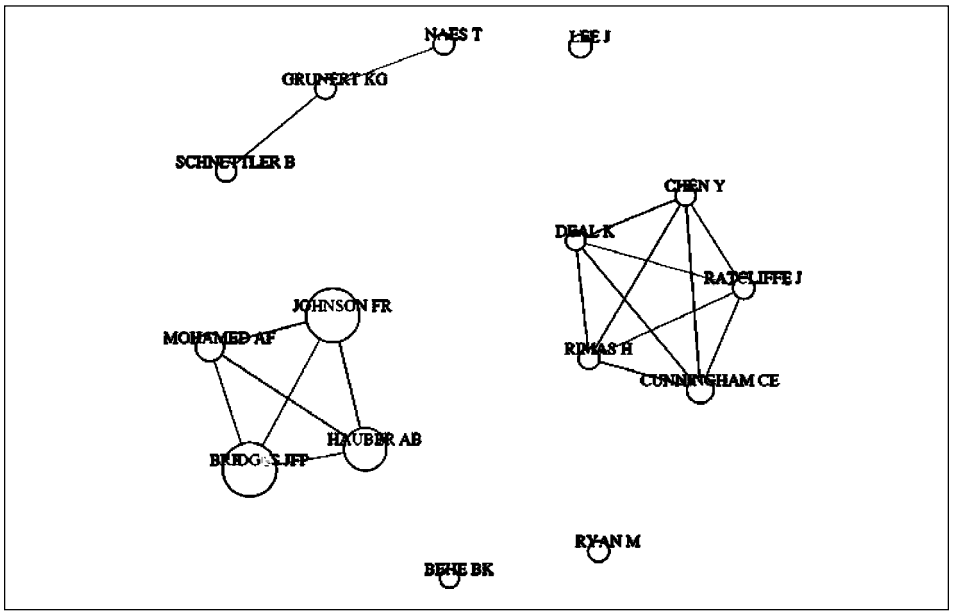

Fig. 4: Co-authorship network

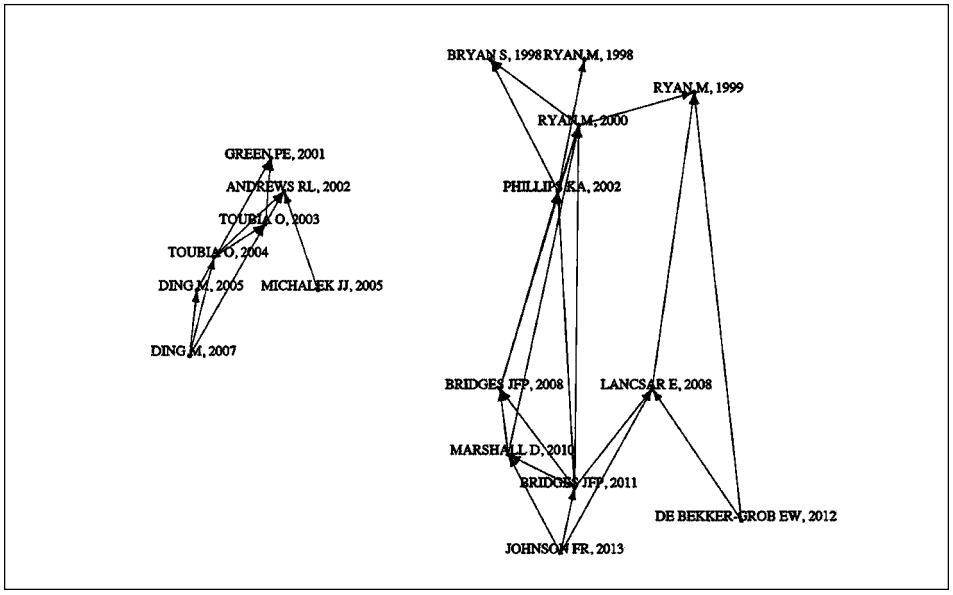

Fig. 5: Historiograph network

The co-citation network is showed in Figure 6. Differently from the results reported in Table 7, the global citations were considered. Two communities of references can be highlighted in the network. On the left, the role of Green in the history of CA clearly emerges, considering the large application of these techniques to market research. On the right, there are several important authors working on CA methodological development (e.g. McFadden, Louviere), and the applications in the health area are considered.

