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Traceability Management as a Multidisciplinary Topic:

Trends and Gaps in Recent Scholarly Research

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ABSTRACT

Traceability can be studied from different viewpoints. In this paper, we analyze it as a management tool whose implementation implies organizational changes for the firm, but via which improved competitiveness may be realized. More specifically, the aim of this paper is to analyze the evolution of traceability management topic over the past twenty years (1994-2014) through a literature review, to identify the related concepts and settings that have been considered, and further, to delineate possible research gaps in the literature. To achieve this objective we created a self-assembled database, which permitted us to carry out a descriptive analysis of papers and to derive relevant conclusions and different implications for the future. We found that the concept of traceability as a tool to improve organizational performance has gained legitimacy and consequently is now widespread. Hence, traceability is treated from different areas of the firm embracing implementation, control, information systems, consumers' opinion or supply chain. Additionally, we believe that traceability research has to progress furthermore so as to dismantle its sturdy focus on the food industry because traceability management can be meaningful for broad sectorial applications. This study contributes to the traceability body of literature as it permits defining the trends about this research field and it represents an orientated guide to enrich traceability studies in topics associated to business organizations.

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Abstract

Traceability can be studied from different viewpoints. In this paper, we analyze it as a management tool whose implementation implies organizational changes for the firm, but via which improved competitiveness may be realized. More specifically, the aim of this paper is to analyze the evolution of traceability management topic over the past twenty years (1994-2014) through a literature review, to identify the related concepts and settings that have been considered, and further, to delineate possible research gaps in the literature. To achieve this objective we created a self-assembled database, which permitted us to carry out a descriptive analysis of papers and to derive relevant conclusions and different implications for the future. We found that the concept of traceability as a tool to improve organizational performance has gained legitimacy and consequently is now widespread. Hence, traceability is treated from different areas of the firm embracing implementation, control, information systems, consumers' opinion or supply chain. Additionally, we believe that traceability research has to progress furthermore so as to dismantle its sturdy focus on the food industry because traceability management can be meaningful for broad sectorial applications. This study contributes to the traceability body of literature as it permits defining the trends about this research field and it represents an orientated guide to enrich traceability studies in topics associated to business organizations.

Keywords: Traceability Management; Business Administration; Production Management; Supply Chain; Information and Communication Technology; Process.

1. Introduction

Traceability is a topic that has been traditionally attached to the food industry due to its strong link to safety requirements, entailing two palpable research trends. On the one hand, there is a technical propensity referring to the biochemical features of the product. On the other hand, a meaningful group of studies concentrate on the role of traceability as a management tool with the promise to improve firm competitiveness. We name this latter thread in the literature as "traceability management" which serves as our point of departure for the present review.

According to the international ISO 8402 standard, traceability is referred to as "the ability to trace the history, application or location of an entity by means of recorded identifications" (European Standard, 1995), which directly relates the concept to synonyms such as detection, follow up or identification of organizational processes and results (Bertolini and et al. 2006 and Canavari et al. 2010). The traceability notion taken by Bosona and Gebresenbet (2013) highlights that traceability information flow is not unidirectional but displays both a backward (tracing) and a forward follow-up (tracking) of products[1]

As emphasized by Bosona and Gebresenbet (2013), in recent years there has been an increased focus on product traceability in food supply chains. Around the turn of the twenty-first century the main reason for improved food safety traceability was the many tragic and costly food crises that took place. As a consequence of these scandals traceability gained importance in the minds of public policymakers, business decision makers, consumers and special interest groups, and hence traceability requirements become strengthened (Aung and Chang 2014).

In January 2005, traceability turned into a legal requisite in the food industry when the European Union began to require that all firms must trace their products in all stages of the manufacturing process. However, with time, the concept evolved beyond being solely a mechanism to assure food safety, and now it is also beneficial in terms of control, flexibility and differentiation; it gained importance from a management perspective since it helps the company to improve inventory performance and operational agility. For example, if an organizational course of action deteriorates, traceability facilitates the process of determining when and where the error occurred.

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[1] Bosona and Gebresenbet (2013) provide a deep overview of relevant traceability definitions (similarly to Olsen and Borit, 2013), discussing the driving forces, benefits and barriers for traceability systems, as well.

Traceability, therefore, has become a management tool that can be applied not exclusively in the food industry, but also in other sectors like fashion, chemistry or technology.

Our study is not the first that makes an exhaustive review of traceability literature. Moe (1998) analyses perspectives on traceability in food manufacture, and concludes that the information flow throughout the manufacturing chain should be analysed in terms of competitive advantage. Jansen-Vullers et al. (2003) develop an approach about how to design information systems for traceability. Lupien (2005) discusses food systems in general, their development over the past 120 years, accompanied by realities and problems faced by a world population exceeding 6 billion people. Opara (2003) reviews the concepts of supply chain management and traceability in agriculture, and highlights the technological challenges in implementing traceable agricultural supply chains. Regattieri et al. (2007) analyse legal and regulatory aspects of food traceability and provides a general framework for the identification of fundamental mainstays and functionalities in an effective traceability system. Bosona and Gebresenbet (2013) provide a deep overview of relevant traceability definitions (similarly to Olsen and Borit 2013), discussing the driving forces, benefits and barriers for traceability systems, as well. Karlsen et al. (2013) define a common theoretical framework, but it focuses on food traceability. Dabbene et al. (2014) review the influence of traceability aspects with regard to supply chain management. Concerning food supply chains, Aung and Chang (2014) highlight the role of traceability systems in improving the efficiency of production and distribution, and in increasing the quality of products.

More recently, Borit and Santos (2015) develop a review of legislation in food traceability, and Badia-Melis et al. (2015) highlight the new trends and advances in food traceability, but from a technical view rather than a management perspective.

In spite of rising interest in using the traceability construct, systematic reviews of traceability tend to almost exclusively focus on the food industry rather than taking into consideration its usefulness in other industries. Also, it remains silent and divergent about the main thematic areas, academic outlets, industry scopes and methodologies within the traceability stream of research. Further, an additional gap is apparent via-à-vis the construct's embeddedness into the management sciences. In this sense, our study's main contributions are comprised of the analysis of papers in terms of different criteria that other articles have not analysed globally, such as chronological evolution,

type of journal, research methodology, and empirical implementation (embracing sectors and countries). Furthermore, we define a mapping of distinct topics that will be our reference point to delineate which fields of traceability should be analysed more deeply in the future, and to draw attention to the multidisciplinary nature of the traceability management field.

Our approach is to provide a distinct analytical frame to answer questions associated with the traceability body of literature. How can we define the major thematic areas of the field? What are the most relevant academic outlets? Can we discern any presence of management perspective, such as performance, implementation, consumer involvement, success/failure factors? What is the diversity of methodologies applied by the researchers? Does the research conducted come from a wide range of industries and geographic areas? By nurturing information of this type, it is possible to gain a more comprehensive picture about the development of such an emerging field.

