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The Impact of International Management Standards on Academic Research

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Abstract: Management standards serve as an effective knowledge diffusion channel, considering that they offer comprehensive scientific and practical knowledge for many different stakeholders. This research aims to study the potential of management standards to diffuse knowledge, especially within the scientific community. Therefore, it analyzes the relationship between management standards and the academic literature. It focuses on international management standards, namely ISO 14001 and ISO 9001 and their 'European counterparts' EMAS and the EFQM Excellence model. We tested whether scientific publications, which address these international and European management standards, are more likely to lead to follow-up research than comparable scientific publications measured by the impact on average forward citations. Hence, we applied a negative binominal regression model on bibliometric data. Findings show that publications addressing ISO 14001 alone or in combination with other standards lead to higher average forward citations than the comparison group. In conclusion, international management standards foster the academic research progress of the topics addressed by the respective standard. Our research implies the importance of monitoring standards for the scientific community and suggests Standard Setting Organizations to foster actively the research progress.

Keywords: scientific publications; standardization; knowledge diffusion; ISO 14001; ISO 9001; EMAS; EFQM

1. Introduction

Standards are beneficial for different reasons: they facilitate the market access, support the diffusion of technologies [1], enhance the flexibility of management [2], and they can foster different forms of innovation [3]. Standards provide comprehensive scientific and practical knowledge for everyone at low cost [4]. Therefore, standards possess two essential functions within an innovation system. On the one hand, they serve as a technology transfer channel considering the knowledge entering the standards [5,6]. On the other hand, they enable the development of innovative technologies, which build upon standards [7]. In other words, standards are a source of knowledge and an option to spread and diffuse knowledge.

The extensive application of a certain standard signals that it has an impact on a wide range of units (e.g., companies or organizations) and that the standard was able to spread its knowledge. The number of users of a certain standard is an indicator of its successful diffusion and legitimizes it in this way [8]. It follows that the diffusion of a standard goes hand in hand with diffusion of the standard-inherent knowledge [9]. Using the example of knowledge about sustainability, standards on

the topic of sustainability and environmental management are able to spread knowledge to their target group and thereby generate an environmental impact within their target group [10]. Our purpose is to highlight the function of standards as a knowledge transfer channel beyond the classical company context and to show how they affect the scientific community.

Since this research focuses on international management standards, the properties of this type of standards and their impact on different actors will be elaborated. According to the ISO/IEC Guide 2 (2004: definition 3.2)), a standard is defined as a "document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" [11]. Pember [12] divides standards into product, process and management system standards. Product standards usually deal with issues of the corresponding product, like quality and safety. Process standards aim to describe the conditions, which are necessary to execute diverse processes related to a product or service, like its production or its packaging. Management system standards - or also called meta-standards [13] - delineate certain organizational operations [12]. This study deals with the international version of these standards, the international management standards. They foster knowledge on management practices, e.g., the dissemination of the topic 'quality management' through ISO 9001, or environmental management through ISO 14001 or the issue of social responsibility through SA 8000 and ISO 26000. Hence, international management standards do not focus on technologies, but instead on improving the performance of an organization.

Usually, standard setting organizations (SSO) develop standards with the help of a wide range of interested actors. International management standards, in particular, entail a huge variety of stakeholders. A famous example for a multi-stakeholder standardization process is the "ISO 26000—Social responsibility" [14,15]. The standardization process involved 660 experts and observers from 99 ISO member countries and liaison organizations, including the OECD (Organization for Economic Cooperation and Development), UN Global Compact and UNIDO (United Nations Industrial Development Organization) [16]. The underlying motivations to attend the process are manifold. For practitioners, the dependence on external knowledge is a reason to participate at a standardization process and thereby standardization is a form of knowledge sourcing [17]. In addition, other studies refer to the positive effects of a participation in standardization, such as an increasing knowledge base and the influence on future developments [18–21]. The participation at the standardization process is even described as a special form of research and development collaboration or an open innovation space [1,21]. Thus, multi-stakeholder standardization processes are one way to foster the diffusion of the standard inherent knowledge among practitioners and researches. Additionally, other ways are national and international bodies of regulations. They use management standards to enforce their regulations, e.g., the European Directive 2014/95/EU recommends among others the Eco-Management and Audit Scheme (EMAS) to report on non-financial information. The elaboration of knowledge and a common understanding on an international level makes international management standards a valuable instrument. In the same vein, Murmura and Bravi (2017) study the perception of different international management studies for (end-) customers [22]. Overall, this illustrates that management standards and their inherent topics affect not only the users who implement the standards (e.g., companies), but also government agencies, international federations, researchers and other stakeholders.