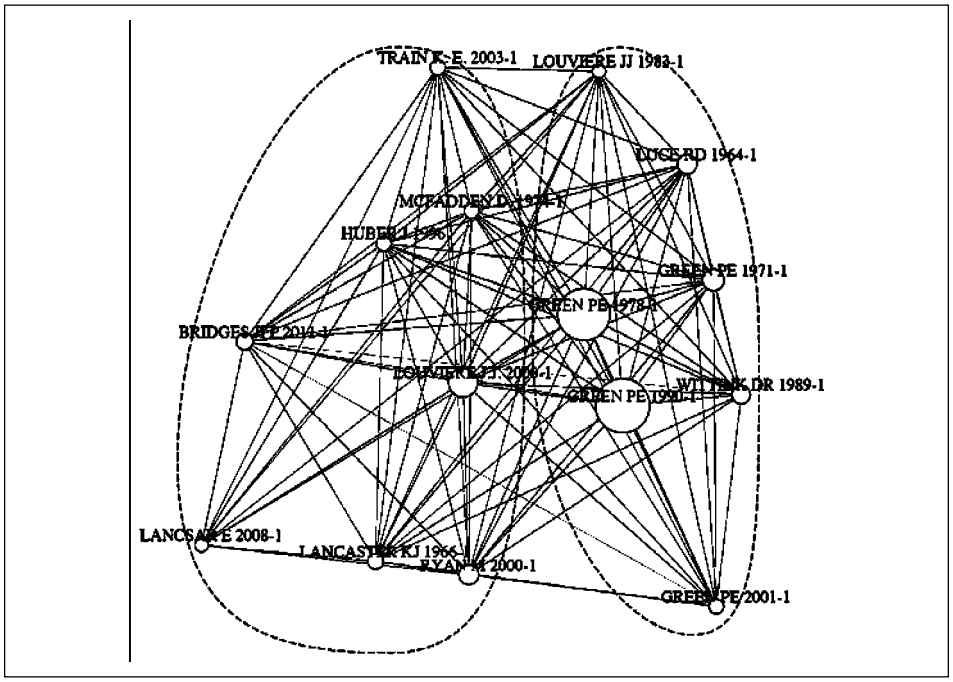

Fig. 6: Co-citation network

3.3 THEMATIC ANALYSIS AND EVOLUTION OF THEMES

In order to highlight the main research issues on CA, we decided to divide our temporal interval into four subperiods of 5 years (1998–2002, 234 publications; 2003–2007, 427 publications; 2008–2012, 786 publications; 2013–2017, 1012 publications). A normalisation of the keywords was considered in order to avoid the trivial duplications. Moreover, a minimum threshold of 3 was imposed to filter the most unfrequent keywords. We built a co-occurrence matrix of the selected

keywords, in which each cell outside the principal diagonal contains the similarity of two keywords in terms of *equivalence* (Callon et al., 1991):

$$eqv_{ij} = \frac{n_{ij}^2}{n_i \times n_j} \tag{1}$$

with n_{ij} as number of publications in which two keywords i and j co-occur, n_i and n_j number of publications in which each one appears. This measure assumes values in the interval [0;1] and evaluates how much two keywords are associated.

The co-occurrence matrices can be seen as adjacency matrices and graphically visualised as an undirected weighted networks. On each subperiod co-occurrence matrix, we performed a cluster analysis based on the *simple centre algorithm* (Coulter et al., 1998). This analysis allowed finding subgroups of strongly linked keywords, where each subgroup corresponds to a centre of interest or to a given research issue. Once the analysis is carried on, it is possible to plot the results in a so called *strategic diagram* according to the centrality c_t and the density d_t of each cluster/theme t:

$$c_t = 10 \times \sum eqv_{i_t h_{t'}} \qquad d_t = 100 \times \sum \frac{eqv_{i_t j_t}}{k_t} \tag{2}$$

with keywords i_t and $h_{t'}$ belonging to different themes, keywords i_t and j_t belonging to the same theme, k_t total number of keywords of a theme. Centrality can be read as the importance of the theme in the development of the entire research field, whereas density can be read as a measure of the theme's development:

- higher values of centrality and density characterise the *motor themes*, well developed and important for the structuring of the research field;
- higher values of centrality with lower values of density characterise *basic and transversal themes*, important for the research field but not developed;
- lower values of centrality and density characterise *emerging or declining themes*, weakly developed and marginal in the research field;
- lower values of centrality with higher values of density characterise *highly developed and isolated themes*, strongly developed but marginal in the research field.

In the following, the diagrams referred to each 5-years subperiod are showed. Each cluster/theme is labelled only with its most central keyword. To enrich the

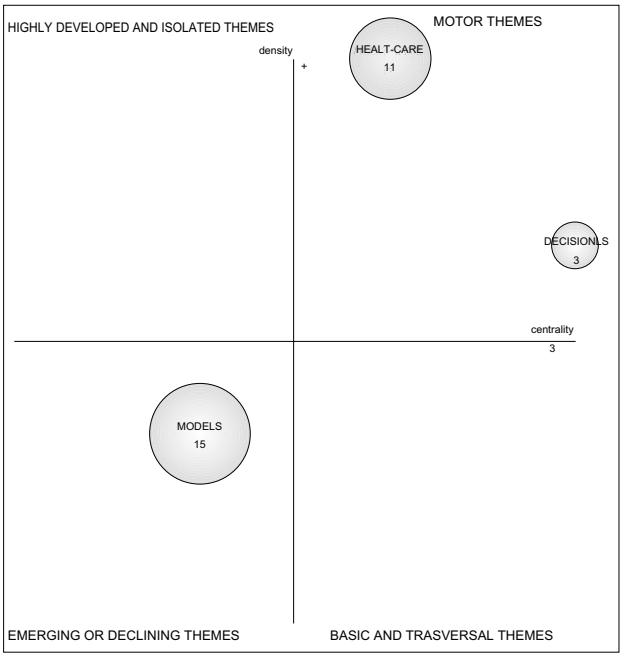

Fig. 7: Strategic diagram of the subperiod 1998 – 2002

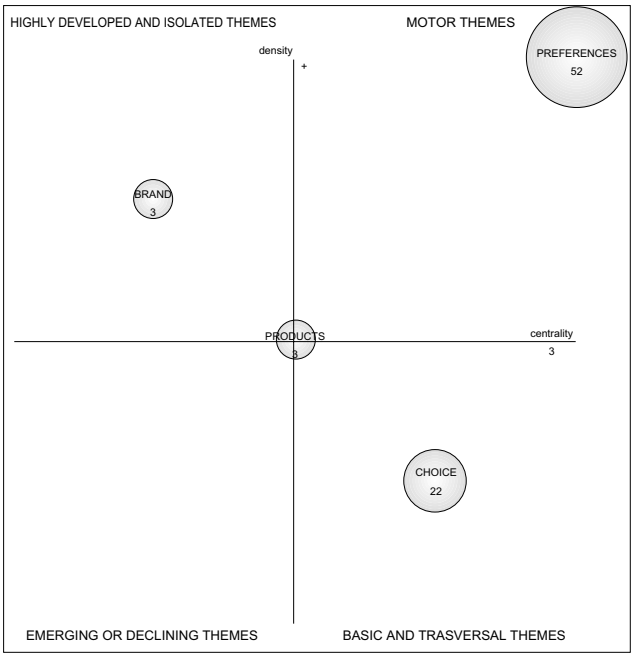

Fig. 8: Strategic diagram of the subperiod 2003 – 2007

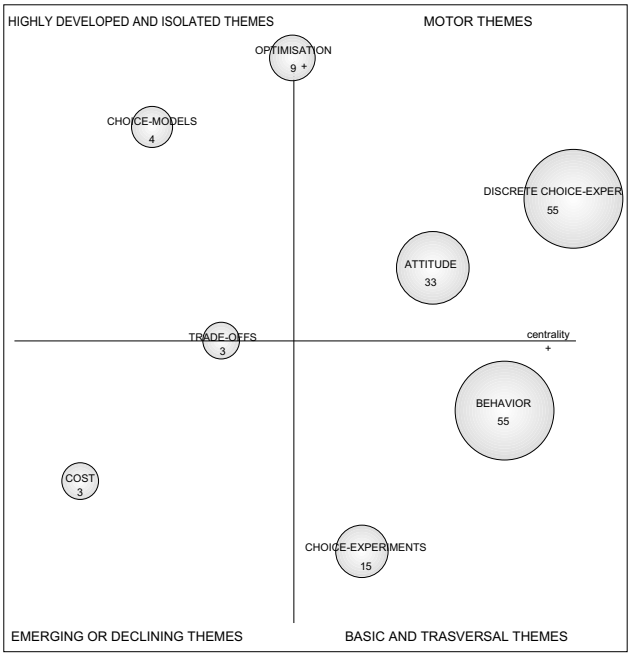

Fig. 9: Strategic diagram of the subperiod 2008 – 2012

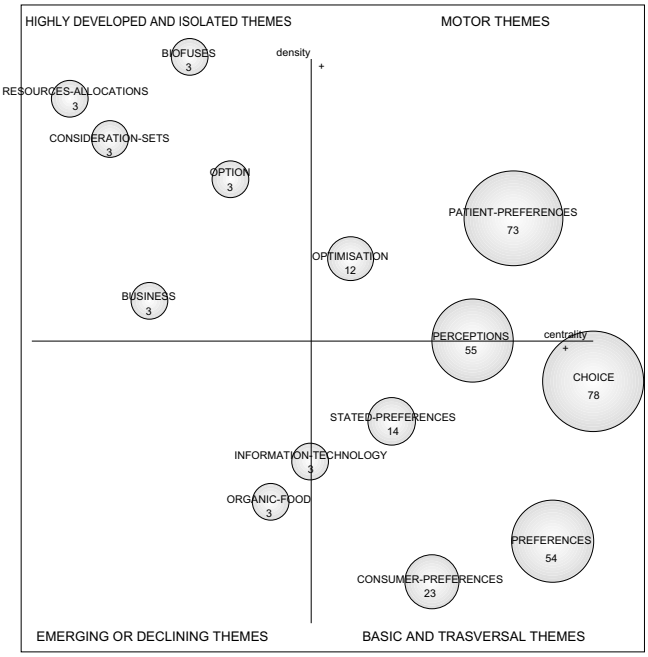

Fig. 10: Strategic diagram of the subperiod 2013 – 2017

readability of the representations, the dimensions of the clusters/themes are proportional to the number of publications using the central keyword.