This paper is organised in several additional sections in which we review the sample selection methodology employed in the study (Section 2), an analysis of the journals from which we have obtained the papers (Section 3), a further analysis of the different topics covered by the articles (Section 4), a classification of the methodological approaches employed by each article (Section 5), and then a sector- and country-specific analysis of the empirical papers (Section 6). The final concluding section of the paper embraces the results obtained in terms of the research question we have posed, avenues for future research, managerial implications and limitations concerning our research (Section 7).

2. Review method

The applied review method bears the feature of a systematic review outlined by Tranfield et al. (2003). Its protocol involves systematic data gathering procedures, accessing and retrieving relevant research, and descriptive and qualitative data analysis techniques. This procedure is pursued by reporting the findings, exploring new developments and identifying areas for future research. Following prior literature reviews (Crossan and Apaydin 2010; Macpherson and Holt 2007; Mari and Poggesi 2013), we triangulated various databases to retrieve traceability research. The study was centred on the scholarly contributions indexed in the following databases: Social Sciences Citation Index, Business Source Premier, EconLit, Science Direct and

Academic Search Index. As part of the screening process (MacPherson and Holt 2007), we adjusted for study duplications.

A search was therefore conducted using the basic keyword "traceability" that had to be mentioned simultaneously in the title, in the abstract and in the subject terms. As suggested by Macpherson and Holt (2007) or Gough et al. (2012), we established several inclusion (theoretical papers, quantitative and qualitative empirical studies, all sectors, theoretical papers, quantitative and qualitative empirical studies, and written in English) and exclusion criteria. The only relevant exclusion criteria pertained to the time frame as we retrieved articles published from 1990 to 2014[2]. We opted to restrict our sources to peer-reviewed journals[3] because these are supposed to produce validated knowledge and are the most prominent ones in the field (Crossan and Apaydin 2010; Dahlander and Gann 2010). The number of papers considered after implementing these restrictions numbered 739.

Since our focus lies in the organizational and administrative aspects of traceability systems, an additional criterion was added: the word "management" had to be mentioned in the keyword listings. This filter reduced the sample from 739 to 138 papers. Then, after analysing one-by-one each paper, it turned out that a great many publications are very technical or belong to narrow specialized knowledge fields, for instance in chemistry, and are out of the scope of the current analysis, thus they were discarded[4]. Consequently, the final sample size further diminished to 93 scientific publications[5].

Our search process covered the period from 1990 to the present. Figure 1 shows the chronological distribution of the papers embedded in our study. It also makes clear that the first article was published in 1994, and that the first decade witnessed a low number of articles. The explanation of this phenomenon is that the topic of traceability became discussed in fairly specific and technical knowledge fields, mostly in chemistry or health sciences, and then gradually evolved toward subjects related to management which are of interest to us. The number of articles about traceability reached its peak in 2009 with fifteen papers, but also the years 2011 and 2013 contribute eleven articles.

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[2] This time frame permitted us to capture the earliest work in the field. An additional check encompassing the period between 1985-1990 revealed no studies dealing with traceability issues.
[3] By the same argument, we excluded book chapters similarly to Crossan and Apaydin (2010).
[4] Performing a systematic review of empirical research on knowledge and growth in small firms, the focus of Macpherson and Holt was on business organizations, which lead to the exclusion criteria on diverse sectors and scientific areas, like education, medical, artifical intelligence and natural science.
[5] The full list is available upon request from the authors.

Figure 1. Chronological distribution of sampled papers
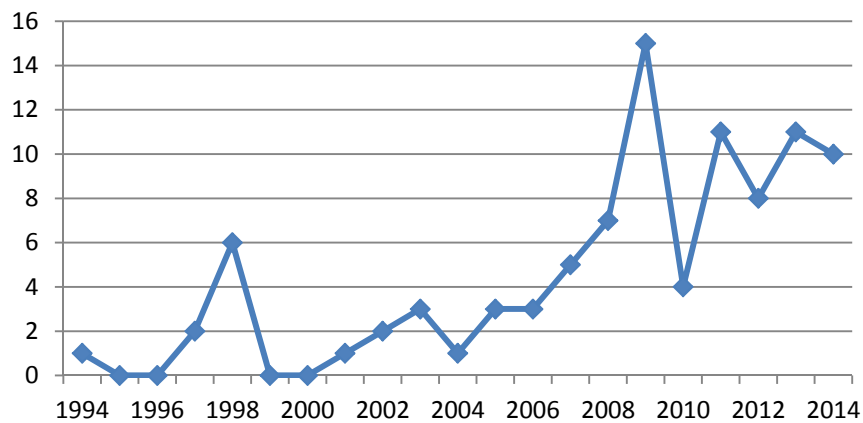
Notes. The figure depicts the evolution of all sampled papers. The total sample includes 93 articles.

3. Analysis of journals and thematic areas

We follow earlier systematic reviews (Crossan and Apaydin 2010; Dahlander and Gann 2010; Filippini 1997; Macpherson and Holt 2007) and feature the journals involved in the consideration set. Table 1 shows the number of papers provided by each journal. The articles were drawn from fifty-five different scientific journals, among which forty-one published exactly one, seven of them two papers, while seven outlets issued at least three. It is the journal "Food Control" that yields the highest number of articles, thirteen in total, followed by "Journal of Food Engineering" with eight articles. Then, both "Computers and Electronics in Agriculture" and "Supply Chain Management" provide four papers.

Table 2 shows the number of papers classified according to the thematic area of each journal. Most of the articles come from food journals, but also operations, information technology and agricultural outlets have a relevant presence.

Table 1. Distribution of papers by journal

Journals ♣	Frequency ♠	Journals ♣	Frequency ♠
Food Control	13	Geographical Review	1
Journal of Food Engineering	8	IEEE Software	1
Computers and Electronics in Agriculture	4	IEEE Transactions on Industrial Electronics	1
Supply Chain Management	4	IEEE Transactions on Software Engineering	1
Food Policy	3	Industrial Management and Data Systems	1
International Journal of Production Economics	3	Industrial Marketing Management	1
Trends in Food Science and Technology	3	Information and Software Technology	1
American Journal of Agricultural Economics	2	Information Systems Frontiers	1
British Food Journal	2	International Food and Agribusiness Management Review	1
Food Quality and Preference	2	International Journal of dairy Technology	1
International Journal of Consumer Studies	2	International Journal of Food Science and Technology	1
International Journal of Information Technology and Management	2	International Journal of Information Management	1
International Journal of Production Research	2	International Journal of Operations and Production Management	1
Meat Science	2	International Journal of RF Technologies: Research and Applications	1
Agrekon: Agricultural Economics Research and Practice in Southern Africa	1	Journal of Business and Industrial Marketing	1
Agribusiness	1	Journal of Cleaner Production	1
Annals of Operation Research	1	Journal of Consumer Protection and Food Safety	1
Assembly Automation	1	Journal of Food Agriculture and Environment	1
Biosystems Engineering	1	Journal of Industrial Technology	1
Canadian Journal of Animal Science	1	Journal of Operations Management	1
Computer-Aided Design	1	Journal of Purchasing and Supply Management	1
Critical Reviews in food science and nutrition	1	Journal of Supply Chain Management	1
Decision Support Systems	1	Journal of Systems and Software	1
Distributed and Parallel Databases	1	Journal of the Science of Food and Agriculture	1
European Journal of Law and Economics	1	New Zealand Journal of Agricultural Research	1
European Journal of Marketing	1	Sociologia Ruralis	1
European Review of Agricultural Economics	1	Technovation	1
Food Research International	1		

Notes. ♣ The ninety-three papers were published in fifty-five journals. ♠ The seven journals with at least three articles encompass 41% of the articles.