Due to their characteristic of compromising verified knowledge—standards can serve as a basis for further scientific discussions. Thus, they are also a knowledge diffusion channel, which are useful to researchers. Therefore, we wonder if and how international management standards are able to influence the scientific community and to stimulate scientific discussions. Academic literature, i.e., journal publications, are an important output of scientific discussions. The question arises how international management standards affect in particular the academic literature and vice versa. To our knowledge, only sparse literature exists in this field. The review and research agenda developed by Heras-Saizarbitoria and Boiral [13] states that the existing literature on management standards focuses on the creation and international diffusion of management standards, motivations and

benefits of their adoption or integration as well as consultancy auditing aspects regarding these standards. In addition, other reviews show that the main objectives of current studies regarding international management standards are: Sustainability and Corporate Social Responsibility; strategy, performance and innovation; motivations, benefits and difficulties for implementation as well as maturity-based thinking [23,24]. With regard to interdependencies of standardization and scientific publishing Zi and Blind [4] analyzed how the participation in standardization affects researchers' publication performance. Raven and Blind [25] studied the citation behavior of articles referenced by standards developed by the BioSharing standardization consortia. Their findings show that these publications have a higher number of citations than a comparison sample. However, these studies focus on technological product or process standards. Hence, our research aims to contribute to the knowledge about the interdependencies of international management standards and the academic literature. As described above, technical standards have a vivid role within the research process and thereby for the academic literature. International management standards, in particular, are in the position to stimulate the academic literature of social sciences, in particular management and economics. Moreover, since they affect the process of all business operations, they also shape the research process. As a result, research departments of companies and research institutes can apply certain international management standards. Quality management standards, for example, are able to optimize quality-related processes and enhance thereby an organizations efficiency [9].

Hence, this research enlarges the literature by making a first attempt to analyze the relation between international management standards and the academic literature with the example of quality and environmental management. The main research questions are: (1) How do researchers use management standards in their scientific publications? (2) Are standards able to diffuse knowledge within the scientific community? In other words, we analyze the effect of standards on the academic literature, i.e., if publications addressing international management standards are more likely to lead to follow-up research than comparable scientific publications measured by the impact on average citations. To do so, this research focuses on two quality management standards (ISO 9001 and EFQM Excellence Model) and two environmental management standards (EMAS regulation and ISO 14001). Additionally, the different characteristics of the standards, in terms of content, requirements and number of certifications enable comparative analyzes.

This article is structured as follows: the next section will elaborate the theoretical framework and develop the propositions. In Section 3, we introduce our data and the summary statistics followed by Section 4, which presents the empirical model and discusses the results of the empirical analysis including the derivation of the implications of our results. Finally, the paper ends in Section 5 with conclusions of our research and suggestions for future activities.

2. Framework Regarding the Effects of Standards on the Academic Literature

This chapter aims to derive propositions guiding the investigation about the impact of international management standards on the academic literature. For that reason, we present the four investigated international management standards followed by a discussion on general considerations about standards and their role within the academic literature.

2.1. Introduction of the Investigated International Management Standards

This section briefly presents the characteristics of the four investigated standards (see summary in Table 1). Our analyzes include two standards developed by the International Organization for Standardization (ISO), namely ISO 9001 (quality management system) and the ISO 14001 (environmental management system). The ISO, founded in 1947, is an independent, non-governmental and international standard setting organization with 161 member countries, which provides specifications, guidelines and up to more than 20,000 international standards [26]. The two selected ISO standards are the paragon for a successful diffusion of standards, measured by the number of worldwide certifications [13,27]. A European counterpart for ISO 9001 is provided by the

European Foundation for Quality Management (EFQM), they introduced the EFQM Excellence Model (EEM) [28]. The European equivalent to ISO 14001 is the Eco-Management and Audit Scheme (EMAS). All standards address organizations, regardless of their size, industry sector and legal form.

Table 1. Overview on the discussed international management standards.

	ISO 9001	EFQM Excellence Model	ISO 14001	Eco-Management and Audit Scheme (EMAS)
Publisher	International Organization for Standardization (ISO)	European Foundation for Quality Management	International Organization for Standardization (ISO)	European Commission
First Publication	ISO 9000:1987	1991	ISO 14001:1996	1993
Certifiability	Certification by external certification bodies (Auditors)	Internal (Self-Assessment) or external Assessment	Certification by external certification bodies (Auditors)	Certification by Accredited environmental verifiers
Users in 2015	Europe: 439,477 Worldwide: 1,033,936	Europe: over 30,000 organizations *	Europe: 119,754 Worldwide: 319.324	Europe: 3928
Relation to the other standards	Refers to ISO 14001	Similarities to ISO 9001, based on PDCA, like ISO 9001 and ISO 14001	Refers to ISO 9001	Integrates the ISO 14001, based on PDCA, like ISO 9001 and ISO 14001

* = Year unknown.