In Figure 7, it is possible to see how HEALTH-CARE (11 publications) and DECISIONS (3 publications) were important for structuring CA in the subperiod 1998–2002, whereas MODELS (15 publications) was marginal. In Figure 8, concerning the subperiod 2003–2007, more attention was devoted to PREFERENCES (52 publications) rather than CHOICE (22 publications). More developed but still isolated in this subperiod was BRAND (3 publications). In the subsequent superiod (Figure 9), the motor themes were DISCRETE-CHOICE-EXPERIMENT (55 publications) and ATTITUDES (33 publications). BEHAVIOUR (55 publications) and CHOICE-EXPERIMENT (15 publications) were important for CA even if not developed, while COST (3 publications) and TRADE-OFFS (3 publications) were marginal and less deepened. Again with a marginal but instead more specialised role, were CHOICE-MODELS (4 publications) and OPTIMISATION (9 publications). In the last map (Figure 10 more themes appeared, and some of them started to become central with respect to the antecedent subperiod. In particular, OPTIMISATION (12 publications) became a motor theme together with PATIENT-PREFERENCES (73 publications). At the same time, CHOICE (78 publications) increased both the level of centrality and density although remained a basic and transversal theme, as well as PREFERENCES (54 publications) which decreased the level of development in CA. Interestingly, new applicative themes appeared after 2012 like for example RESOURCES-ALLOCATION (3 publications) and BIOFUELS (3 publications).