Table 2. Distribution of journals by theme

Thematic area	Number of articles	Percentage
Food	42	45
Operations	20	22
Information Technology	12	13
Agriculture	9	10
Marketing	5	5
Management	2	2
Geography	1	1
Law	1	1
Sociology	1	1
TOTAL	93	100

Regarding the papers in food journals, we cannot establish a clear trend until 2005. The publication date of the first paper is 1998 while the next is not until 2003 when an upward trend began. Around the turn of the century many food scandals took place. For instance, in Europe, adulterated olive oil was responsible for a number of deaths and illnesses in Spain, and subsequent investigations were not able to show the origin of the problematic oils (Borit and Santos 2015); in the United Kingdom, an epidemic of bovine spongiform encephalopathy, commonly called "mad cow disease," led to the destruction of many thousands of cows (Loureiro and Umberger 2013); in Belgium, during 1999, animal feeds containing high levels of dioxins, which are toxic and carcinogenic contaminants, caused the destruction of a huge amount of poultry, eggs, and pork products. In Borit and Santos (2015), these events are brought under scrutiny altogether with the consistency of EU legislation. These scandals increased the demand of documentation and food products traceability. As a result, traceability became a requisite in the food industry in January 2005. It has been considered a way of responding to potential risks that can arise in food and feed production, and also a mechanism that can appropriately ensure food safety. Later on, it was shown that investments made in the deployment of a traceability system bring various sorts of benefits along the supply chain, such as reduced operative and labour costs, optimized inventory and logistics activities, access to more accurate and timely production process information, or stronger competitive advantage through the ability to document desirable product characteristics (for instance, Alfaro and Rábade 2009, Asioli et al. 2014 and Hu et al. 2013). It is not surprising that it has become an important tool not only in the food industry, but also in different areas and industrial sectors (Guercinia and Runfola 2009, Ouertani, et al. 2011, Sohal 1997, and Ramesh and Jarke 2001).

Nowadays, traceability represents much more than merely a mechanism to assure food quality which could explain why along with food journals, information technology and operations journals started to deal more comprehensively with this field of research.

Papers published by operations management journals represent the second most frequent category. This subject has undergone several highs and lows since 1994, when the first article appeared. One can deduce that the number of papers increased some time after 2005, when traceability became a requisite in the food industry; accordingly 60 percent of papers was published during the period 2009-2014. Operations journals began to publish papers that embrace the topic of traceability once it became more than a simple food safety measure. The majority of the papers published in this category of journals analyse traceability as a management tool that can be applied in different sectors (Rábade and Alfaro 2006; Jansen-Vullers et al. 2003). About the operations journals that publish traceability papers, one may select a few such as the Supply Chain Management (Calder and Marr 1998), International Journal of Production Economics (Brofman and Garcia Martinez 2014; Resende-Filho and Hurley 2012), the Journal of Operations Management (Marucheck et al. 2011), the International Journal of Production Research (Khabbazi et al. 2011) and the International Journal of Operations and Production Management (Cheng and Simmons 1994). As a matter of fact, we consider that traceability should be a reinforced and stressed topic precisely in this category of journals.

In recent years there has been an increase in the number of traceability-related articles published by technological journals embracing thematic areas like agriculture and technology, food and technology, and technology being a robust thematic field of study. This is shown by the fact that the 83 percent come from the concluding five years of the sample period. Most of these articles provide data models or talk about Radio Frequency Identification (RFID) which thereby became a prominent source of traceability technologies (for instance, Azuara et al. 2012, Gandino et al. 2009, and Mehrjerdi 2011).

With regard to traceability tradition, it is also noteworthy to mention that there are a few papers published in marketing, management, geography, law and sociology (Table 2). The fact that both marketing and management outlets admit traceability research points toward the strong link of the concept with administrative sciences.

4. Mapping topics

Once the final sample was generated, we proposed different topics to be able to classify the articles. Before establishing an appropriate categorization for the topics addressed by the traceability literature, we kept in mind some guidelines. First, traceability is an emerging field with a variety of economic applicability that might presumably encompass a range of topics. Under such a circumstance, we did not heavily impose a priori categories and better relied on our readings to deploy a plausible classification. This consideration was impulsed by Baumeister and Leary (1997) who believed that 'literature reviewers should allow themselves to be led by their evidence' (p. 314), and the application of a priori categories might introduce extreme rigidity that will result in misleading conclusions. Second, our further objective was to merge the emerging groupment with existing topics that hail from literature reviews (Filippini 1997) and broad areas of management and organizational studies[6].

According to these guidelines, we have considered nine different topics to classify the sampled articles:

T1: Concept and the state of the art of traceability.

T2: Factors influencing the success or failure of a traceability system.

T3: Traceability and performance.

T4: Implementation of a traceability process.

T5: Traceability and legal issues.

T6: Build-up of traceability.

T7: Consumer's attitude about traceability.

T8: Information technology

T9: Supply chain management

Across a great many thematic areas encompassed by our examination, this review takes a deliberately cross-disciplinary stance. The definition of these topics represents a relevant contribution to traceability literature in which it sets up a framework for analysing this field and permits defining a more precise map toward traceability topics.

Lead by Scandura and Williams (2000) and Filippini (1997), we distinguished dissimilar spells to illuminate subtleties of the above classification that permits us the

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[6] In this spirit, we considered prior research in management on success and failure factors (Fosfuri and Giarratana 2007; Sorenson 2000), implementation (Klein and Sorra 1996), legal issues (Teece 1986; Gans and Stern 2003), buyers' and lead users' opinion (Von Hippel 1986; Von Hippel and Katz 2002), and technology adoption (Garud and Kumaraswamy 1993).

use of a benchmark comparison period against which current practice could by examined. Table 3 shows the number and percentage of papers classified in each topic for each period (1990-1998, 1999-2006 and 2007-2014). The classification was made according to the aim and basic contribution of each paper. Some papers fit into a single topic area, however most of them had to be assigned to more than one. For example, there are several papers that describe the performance of traceability, and at the same time identify aspects that could be changed for its improvement (Sohal 1997). Hence, those articles make contributions in both directions (T3, T4). Given the grouping displayed in Table 3, we calculated a Berry index[7] for the whole and each single period that gave us a value equal to 0.83 for the entire period under study, 0.71 for 1990-1998, 0.81 for 1999-2006, and 0.83 for the last spell. This lets us conclude that the end period illustrates a higher rate of dispersion of the topics compared to the previous ones while being similar in magnitude to the entire study period.