2.1.1. ISO 9001

ISO 9001 is embedded in standard family, namely ISO 9000. The family includes standards and guidelines for codes of conduct, complaints handling in organizations or for quality plans to name just a few. Whereas ISO 9000 provides fundamentals and vocabulary, "ISO 9001:2015 Quality management systems—Requirements" provides a reference model for implementing quality management system to ensure consistent quality of an organizations products and services [29]. The first version of the ISO 9001 was launched in 1987 and in 2015; more than one million organizations worldwide are certified [30]. ISO 9001 and ISO 14001 are compatible and therefore have similarities according to their structure and philosophy: both integrate the Plan-Do-Check-Act (PCDA) cycle and both offer procedures on how to implement the certain management system [31]. Consequently, the academic literature analyzed different common aspects of these standards, like motives for implementation [32], their diffusion [27,31] and their effects to the implementing organization [33,34].

2.1.2. EFQM Excellence Model

In 1988, 14 European companies initiated the founding of the European Foundation for Quality Management (EFQM) with the objective to "increase the competitiveness of European organizations and support the sustainable development of the European economies" [35]. They developed the EFQM Excellence Model (EEM) introduced in 1992. EEM is a comprehensive management framework aiming to enhance the overall performance of organizations and is used by over 30,000 organizations. It follows a similar logic like the concept of total quality management (TQM) [36]. Analogical to EMAS, EFQM provides documents and even webinars to inform stakeholders about the distinction between EEM and ISO 9001 [37]. EFQM states, that ISO 9001 and EEM can be combined, especially since EFQM has a more holistic view, while ISO 9001 focuses on the consistency of quality for customers. The academic literature discusses the similarities of EFQM and ISO 9001. Heras-Saizarbitoria et al. [38] studied the motives and results of the implementations of EFQM and ISO 9001. Thus, the implementation of ISO 9001 leads to improvements in the efficiency and internal control of organizations and EEM directs towards an improved view of the organization as a whole [38]. Bayo-Moriones et al. [39] study the standards and infer that the EEM is more convenient to foster innovative practices than ISO 9001. In contrast to ISO 9001, the EEM is not certifiable. Instead, EFQM offers the assessment of the level of excellence concerning the EEM [37]. Therefore, an organization can choose between internal (self-assessment) or external assessment, by an EFQM assessor. EFQM provides a set of instruments to conduct the self-assessment, for instance, a questionnaire. Trained assessors conduct the external assessment, which results in the label "EFQM Committed to Excellence", "EFQM Recognized to Excellence" or "EFQM Excellence Award", depending on the intensity of the assessment.

2.1.3. ISO 14001

The ISO 14001 is embedded in the "ISO 14000—Environmental management" standards family. The ISO 14000 family includes over 20 different documents, which support the ISO 14001 and concerning various issues, like environmental labels and declarations, greenhouse gas (GHG) accounting and verification and environmental aspects in product standards [40]. The first version of ISO 14001 was launched in 1996 and provides a framework for an environmental management system (EMS). It is an international, certifiable standard and is with more than 300,000 certified companies in more than 170 countries the most recognized standard in its area [29] (International Organization for Standardization (ISO) 2016b). Thereby, ISO 14001 is the core of the ISO 14000 family.

2.1.4. EMAS

The Eco-Management and Audit Scheme is based on EU-Regulation 1221/2009 [41] and was developed in 1993 by the European Commission (EC). The EC designed EMAS as premium management instrument to enhance the environmental performance of organizations and can be certified through an accredited or licensed environmental verifier). ISO 14001 and EMAS are both environmental management standards (EMS) with the purpose of enhancing the environmentally friendly practices. The uptake rate of EMAS regulation is much lower than that of ISO 14001 due to its focus on the member states in the European Union [42], but in 2009, EMAS was extended to non-EU countries. Hence, EMAS and ISO 14001 show various similarities in content and effect, which has been the subject of research [43–46]. The EC published several documents to distinguish between EMAS and ISO 14401 [47–49]. Accordingly, EMAS integrates ISO 14001 in the appendix and even goes beyond it. Testa et al. [45] confirm the superiority of EMAS in comparison to ISO 14001, by proving that ISO 14001 serves as a good basic environmental tool, which enhances an organization's long-term environmental performance especially in combination with the additional adoption EMAS. In addition, Neugebauer [46] concludes that in the future ISO 14001 could develop as a global industrial standard and EMAS in the direction of a premium standard.

2.2. The Role of (International Management) Standards for Academic Literature

Applying the technology transfer model of Bozeman [6] Blind and Gauch [5] establish on the one hand that standardization and standards are an additional channel of knowledge and technology transfer. On the other hand, they specify the various functions of different types of standards for the phases of research and innovation following Tassey's approach of standards as technology infrastructure [50]. Whereas Blind and Gauch [5] specifying the role of standards in innovation management focus on technological standards and the related development of specific technologies, we transfer this approach to international management standards. In detail, we assume that these types of standards provide the basis for subsequent management research.