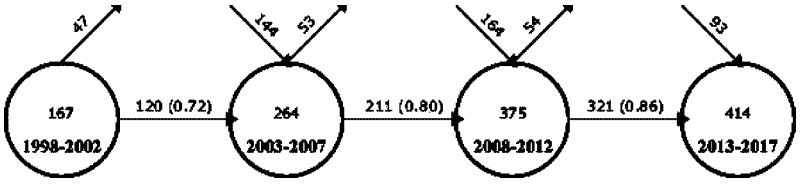

Fig. 11: Overlapping-items graph across successive subperiods

After interpreting each subperiod separately, it was possible to follow the evolution of themes across the whole temporal interval. In Figure 11, it is shown the number of keywords of each subperiod together with the number of emerging and declining keywords. This latter are referred to the keywords that started to be used in a subperiod with respect to the previous one and to the keywords disappeared in a subperiod with respect to the previous one. For instance, in 2003–2007 there

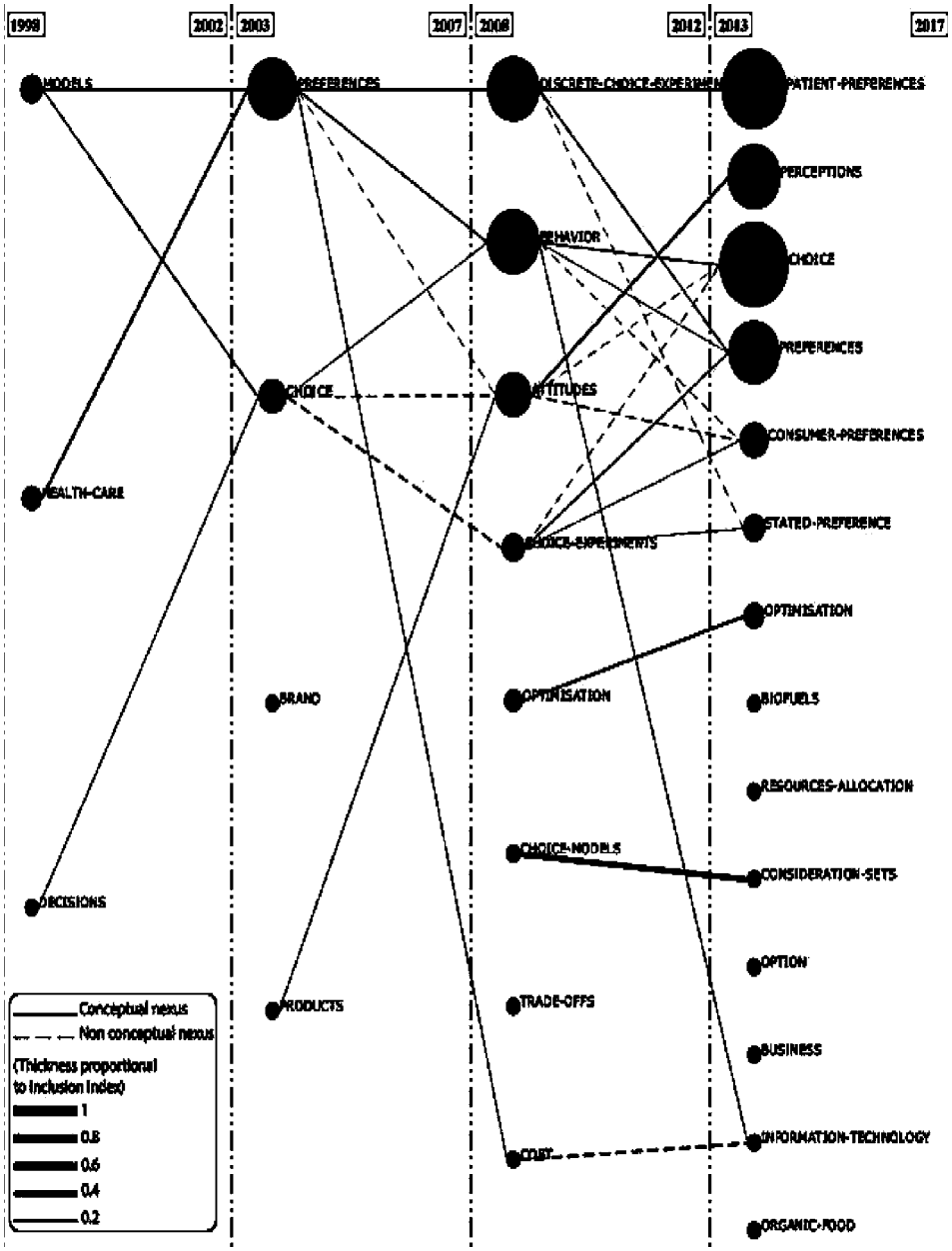

Fig. 12: Thematic evolution of Conjoint Analysis (1998–2017)

were 120 keywords already used in CA with 144 new keywords not previously used in the research field. The ratio between the number of keywords shared between two consecutive subperiods and the number of keywords used in the observed subperiod can be read as a measure of theme stability. In our case, we saw that the total number of keywords increased at a quite stable rate of growth. The high level of stability in each transition meant that the scientific community working on CA consolidated his terminology.

The evolution of the different thematic areas is shown in Figure 12. If two themes share the central keyword there is a conceptual nexus (represented with a solid line), if two themes share instead at least one keyword there is a non conceptual nexus (represented with a dotted line). The thickness of the lines representing nexuses is proportional to the number of shared keywords, in terms of *inclusion*:

$$inc_{tt'} = \frac{k_{tt'}}{min\{k_t, k_{t'}\}} \tag{3}$$

where $k_{tt'}$ is the number of shared keywords of the themes t and t', k_t and $k_{t'}$ are the number of keywords of each theme, respectively. The two major areas evolved during the years were the theoretical developments of models and the application of CA in the healthcare sphere. This latter was confirmed also from the results in Table 3, where the journals focused on health issues were predominants. Another important thematic area concerned models oriented to the marketing applications. Starting from 2008, new thematic areas emerged considering in particular optimisation and novel choice models used in operational research and other domains. The thematic linked to CA, in the last subperiod, seemed to be more associated with topical issues such as organic food, biofuels and resources allocation.

4. FINAL REMARKS