Table 3. Distribution of papers by topic

Topic ♣	Number of articles ♣	Percentage	1990-1998	1999-2006	2007-2014
T1	10	6	1	2	7
T2	6	4	0	1	5
T3	46	29	4	6	36
T4	27	17	4	4	19
T5	1	1	0	0	1
T6	18	11	0	4	14
T7	9	6	1	0	8
T8	14	8	1	1	12
T9	28	18	0	2	26
Total	159	100	11	20	128

Notes. ♣ Topic categories on traceability denoted in the first column are the following: concept and state of the art (T1), success or failure factors (T2), performance (T3), implementation (T4), legal issues (T5), build-up (T6), consumers' attitude (T7), information technology (T8) and supply chain management (T9). ♣ As any paper can be classified into more than one topic, the number appearing with the asterisk surmounts ninety-three, the total number of sampled articles.

Regarding the papers that describe the performance of traceability (T3), Table 3 reveals that this is the topic with the most articles and that there is a growing trend through the third spell of the study period, especially during 2007-2014 with more than four papers on average annually (equalling almost 80 percent of articles within the

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[7] This is a one minus a Herfindhal index multiplied by 100 based on the proportion of the sampled papers in each topic. The Berry varies theoretically from 100 (maximum dispersion) to 0 (no dispersion). The Berry index is a widely applied concentration measure in the management literature (Fosfuri and Giarratana 2007; Sorenson 2000).

topic). The first historical article in the category was published in 1994 followed by only five additional works until 2005. The discontinuity could be attributed, as explained in Section 3, to the fact that in January 2005, the European Union authorities prescribed that firms operating in the food industry had to ensure quality by tracing their products in all stages of production, tracking the way from the supplier to the end consumer. Since then, traceability apparently became a constraint for organizations, and hence a relevant aspect to study from practical considerations. The articles standing out in those inceptive years are the ones that primarily describe the performance of traceability as a food safety technique (e.g. Lupien 2005; Regattieri et al. 2007). However, traceability recently gained emphasis as a management tool without diminishing the proportion of papers dealing with the food industry. The upsurge concerns articles that discuss traceability as a valuable tool to marketers and consumers through the provision of marketing advantages (Shackell 2008; Guercinia and Runfola 2009), managing information in order to capture competitive advantage (Canavari et al. 2010), or how buyer-supplier relationship influences traceability on raw materials (Rábade and Alfaro 2006). Lately analysis conducted on the performance implications of traceability did not fade, shown by the fifteen papers published between 2012-2014.

The second most frequent topic discussed by the sampled articles deals with supply chain management (T9) whose growing importance over time is salient as 92 percent of the articles were published (twenty-six papers published) between 2007-2014. This body of research addresses the complex interrelation of traceability and supply chains, for instance by introducing novel criteria and methodologies for measuring and optimizing the performance of a traceability system (Dabbene and Gay 2011), offering some evidence of the adoption of different traceability approaches (highlighting its exploitation) by actors along the supply chain (Guercinina and Runfola 2009), and providing important policy implications for regulators and businesses to ensure food supply chain integrity (Brofman and Garcia Martinez 2014). In a similar vein, the study of Manikas and Manos (2009) attempts to design an integrated supply chain model for supporting traceability of dairy products. To this topic, we included two papers that analyze how traceability influences inventory decisions (Bellon-Maurel et al. 2014, and Alfaro and Rábade 2009). Additionally, it is worth noting that we have not found any specific paper that relates traceability with logistics issues, leaving a gap to be filled in future studies.

Regarding the issue of traceability implementation (T4 in Table 3), the majority of the papers adopts a practical perspective and proposes improvements through a case study, but all of them look almost exclusively into the food (Alfaro and Rábade 2009; Pinto et al. 2006) or farming sector (Bertolini et al. 2006). There is an article that presents two hypothetical improvements on the traceability system within chocolate production and a supply chain system with the help of a case study (Saltini and Akkerman 2012). Meanwhile one paper analyses a case study in the Canary Islands to propose improvements (Sanfiel-Fumero et al. 2012) and another's test bed is in Quebec, Canada (Lavoie and Forest 2009). Once a new concept is established, it requires time and effort to check and improve upon it. This trait is reflected by the increase of the number of papers (nineteen) published in the third period compared to the second (four papers).

The papers that describe the build-up of a traceability model are the fourth most frequent (see T6 in Table 3). This group of articles exhibits more technical sophistication and practical concern. We distinguished between two types of models: mathematical and theoretical. The first consists of the description of a system using mathematical concepts and language, and the other is basically theory driven aiming to explain an entire situation or behaviour, toward a more precise prediction as a final objective. This subject matter does not appear to have lost its appeal until recently, demonstrated by the fourteen published during the third period of our time frame. Most of the articles develop a theoretical model and they do not share a common thread of subject with the aim to predict a more precise solution for a given case; one explains the different functions and the incentives to use a traceability system involving quality verification (Hobbs 2004), another introduces the concept of Electronic Product Code Information System (EPCIS) framework and Unified Modelling Language (UML) state charts (Thakur et al. 2011), and others develop a theory about the relationship between supply network complexity and the traceability of adverse events (Skilton and Robinson 2009). There is only one paper that develops a mathematical model, which introduces a detailed model to assess the economic impact of RFID (Bottani 2009).

Papers concerned with information technology (classified as T8) began to appear in 2007, with twelve articles (out of fourteen in total) published in the last spell of our study period, shown by Table 3. We originally thought of defining this topic as Information System to link with a specific area of the firm, but most of the paper cohere to RFID, a relevant type of traceability technologies that has been used for years in

animal identification and tracking (Voulodimos 2010). It has also been used in the food chain for traceability control. Further, manufacturers can use RFID solutions to reduce operating costs through decreasing labour costs, claims and returns of defective items which eventually increases the level of operating income. Additionally, they can reduce working capital by enabling reductions in inventory. These strategies can bring higher levels of profitability and productivity to the business. Since RFID traceability systems are quite recent, most of the articles are general and describe the performance of RFID traceability and its benefits (Mehrjerdi 2011), but also its challenges and limitations (Ruiz-Garcia and Lunadei 2011; Sun et al. 2007). For example, Mehrjerdi (2011) through several case studies identifies the benefits that RFID has induced to various industries and supply chains that encompass automation, transparency, asset management, velocity inside and security. Once RFID gets consolidated, the problem of how to improve RFID traceability systems could become an interesting and somewhat compelling issue. One can observe that the research stream analysing RFID from a traceability perspective brings into focus the performance of the supply chain (Azuara et al. 2012, Barge et al 2013, Bottani 2009, Mehrjerdi 2011, Parreño-Merchante et al. 2014). In this respect, we deem that the RFID-traceability relation could be analysed from novel angles, like internal logistics and the influence of human apsects in the successful implementation of RFID, as such also highlighted by literature reviews on RFID (Chao et al 2007 and Ngai et al. 2008).