The relation between the research process in science and technology and standards is more tangible than in the case of international management standards. However, management standards also affect the research of their respective fields. For example, the ISO 14001 could stimulate research about environmental management. In addition, the investigated management standards are applicable for various industry sectors. Therefore, those standards could also affect other research disciplines. EFQM, in particular, is often applied within the healthcare sector [51,52].

During this study, we could identify three main functions of international management standards within the academic literature. The first function is standards as an "object of study", for example To and Lee [53] study the diffusion patterns of ISO 14001. Other studies analyze EMAS and the factors, which influence the implementation of the standard [54] as well as the effect of the motives and barriers on the perceived benefits of EMAS implementation [55]. Boiral et al. even analyze 94 other papers on the effectiveness of ISO 14001 in different dimensions [56]. As a second function, standards serve as sources for reliable definitions and explanations similar to terminology standards

in nanotechnology [5] biotechnology [25], or in the case of Life Cycle Assessment [57]. In the same vein, many studies examine the standard inherent topic and a certain standard served as a role model or simply as an example to emphasize the relevance of a certain research question. Rinaldi et al. for example, provide a new method to measure the water and carbon footprint and they prove the importance of those indicators by illustrating that a standard of the ISO 14000 family requires those indicators [58]. Also, Singh et al. use different environmental management standards as examples to describe environmental management system practices [59]. Since international management standards are developed through a multi-stakeholder process, the use of standards as a trustworthy source of information is evident. Another function of standards is to identify research samples of companies or organizations. On the example of ISO 14001 this means, the studies examined the relation of an environmental management system and firm performance—ISO 14001 is used to identify companies with an environmental management system, like in the case of Abidin et al. [60]. Their research is about the impact of stakeholder integration on environmental sustainability performance. They identified environmentally orientated companies with the help of ISO 14001. Function one fosters research on standards and comparable disciplines, like diffusion patterns and impacts of standards on their inherent topic. Function two triggers further research on the standard inherent topics—especially if the standard serves as a role model. Finally, function three enables new scientific propositions within related topics. Additionally, as previously noted, the particular importance of international management standards is visible through the huge efforts to develop them. International management standards with social implications, in particular, employ a large body of stakeholders and thereby legitimate and at the same time diffuse the standard inherent topic in a different manner than technical standards. Moreover, management standards do not only have an effect to a single technical process but instead on the whole value chain of an organization. Therefore, it is reasonable to ask: Do international management standards affect the knowledge flows within the academic research and consequently literature? Due to the outstanding role of management standards, we argue that research publications addressing these standards have a higher impact on the academic literature than comparable publications. The following proposition derives:

P1: Scientific publications, which address international management standards, generate more forward citations than comparable scientific publications.

Since standards foster their inherent topic, it is most likely that international management standards have a major influence on the research about management practices, thus the economic and management literature. Indeed, standards could also be relevant for other research domains. Standards are developed by and for practitioners, in this way, they could have an impact on applied sciences. Thereupon, Zi and Blind [4] find that researchers involved in formal standardization tend to publish less often in journals with a high scientific reputation but instead more often in applied and industry- related journals. The four international management standards investigated within this research not only influence an organization as a whole including all kinds of departments, but they are also not limited to a certain sector. Therefore, we address the question as to whether standards have a particular relevance for a certain research field. It follows:

P2: The impact of scientific publications, which address international management standards in contrast to comparable publications, depends on the research field.

The following two propositions focus on the comparison of the standards based on their characteristics. In Chapter 2.1. we described the investigated standards. Thereby, EMAS and EFQM Excellence Model proved to demand higher requirements than their equivalents ISO 14001 and ISO 9001. At the same time, it is obvious that ISO 14001 and ISO 9001 show a much higher user rate. One reason is the European focus of EMAS and the EFQM Excellence model, but even compared to the European base, ISO 14001 has thirty times more certifications than EMAS and ISO 9001 has thirty-four times more users than the EEM. Another explanation would be the adoption of the theory

of success breeds success [61] to standards. In other words, standards used by a large number of organizations, are more likely to be used again than a rarely used one. A third reason is the influence of the institution—in this case the standard setting organization (SSO) [62]. Furman and Stern [63] explore the role of research-enhancing institutions on the accumulation of knowledge. The policy and reputation of ISO, EC and EFQM affect the adoption of the standard and its effects on the literature. Thus, positive spillover effects to the academic literature, because of the high public awareness of ISO and its standards ISO 9001 and ISO 14001, are conceivable. Therefore, the question arises whether the quality of a standard measured by their requirements or the user rate of a standard has a greater impact on the diffusion within the academic literature. Consequently, the two propositions derived:

P3: Scientific publications, which address international management standards with high requirements, generate more forward citations than those, which emphasize international management standards with basic requirements.

P4: Scientific publications, which address international management standards with high user rate, generate more forward citations than those, which address international management standards with a low user rate.

3. Data Source and Methodology

This chapter presents the data collection and the method to create the matching data. Subsequently, it presents some basic descriptive statistics.