In this paper, a performance analysis and a thematic analysis were carried out to describe the past 20 years of CA. To the best of our knowledge, this is the first study aimed at evaluating the evolving trends of CA from a quantitative viewpoint.

Research activity on CA still showed a notable increase (Figure 1), with USA as leading country in terms of number of publication and received citations (Table 4). The lower contribution of the other countries could be explained with the lack of funding, or because of an interest in different research areas. Inter-country collaboration has been quite modest and institutions tended to form some research groups (Figure 2). It is quite surprising since the technology development and the dissemination of scientific information should have reduced geographic barriers

and broadened interdisciplinary collaboration.The thematic analysis highlighted an interest both on the methodological side and on the applicative side. About 50 years after the work of Luce and Tukey, there are still domains discovering the utility of this technique and experimenting new solutions (Figure 12).

This study presents several limitations, mainly related to the bibliometric approach itself. There are always false positive and false negative results in bibliometric analyses because it is impossible to generate a precise and full query. We retrieved publications only from WoS. However, it appears that no complete collections exist, since each of the most common ones has strengths and weakness (Falagas et al., 2008). The present study was limited to the publications written in English and included only in four type of publications. However, some CA research contributions included in other research area, type of publications and written in a different language may have been missed. Additionally, many other publications might have been published in not-yet-indexed resources, therefore unable to be retrieved. Another limit is that this study only included publications where the term CA is in the title or abstract or keywords, but not inside the full-text. This means that some publications might have been not retrieved. Moreover, self-citations have not been excluded, over-estimating the total citations.

Considering all these limitations, the publications analysed in this study might not precisely reflect the entire research activity on CA of the last two decades, but the data presented may still provide significant insights into the evolving trends and the future developments of the technique.

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