Compared to previous groups, the topic on the concept and the state of the art of traceability (T1 in Table 3) represents less weight, six percent in the consideration set with ten articles, mostly published from 2009. These articles in the majority of the cases resort to some sort of qualitative methodologies, notably to literature reviews. Consequently, the fundamental theoretical issues of traceability systems are addressed with a more practical discussion over its extent (Moe 1998), or an overview of relevant traceability definition is provided (Olsen and Borit, 2013). Other studies investigate how traceability helps process knowledge evolve in software development organizations (Ramesh 2002). Following this path on knowledge management, Ouertani et al. (2011) aim to enhance the sharing and use of product knowledge acquired during the development process using traceability information. Finally, a recent paper by Aung and Chang (2014) illuminates the link between the notion of traceability and supply chains by offering comprehensive information about traceability with regards to safety and quality in the food supply chain.

The consumer is at the final downstream end of the food chain which starts at farms or other primary input producers. They may be concerned with several issues related to food manufacturing as is the food they have purchased. Little is known about consumers' opinions and beliefs associated with traceability nor their preferences for information provision, since very few articles cover this subject. In our final sample we detected nine papers that address this topic (shown in Table 3 at T7). Some of them are very general and simply analyse consumer behaviour within the system, explain how consumers understand traceability, what are their expectations about it and the benefits they associate with it (van Rijswijk et al. 2008; Kehagia et al. 2007; Dimara and Skuras 2003). Additionally, one can discern studies with regard to consumer responses about relative preferences for food safety (Loureiro and Umberger 2007) or that analyse consumers´ involvement and perception on traceability system (Chen and Huang 2013). However others are more specific and talk about consumers' interests in traceability to verify whether production is environmentally sustainable (Myae and Goddard 2012), consumers' interest in the information provided through food traceability systems (Jin and Zhou 2014), or how consumer reactions after a food crisis evolve, or the degree of necessity they have with regard to traceability (Latouche et al. 1998). Increasingly, consumers in many parts of the world demand verifiable evidence of traceability as an important criterion of food product quality and safety. Furthermore, they are becoming more discerning and conscious in their food choice. In order to meet the demands for consistent supply of top quality, safe and nutritious food, the design and implementation of traceability systems has become an important part of the overall food quality assurance system. From the consumers' point of view, traceability emerges as more than a simple mechanism to assure food safety given it overwhelmingly plays a more distinguished role in promoting price premium and incentivizing purchase intention. Accordingly, very probably analysing consumers' behaviour and opinion toward traceability will become an important subject field for future studies. This viewpoint is perhaps buttressed by the fact that eight out of the nine papers in the topic emerged during 2007-2014. It is remarkable that this topic fits with the marketing area of the firm, whereby directly emphasizes the interdisciplinary feature of traceability.

Among the factors influencing the success or failure of a traceability system (T2), Kirezieva et al. (2013) analyse the major context factors that create risk to decision-making in food safety management systems in the fresh product chain. It

includes a specific list of factors that are clustered in terms of technology, product, production, supply chain and organizational characteristics. In a recent paper, Barge et al. (2014) explore factors such as tag type and shape, required power, antennas polarization and orientation to verify their effect on reading performance and system reliability. The findings of Brofman and García Martinez (2014) highlight the impact of physical and human innovations in food traceability systems to accomplish business objectives where innovation in human resources represents a major source of improved sustainable performance.

In summary, we can conclude that the number of articles in all topics underwent an increase from the inception of observation until 2007-2014, the third spell of our study period. Topics such as traceability's effect on firm performance (T3), supply chain management (T9), traceability implementation (T4), the build-up of traceability (T6), information technology linked to traceability (T8), the concept and the state of the art of traceability (T1), and opinion of consumers (T7) proved to be, in this order, the most extensively studied topics during the sample period. In the beginning we considered two other topics as possible classification categories: factors that influence the success or failure of traceability (T2) and traceability from a legal perspective (T5); however only six and one articles in the final sample cover these topics, respectively. For this latter, we speculate that the outcome could be related with the insignificant number of articles offered by law journals.

In Table 4, we provide a list of the mostly cited articles of our database denoting the reference, the name of the journal, and the topic and the methodology of the paper. In order to obtain the number of citations received for each sampled article we resorted to Google Scholar and accomplished the citation search process up until May 2015. The most widely used topics by the ten articles are traceability performance, classified as T3 and the application of a model (T6) with six and three papers, respectively. Furthermore, the food industry clearly emerges as the most adopted setting by the articles listed in Table 4. Among the methodologies, the use of literature review somewhat excels, followed by case study and theoretical model with 2-2 articles.

The most cited paper by Ramesh and Jarke (2001) has more than the double number of citations to the second one. Further, it is related to Information Technology (T8) and even more importantly it represents a study not centering upon the food industry. In fact, most of the papers that subsequently cite this study appear alone in IT journals which demonstrates the interdisciplinary traceability management topic.

Table 4. Ten most cited articles from our database papers

Reference	Citations	Title	Journal	Topic	Methodology
Ramesh and Jarke (2001)	864	Towards reference models for requirements traceability	IEEE Transactions on Software Engineering	T6, T8	Questions to experts
Regattieri et al. (2007)	413	Traceability of food products: General framework and experimental evidence	Journal of Food Engineering	T3	Literature review
Loureiro and Umberger (2007)	336	A choice experiment model for beef: What US consumer responses tell us about relative preferences for food safety, country-of-origin labeling and traceability	Food Policy	T3, T7	Survey
Moe (1998)	301	Perspectives on traceability in food manufacture	Trends in Food Science and Technology	T1, T3	Literature review
Jansen-Vullers et al. (2003)	246	Managing traceability information in manufacture	International Journal of Information Management	T6	Case study
Hobbs (2004)	229	Information Asymmetry and the Role of Traceability Systems	Agribusiness	T6	Theoretical model
Opara (2003)	232	Traceability in agriculture and food supply chain: A review of basic concepts, technological implications, and future prospects	Journal of Food Agriculture and Environment	T3,T4	Literature review
Latouche et al. (1998)	162	Food Safety Issues and the BSE Scare: Some Lessons from the French Case	Food Policy	T7	Case study
Smith et al. (2005)	177	Traceability from a US perspective	Meat Science	T1,T3,T4	Descriptive
Pouliot & Sumner (2008)	161	Traceability, liability, and incentives for food safety and quality	American Journal of Agricultural Economics	T3	Theoretical model

Notes. The search process for the number of citations received by each paper in our sample was conducted up until May 2015.