3.1. Data Sources

To answer the research questions this study uses bibliometric data from Scopus. Scopus is Elsevier´s abstract and citation database [64]. To identify articles, which relate to certain standards Raven and Blind [25] concentrated on citations to articles referred to by standards relevant for biotechnology. They follow the approach developed by Rysman and Simcoe [65], who analyze citations of patents disclosed during the standardization process. Glänzel and Zhou [66] exceed this by not only considering papers cited by patents but also papers citing patents. Neither of the investigated international management standards refers to academic literature, like the majority of the international standards (Fenton et al. 2018). Thus, to identify standard-related articles, this research focuses on publications that refer to one of the standards. We developed a set of keywords to identify 'articles', 'articles in press' and 'reviews' from 1985 to 2017, which deal with at least one of the standards ISO 14001, EMAS, ISO 9001, and EFQM. Thereby, it is possible to distinguish the publications according to mentioning one or two of the standards 'only in the references', 'only in Title-Abstract-Keywords' or 'in both'. Additionally, we restricted the search request to publications in English and only journal publications. The Scopus API (application programming interface) enabled a comprehensive search request, which resulted in 15,578 publications in total. An additional quality check by hand was necessary to guarantee, that the publications actually deal with one of the standards and not using the same abbreviation for another content. However, many articles mention one of the standards in the Title-Abstract-Keywords but not in the references and vice versa. On the example of ISO 14001 that means, we found 298 articles, which mentioned the standard in the Title-abstract-keyword but not in the references. In addition, the referenced documents are often not the standards themselves, but instead publications about the standards. For this reason, we use only publications addressing one of the standards within Title-Abstract-Keywords for the further research. In this way, we included all three functions of standards in the academic literature, except from merely mentioning one of the standards within the text body. In this case, we assume that the contribution of the standard for the research is only minimal.

3.2. Data Set Creation

Regarding the examining of the propositions, we use scientific articles and reviews as defined units of knowledge. These units should include publications addressing standards and comparable publications, which are not addressing standards. In other words, this implies that the set of publications addressing standards (original set) is extended by a comparable set of most-related publications (matching set). Figure 1 illustrates the procedure to identify the most-related publications for each publication of the original set. An algorithm was designed which firstly, collects all articles not referring to one of the standards in the same journal and publication year. Secondly, the algorithm seeks for articles with the same number of authors to mitigate against the risk of self-citation. If no article was found with the same number of authors, the number of authors is extended by plus/minus one author. Finally, we measured the content conformity of articles through a comparison of the title, abstracts and author keywords similar to the search algorithm of the National Library of Medicine (NLM) [25,63]. The content similarity was conducted via text mining (with the weights: Article 0.5; Title: 0.3; Keywords: 0.2). There is no match if no other article in the same journal and the same publication year or no other article with plus/minus one authors exists. Likewise, there is no match if there is neither an abstract nor author keywords available for the original article.

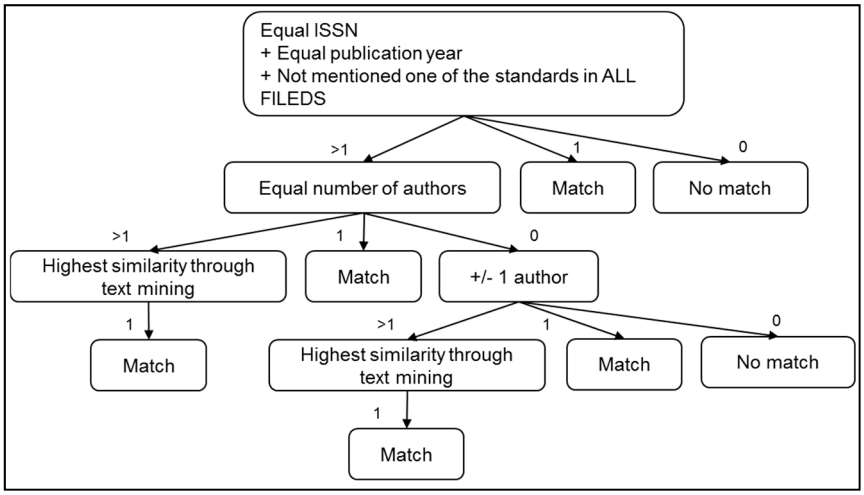

Figure 1. Procedure to find a most related publication.