5. Methodological approaches

Within the field of business administration, there is a vast diversity of research methods and approaches that can be used for knowledge generation purposes. Sampled articles for the present review were collected over a period of 20 years which incorporated multiple viewpoints and approaches. For the progressively evolving traceability stream, the application of a richness of methods can greatly facilitate the exploration of new ways of capturing relevant research problems and/or to balance the results. Preceding contributions (Crossan and Apaydin 2010; Eisenhardt 1989; Filippini 1997; Garud and Kumaraswamy 1993; Leonard-Barton 1988; Marshall and Rossman 2006; Scandura and Williams 2000; Jick 1979) addressing research methodologies, prompted us to identify eight categories to be able to classify our sampled papers, as it appears in Table 5. In line with Jick (1979), Filippini (1997) and Crossan and Apaydin (2010), we made a further effort to distinguish between theoretical and empirical works. An empirical

method usually consists of the use of data collection to develop propositions, verify a theory or derive conclusions (Jick 1979). In contrast, theoretical works generally may not apply any kind of empirical analysis (or with a limited scope), focus on context, are emergent rather than tightly prefigured, and propositions derived by the authors are grounded from the established body of the literature (Jick 1979; Creswell 2007; Marshall and Rossman 2006). Methodological categories, such as descriptive, theoretical/mathematical model, literature review and application of a system belong to the group of theoretical works, while the categories with empirical focus embrace case study, survey, questions to experts and secondary source[8].

After defining the eight different categories, each paper was classified according to the methodological approach adopted. Most of the papers employed one single method, however some of them combined two different approaches. All these cases with mixed categories were denoted under the more dominant approach. Then, we calculated the percentage of papers classified under each approach with regard to the overall number of articles belonging to it. We have conducted this grouping process taking into account the final sample and considering each thematic area (like food, operations, technology etc.). The results are presented in Table 5.

Table 5. Distribution of papers by methodology

Methodology	Number of articles	Weight in the final sample (%)	T1	T2	T3	T4	T5	T6	T7	T8	T9	Berry index
Theoretical categories	*48*	*52*										
Descriptive	22	24	2		12	6		1	2	5	3	77
Theoretical model	15	16	1	1	5	4		7			5	78
Literature review	10	11	6	1	7	2		1			4	76
Mathematical model	1	1			1	1				1	1	75
Empirical categories	*45*	*48*										
Case study	30	32	1	2	15	12		9	1	7	13	81
Survey	11	12		2	6	2	1		7		3	77
Questions to experts	3	3			1	1		1		1	1	80
Secondary source	1	1			1							0
Total	93	100										
Berry index			58	78	79	72	0	63	46	61	74	

Notes. Any paper with its idiosyncratic methodology can be classified into more than one topic category, therefore, taking into consideration the number of papers for a specific methodology (for example, 11 for survey), the total number of topics under T1-T9 in the same line can easily surmounts this number (21 in case of surveys).

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[8] The concise description of the main properties for each category is available upon request from the authors.

Regarding the papers in unison, one can conclude that theoretical works outweigh empirical works in number. The number of theoretical works amount to forty-eight with a total weight of 52%, in which papers with descriptive focus play the leading role. This phenomenon could be explained by a high percent of explanatory topics, such as traceability as a concept, the performance of traceability or application of a RFID traceability system, which require description to be well covered and developed. Thus, there are twenty-two articles with descriptive characteristics with a twenty-four percent weight in the final sample. As we can see theoretical models account for 16% with fifteen papers, in which half addresses the build-up of a traceability model. It is noteworthy to mention that only one article develops a mathematical model (Bottani 2009). A greater presence might be expected, as mathematical models are treated the main scientific or quantitative approach in the long-standing tradition of operations management (Meredith 1989). Literature review, the remaining methodological approach within the theoretical category, reaches the weight of eleven percent. We can deduce that few articles represent a pure literature review, however some of the other articles tend to use this method as a technique, such as descriptive articles (Popper 2007), or those that develop a theoretical model (Skilton and Robinson 2009; Manikas and Manos 2009). In this category, we have also included the review papers, such as Moe (1998) and Olsen and Borit (2013).

Empirical works total forty-five with a total weight of 48 percent. Case studies with thirty sampled articles surmount surveys with eleven sampled articles. Case studies are suitable for analysing new issues that are still without clear theoretical models and for formulating hypotheses (Barge et al. 2014; Donnelly et al. 2009; Eisenhardt 1989; McCutcheon and Meredith 1993; Yin 1994), while surveys are tools designed for verifying these hypotheses and for determining the validity of the theories developed. Taking into account this peculiarity, it leads us to the conclusion that, regarding the study of traceability systems, the scientific literature is still in an exploratory phase and focuses on theoretical construction. Our research yielded three papers that posed questions to experts (Canavari et al. 2010; Kirezieva et al. 2013; Ramesh and Jarke 2001), while our sample indicates secondary source with one article is a non-frequently applied methodological category in traceability studies. The reason is that the databases and public reports focus on financial or specific organizational aspects which causes the information they display about traceability to be either non-existent or extremely scarce.

There are some articles that concurrently combine theoretical and empirical works, for example the ones that unite the development of a theoretical model with a case study, or a system application with a case study. All of them have a similar structure, first the development of the theoretical model is performed and then the case study guarantees the correct and seamless application of the principles derived (Manikas and Manos 2009).

When we consider segmentation by topics (displayed in Table 5), the pattern described before is generally repeated, although there are some aspects that we have to highlight. In some subject areas, specifically those that analyze consumers' behaviour toward traceability (T7), surveys gain greater weight compared to case studies and descriptive papers. As we have seen before, little is known about consumers' opinions and beliefs associated with traceability, and the main objective of these surveys is to discover consumers' points of view, their needs and requirements, and the benefits they associate to traceability - aspects not having been studied before. As a general observation, it is hardly probable that all hypotheses have already been formulated in this specific topic due to the changing nature of traceability in conjunction with consumers' needs and requirements that condition the study of consumers' behaviour as a concept not yet entirely investigated.

Case studies represent the most frequently used technique for articles proposing implementation of and improvements (illuminated by T4) on traceability (shown by Table 5). Returning to our earlier discussion, this may reflect that there are no clear theoretical models in this area. These articles try to find the critical points and propose solutions for optimising traceability. For example, one of the improvements consists of setting a computerised system for managing product traceability (Bevilacqua et al. 2009), while another presents a production strategy based on a low batch dispersion strategy that would lead to the reduction of potential product recall sizes (Saltini and Akkerman 2012). In addition, case studies display importance in this topic category because quantitative results on real or hypothetical improvements present a significant help to food industries with the decision of whether to improve their traceability systems and how to achieve this task. The employment of this method explains that the implementation of traceability as a theme has not entered a confirmatory phase yet. Perhaps, the implementation of a full-blown traceability system altogether with making efficiency improvements on it would constantly necessitate future exploratory undertakings, thus the extensive use of case studies will be justified.

Descriptive methods are expected to be applied in explanatory topics, such as, the explanation of traceability performance (Cheng and Simmons 1994; T3), the analysis of RFID traceability systems (Ruiz-Garcia and Lunadei 2011; T8), traceability implementation in quality control and production enhancement (Pinto et al. 2006; T9), its interaction with supply chain management (Engelseth 2009; Marucheck et al. 2011; Wilson and Clarke 1998), and the analysis of traceability as a concept combined with implementation and performance considerations (Smith et al. 2005; T1-T3). Those are the most theoretical topics.

Insofar as theoretical models (the second category in theoretical works) are concerned, its application (next to traceability performance issues, T3) is tightly linked to topic six that embraces the build-up of a traceability system (T6), as seen in Table 5. This subject matter addresses diverse issues, such as, the introduction of EPCIS framework and UML (Thakur et al. 2011), the development of a theory about the relationship between supply network complexity and the traceability of adverse events (Skilton and Robinson 2009), or the development of a methodology for the implementation of the vegetable supply chain traceability (Hu et al. 2013).

After analysing the different methodology types, and the number of articles classified by each, we can conclude that the study of traceability across its history has adopted a slightly more theoretical rather than practical orientation. This outcome could be explained by the fact that more than the half of the articles of the final sample covered an explanatory topic, while articles about practical issues like RFID or the development of models represent a somewhat lesser percentage.

As a further analysis, the Berry indexes help examine whether a specific methodology investigates a narrow or broad set of the identified topics. By taking a look at the last column of Table 5, one can conclude that the category case study displays the highest value of the Berry index indicating a widely dispersed application toward the different topics. In contrast, the category secondary source shows up a Berry index of zero by illuminating uniquely the performance topic. In addition, it could also be straightforward to draw conclusion on the topics that are researched by the widest repertoire of methodologies. In the last row of Table 5, one can observe that traceability performance is the topic that is built upon the widest methodological background. This finding is not surprising given the performance dimension of organizations, groups or systems in management science has always been at the forefront in scientific inquiries.

The topic covering legal issues has the minimum Berry value equal to zero that is attributable to the scarce number of articles looking into this field of study.

6. Sector and country analysis of empirical papers

We already defined the different methodological approaches and used them to classify all articles, where a distinction between empirical and theoretical works was made. In this section, we turn our attention to the analysis of the empirical papers.

With regard to our final sample, three different types of empirical works are considered: case studies, surveys and questions to experts as only one article was classified to the secondary source methodology. Questions to experts can be reckoned a specific kind of survey, with the main difference that questions are asked to people with a high degree of traceability-related skill and knowledge. This trait combined with the fact that we have only three papers classified into this category leads us to draw attention particularly to case studies and surveys. Data in Table 5 reveal that case studies take on almost three times more weight than surveys.

About surveys: We can conclude that this method is predominantly found in the traceability stream of literature for performance issues (T3) and for analysing consumer's opinion (T7) about the concept (van Rijswijk et al. 2008). Case studies are applied concerning the similar manner in which traceability performs (T3; Donnelly et al. 2009), but moreover in very different topics as well, like the link between traceability and supply chains (T9), its build-up (T6), the usage of RFID in traceability (T8; Mehrjerdi 2011) or ways for implementing traceability (T4; Saltini and Akkerman 2012).

Concerning empirical studies, two variables, the geographic context and the industrial sector were primarily analysed. Regarding empirical studies in our sample, twelve of them do not refer to a specific geographic context. The geographic distribution of the empirical papers reveals that most of them, twenty-six articles, are developed in Europe (depicted by Figure 2). As displayed by Table 6, Italy excels as the country of analysis with nine articles (e.g., Gnoni et al. 2013), five studies refer to Spain (e.g., Rábade and Alfaro 2006), and France follows with three articles (e.g. Dupuy et al. 2005). Next to the European Union, countries from the continent, such as Germany, the United Kingdom, Norway, Belgium, Greece, and the Netherlands serve as the test bed as well. On the contrary, the rest of the world referring to Asia, North America, Africa and Australia represent little weight for the traceability stream. China and United States

emerge as both hosting two articles while Australia, Canada, Japan, South Korea, South Africa, Taiwan serve for only one article published.

Figure 2. European countries as the test beds for empirical analyses

Notes. A further article that addresses the entire European Union is not depicted in the figure.

The sectorial distribution of the case studies reveals that the overwhelming majority, twenty-five papers, is developed in the food sector. From this set, ten works are general and address the food sector without any type of specifications. However, we were able to delineate and categorize the remaining case studies in the following sectors: one in chocolate (Saltini and Akkerman 2012), and in farming (Bertolini et al. 2006), two in agrifood (Gandino et al. 2009; Hobbs 2004; Zhang et al. 2010), in fruit and vegetable (Rábade and Alfaro 2006), in aquaculture (Parreño-Marchante et al. 2014), and finally also two in seafood (Donnelly and Olsen 2012; Karlsen and Olsen 2011). There are other studies that are developed in an industry different from the food industry, for example the fashion industry (Guercinia and Runfola 2009), the solid waste management industry (Gnoni et al. 2013), and the automotive sector (Sohal 1997). In recent years, traceability has become much more than an exclusive mechanism to assure food safety or a requisite in the food industry. Traceability has become a management tool that provides benefits in terms of control, flexibility and differentiation. In addition, it can help a company to improve inventory performance and operational agility. As a result, traceability is not applied exclusively in the food

sector any longer, but due to its multifaceted nature, it is evolving into a useful tool with possible application in other areas or industries.

When we consider articles that used surveys as the method, we must highlight that seven out of eleven deal with consumers' behaviour towards the implementation of a traceability system. Questionnaires (Banterle and Stranieri 2008) and semi-structured interviews are the most popular techniques. Geographic context for surveys include, for instance, Greece, where the survey was conducted to understand consumer evaluations in connection with product certification, geographic association and traceability (Dimara and Skuras 2003). Elsewhere in Europe consumers in four different countries were queried about the benefits they may associate with traceability related attributes (van Rijswijk et al. 2008). Regarding the potential sectors under analyses, the same pattern emerges as with case studies, namely a study exclusively enjoyed by the food industry as exemplified by these areas: fast food (Chen and Huang 2013), seafood (D'Amico et al. 2014) and beef and wine (Dimara and Skuras 2003).