Table 2 provides an overview of the dependent and independent variables applied in our research. The descriptive analysis in the form of diagrams resorts to the forward citation. The average forward citations are essential for the multivariate analysis. For propositions P1 to P4 the average forward citations serve as a dependent variable. In order to examine our propositions, we use the following explanatory variables. Firstly, to test the basic assumption (P1) the variable "publication addresses standard(s)" enables us to differentiate between the articles, which address standards (original set), and those which not (matching set). Additionally, the variable "No of addressed standards" refines the before mentioned variable by adding the number of standards addressed by a publication. Secondly, the standard type indicates which standard respectively standard combination the publications address. Furthermore, we condensed this variable into publications addressing high or low-quality standards or a mix of both (P3). The same is done to answer P4, but instead of the standards quality the variable was condensed according to the user rate of the standards. The age of a publication and the number of authors could influence the number of citations. Therefore, we control for these variables. In addition, we control for the journal domain, because of possible different publication behaviors of the research domains and fields. To delineate the domains and fields we use the journal-level taxonomy offered by Science Metrics. Archambault et al. [67] developed the ontology based on existing best-practice taxonomies. Consequently, the matching process and the classification according to the journal domain

decreased the data set from 3498 to 2274 publications; with the most related publication, the final data set equals 4548 units of knowledge.

Table 2. Overview of the dependent and independent variables.

Dependent Variables	Description	Source
Average forward citations	Number of forward citations from publication date to year t divided by the age of the publication	Scopus
Forward citations $_{jt}$	Number of forward citations j in year t	Scopus
Independent variables	**Description**	**Source**
Publication addresses standard(s)	Dummy variable: 1 = addresses at least one standard; 0 for matching group	Scopus
No of addressed standards	Declares how many standards are mentioned by the publication	Scopus
Standard type	Declares on which standard(s) the publication focuses	Scopus
Publication uses high quality standard	3 = high Quality standard; 2 = mixed publication of high and low quality standard; 1 = low Quality standard; 0 = no standard	Scopus
Publication addresses standard with a high user rate	3 = standard with a high user rate; 2 = mixed of high and low user rate standard 1 = standard with a low user rate; 0 = no standard	Scopus
Publication year	Year in which article j is published	Scopus
Age	Year t − Publication Year	Scopus
No of authors	Number of the publishing authors	Scopus
Journal domain classification	1 = Applied Sciences 2 = Arts & Humanities 3 = Economic & Social Sciences 4 = General 5 = Health Sciences 6 = Natural Sciences	Science Metrix Journal Classification

3.3. Summary Statistics

This section portrays the basic picture of the data set and offers a first glance how management standards diffuse within the academic literature. Figure 2 shows the frequency of articles between the first publication in 1988 until 2017. It is obvious that publications addressing ISO 9001 represent the majority followed by ISO 14001. This is line with expectations because the ISO standards have an international audience and much more users around the world. Although, post-millennial the number of publications addressing ISO 9001 decreases.

Likewise, in Table 3 shows that the average citations of ISO 14001 alone and in combination with other standards stands out. Meanwhile, the total and average citations of EMAS, ISO 9001 and EFQM fall below their matching group. However, the average citations of all publications addressing standards 15.85 are higher than the one of the matching set 12.99. Considering the proportions of publications, which are cited at least once the disparity between the original and the matching sets differs by a maximum of four percent. Therefore, the average citations are comparable. The mean age 13.64 years of ISO 9001 shows the former publication boom with a current decreasing tendency. On average, the youngest publications are those addressing ISO 14001 and EMAS in combination. The mean number of authors is with between 2.34 and 3.02 rather low in comparison to other studies [25].

Figure 3 sheds light on the importance of literature about standards in different domains. As expected, the most publications are in economic and social sciences followed by applied, natural science and health science whereas arts and humanities as well as general science published nearly no articles related to the investigated international management standards. Therefore, the former journal domains are worth a deeper investigation.

Table 3. Summary statistics of the independent and dependent variables.

	Mean Publication Year	SD Publication Year	Min Publication Year	Max Publication YEAR	Mean Age	Max Age	Mean Number of Authors	SD Number of Authors	Max Number of Authors	N *
ISO 14001	2007.57	6.297	1994	2017	10.43	24	2.55	1.44	11	855
EMAS	2006.53	7.93	1994	2017	11.47	24	2.69	1.74	9	91
ISO 9001	2004.36	7.30	1988	2017	13.64	30	2.34	1.74	48	2309
EFQM	2009.31	5.95	1989	2017	8.69	29	2.93	1.94	14	440
ISO 14001 & EMAS	2007.53	6.24	1995	2017	10.47	23	2.82	1.63	10	114
ISO 14001 & ISO 9001	2008.65	6.48	1995	2017	9.35	23	2.62	1.19	6	266
ISO 9001 & EFQM	2007.26	5.73	1997	2017	10.74	21	3.02	1.86	9	46
All publications addressing standard(s)	2005.99	7.14	1988	2017	12.01	30	2.49	1.68	48	4130
	% of Publications Without Citations	**Mean Total Citation**	**SD Total Citation**	**Max Total Citation**	**Mean Average Citation**	**SD Average Citation**	**Max Average Citation**	**N**		
ISO 14001	0.23	22.16	51.50	779	2.29	4.234	59.92	855		
	*0.27**	14.29	28.49	368	1.57	2.68	24.53	855		
EMAS	0.21	12.22	27.83	165	1.22	2.30	16.11	91		
	0.29	15.32	38.70	256	1.26	2.40	14.22	91		
ISO 9001	0.28	12.96	29.87	536	1.10	2.33	35.70	2309		
	0.32	12.28	28.17	353	1.01	2.14	29.83	2309		
EFQM	0.21	12.98	22.94	217	1.29	2.01	24.11	440		
	0.29	12.09	26.49	277	1.16	2.02	16.29	440		
ISO 14001 &	0.11	29.34	47.13	218	2.75	3.69	16.58	114		
EMAS	0.15	17.10	27.28	220	1.99	3.02	21.75	114		
ISO 14001	0.26	20.56	40.52	376	2.20	3.51	22.12	266		
& ISO 9001	0.29	13.12	28.96	339	1.40	2.48	24.21	266		
ISO 9001 &	0.13	17.04	15.87	49	1.73	1.70	7.00	46		
EFQM	0.22	13.98	22.01	124	1.22	1.75	10.33	46		
All	0.30	15.85	36.21	779	1.49	2.97	59.92	4130		
publications addressing standard(s)	0.25	12.99	28.38	368	1.20	2.32	29.83	4130		

* = italic numbers present the value for the comparison group.

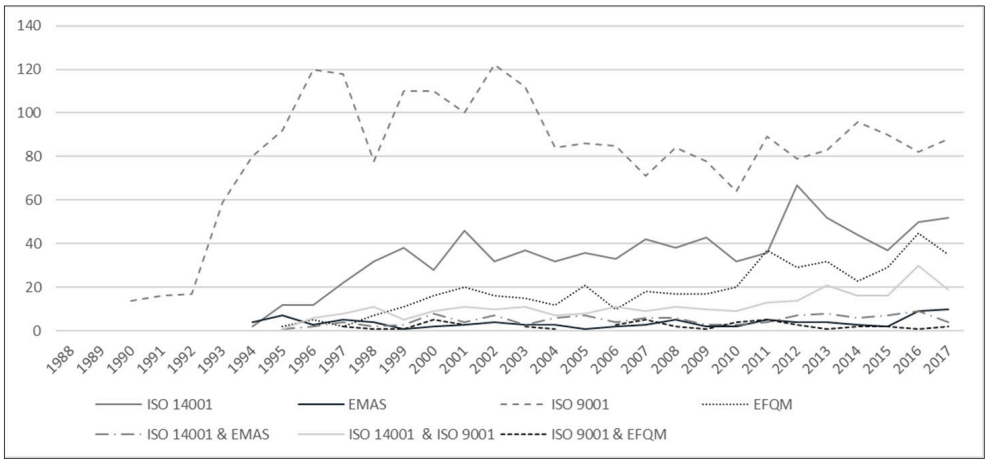

Figure 2. Publications from 1988 to 2016.

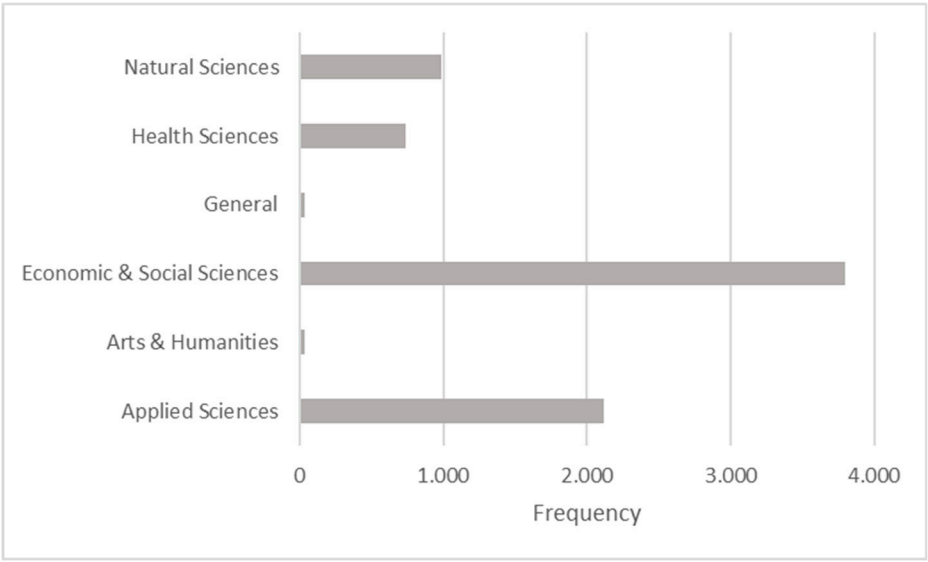

Figure 3. Publications separated by Journal domain.

4. Empirical Analysis

Section 4 describes the empirical model and the methodology for the analysis. Subsequently, the empirical results are presented.