7. Conclusions

According to the goals of literature reviews defined by Baumeister and Leary (1997), we provided a historical account of the development of theory and research on the traceability literature. The analysis of the sampled papers leads us to conclude that traceability as a system has become consolidated during this decade, especially since 2005, when it became established as a requisite in the food industry - an area of great interest for researchers. The concept has been covered by a wide range of journals in which some themes obtained more weight regarding the final sample, particularly those that are related with and focus on the following areas: food, operations and technology. There is a large increase by the third seven-year period (2007-2014) of our data collection in comparison with the earlier two spells (1994-2006) in the scientific output of the traceability field, where one can observe a stronger relative weight in topics associated with technology and management tools to the detriment of food-related topics.

Among our consideration set, we have analysed the content and contributions of each paper according to its thematic area. Each one has revealed tendencies and potential opportunities or critical points. Within the traceability field, we must highlight that the connection between traceability and firm performance, supply chain,

traceability implementation, its build-up, and the usage of information technology represent the topics that gained considerable weight in recent years. It is worth noting the importance and the increasing variety of perspectives which eventually permitted the study of traceability as a management tool, and the abundance of sectorial applications that dismantled the exclusivity held by the food industry.

If we consider the methodological approaches used, the greater number of theoretical works slightly over those that are empirical suggests that the study of traceability has adopted a theoretical rather than a practical perspective during its history. With regard to empirical papers, case studies outweigh surveys, which imply traceability may be a field of study that is still at an incipient stage. Many of the papers have an explanatory nature with a theoretical construction, thus adopting a confirmatory perspective. However we must highlight that some topics, such as consumers' behaviour toward traceability or optimising traceability are still in exploratory phases, and may follow this trend later on as well, since they are fields that require continuous study. A great challenge within this field lies in the difficulty of obtaining representative samples when the unit of analysis goes beyond the company itself. Obtaining valid and reliable information about a traceability case might be very complicated as it requires the cooperation of many different parties. Another important problem is whether secondary sources are available for researchers. The information contained in public databases or the information that companies include in their final reports or those published by business associations, tend to focus largely on financial or commercial aspects, with minimal data of interest, for example, for the analysis of supply chains. This trait means that the majority of the articles have to adopt a static nature.

The analysis of empirical papers reflects that no country has a dominant trend, since almost a third part of the papers do not refer to any specific geographic context. A challenge in this sense lies in the need to produce empirical papers with international focus that allows comparing different contexts and circumstances, and also to examine how the variation in geographic contexts influences traceability concept. Our analysis also shows that concerning the category of case studies in empirical papers, the food sector enjoys exclusivity, though we could also notice papers coming from outside this industry. As a matter of fact, traceability is not any more a simple tool to assure food safety, but rather it is gaining importance as a management tool, though in practice, traceability is still analysed as something strongly related to the food sector.

Avenues for future research

There are several future research directions that emerge from our paper.

Technology trade enjoyed a robust growth worldwide during the preceding twenty years, for instance technology royalty payments of OECD countries between 2000 and 2011 more than tripled (OECD 2012). The term market for technology (MFT) embraces transactions for the use, diffusion and creation of technology (Arora et al. 2001). It is not difficult to acknowledge that the concept of traceability and markets for technology are intertwined. Traceability deals with tracking the final product, incorporating all its components, through all the anterior steps of the vertical production and distribution stages. Technologies, ideas, knowledge or information acquired from technology suppliers might affect several stages of such a vertical value chain (Fosfuri 2006). It is also noteworthy to mention that MFT might not always operate without flaws. Asymmetric information, moral hazards and strategic consideration can spoil the market causing its failure (Fosfuri 2006; Fosfuri and Giarratana 2010; Pisano 2006). Therefore, the incorrect functioning of the market for technology can affect the design of traceability strategies. First, the safety or quality assurance is of key importance in traceability considerations. However, a prototype or technical service acquired through MFT (Arora et al. 2001) might entail doubts regarding technological risks for the former and feasibility of application in a new setting for the latter (Pisano 2006). Second, Teece (1986) notes that in case of specialized assets, contractual relationships might be exposed to hazards. This situation is associated with irreversible capital investments realized by one or both parties which turn out to be valueless if the cooperation between technology seller innovator and licensee collapses (Teece 1986). Such large sunk investments could be committed in manufacturing facilities, in IT infrastructure, in employee skills through training, or in the transfer of tacit knowledge. As a consequence, economic losses suffered by the acquirer could affect the quality of its final product, thus traceability considerations might be harmed.

In a further inquiry, one could examine the interaction between changes in the internal organization of the firm evoked by open innovation and the efficiency of traceability systems. Notably, shifting internal organization might affect organizational structure at managing knowledge accessed from outside through establishing cross-functional teams (Sakkab 2002), and knowledge management systems that are responsible for the transfer and sharing of external knowledge within the boundaries of the firm (Chiaroni et al. 2011). Additionally, as traceability and the associated business

models are subject to change and on the other hand can create strategic positions conducive to competitive advantage, future research could better articulate such aspects hitherto neglected in the literature. Under such an analysis, success and failure factors could also be explored which is currently a non-robust research direction.

Finally, future research shall deliberately address a more extensive use of surveys in order to validate research hypotheses in traceability theory. A more widespread use of survey would permit a robust methodological improvement. For instance, in Arbussa and Coenders (2007), a mixed logit model is applied in which random intercepts and slopes account for industry heterogeneity. This could allow researchers to detect more precise estimates related to the traceability construct for the specific industries.

Managerial implications

In addition to backing research, our study also aims to contribute to practice. Traceability has been influential and appears to be widely adopted in the food industry which thereby can serve as a benchmark, permitting distinct industries for analogous solutions. A straightforward application lies in studying the interaction of traceability and food supply chains. But one can also observe an emerging trend of witnessing the field in different areas and industrial sectors, like operations management and technology-sourcing. This latter can boost applied knowledge in various fields that embrace automation, asset management, internal transparency in inventory management, strategic and operational decision making and quality control during production. Learning from such events is facilitated by the abundance of case studies that is an idiosyncratic feature of the emerging traceability body of literature.

Limitations

Needless to say, the analysis we conducted is not exempt of limitations. We should first draw attention to the fact that we have mainly resorted to the analysis of academic papers. We could extend this search to books, chapter of books and proceedings of relevant congresses. Although, we believe the final sample obtained via our research method can be considered reasonably representative, since this database is a combination of different sources of information. Second, we have dealt exclusively with journals that were published in English, which means that journals written in other languages have been omitted. Ultimately, we have discarded some thematic areas, such

as chemistry or health, and also articles that were extremely technical in nature. Nonetheless, we do not believe that the results identified by the present analysis would be seriously conditioned by these limitations.

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Table 6. Geographical distribution of empirical papers

Country	Frequency	Country	Frequency
Europe		*Rest of the world*	
Italy	9	China	2
Spain	5	USA	2
France	3	Australia	1
Germany	2	Canada	1
Norway	2	Japan	1
UK	2	South Africa	1
Belgium	1	South Korea	1
European Union	1		
Greece	1		