4.1. Empirical Model

We assembled a baseline formal model to analyze the effect of management standards to the academic literature executed by regression techniques. The "average citations" is a count variable. Thus, either Poisson or negative binomial model qualify for the regression. Due of the overdispersion (see Table 4) we use a negative binominal model. Our baseline model tests the first proportion and can be described as follows:

Baseline model a:

$$\begin{aligned} &\textit{Average forward citations}_{jt} \\ &\quad = \propto_{1j} \ \textit{publication addresses standard}_j + \propto_{2j} \ \textit{age}_j \\ &\quad + \propto_{3j} \ \textit{number ot authors}_j + \propto_{3j} \ \textit{journal domain}_j + \epsilon_j \text{ with j} \\ &\quad = 1, \ldots, \text{n}; \ t = 1, \ldots, n \end{aligned} \tag{1}$$

The average forward citations of the publications as a function of the explanatory variable "publication uses standard$_j$" and the control variables age$_j$, number of authors$_j$ and journal domain$_j$. A variation of the baseline model includes the "number of addressed standards" as refinement of the variable "publication uses standard$_j$".

Baseline model b:

$$\begin{aligned} Average\ forward\ \ & citations_{\ jt} \\ & = \propto_{1j}\ number\ of\ addressed\ standards_j + \propto_{2j}\ age_j \\ & + \propto_{3j}\ number\ ot\ authors_j + \propto_{4j}\ journal\ domain_j + \epsilon_j \text{ with j} \\ & = 1, \ldots, \text{n};\ t = 1, \ldots, n \end{aligned} \tag{2}$$

Next, we extended the baseline model in regard to answer P3 and P4. Firstly, we test which standard(s) cause the highest effect on the average citations. Secondly, we use the variable "Publication uses high-quality standard" to analyze the impact of quality respectively the user rate of a standard on the average citations. Since the quality and user rate are mutually exclusive variables, it is necessary to set up only one model.

Model 1-a

$$\begin{aligned} Average\ forward\ \ & citations_{\ jt} \\ & = \propto_{1j}\ standard\ type_j + \propto_{2j}\ age_j + \propto_{3j}\ number\ ot\ authors_j \\ & + \propto_{4j}\ journal\ domain_j + \epsilon_j \text{ with j} = 1, \ldots, \text{n};\ t = 1, \ldots, n \end{aligned} \tag{3}$$

Model 1-b:

$$\begin{aligned} Average\ forward\ \ & citations_{\ jt} \\ & = \propto_{1j}\ Publicadtion\ addresses\ high\ quality\ standard_j + \propto_{2j}\ age_j \\ & + \propto_{3j}\ number\ ot\ authors_j + \propto_{4j}\ journal\ domain_j + \epsilon_j \text{ with j} \\ & = 1, \ldots, \text{n};\ t = 1, \ldots, n \end{aligned} \tag{4}$$

Model 2a-d

$$\begin{aligned} Average\ forward\ \ & citations_{\ jtd} \\ & = \propto_{1j}\ publication\ addresses\ standard_j + \propto_{2j}\ age_j \\ & + \propto_{3j}\ number\ ot\ authors_j + \epsilon_j \text{ with j} = 1, \ldots, \text{n};\ t = 1, \ldots, n \end{aligned} \tag{5}$$

The last model (2a-d) examines the difference between publications addressing a standard and their matching sets within a certain journal domain. Essentially this model is similar to the baseline model, but against the following journal domains: applied science, economic & social science, general and health science. This implies that for this model only age and the number of authors serve as control variables.

4.2. Empirical Results

Turning the attention to the results of the baseline model in the first row of Table 4, publications addressing a standard have significantly higher average forward citations than those that are not addressing a standard. The average marginal effect states the average increase or decrease of the dependent variable if an independent variable changes by one unit, other variables equal. In this case, this implies that a publication addressing a standard has on average 0.28 citations more than those, which do not address a standard. The refinement of the baseline model confirms the results. Publications addressing one standard as well as publications addressing two standards receive significantly more citations Thereby publications addressing two standards stand out. They have on average 0.64 citations more and publications addressing one standard 0.15. Row three offers an even more revealing insight by distinguishing between standards and combinations of standards. Publications significantly profit the most by referring to ISO 14001. Those publications have 0.83 more

citations than those not addressing a standard. This effect even increases even more if ISO 14001 is used in combination with other standards. The highest enhancement triggers the combination of ISO 14001 and EMAS with 1.18 more average citations followed by ISO 14001 and ISO 9001 (0.78 more average citations). This is not surprising since row two already highlighted the effect of addressing two standards in the same publication. However, ISO 9001 causes significantly lower average citations, i.e., −0.12 less citations compared to the matching set. Since the number of papers addressing a certain standard vary a lot from 91 "EMAS papers" to 2309 "ISO 9001 papers", we also tested the model for the subsamples of only the standards and the matching sets. The significance of the results also holds for the sub samples. EMAS, EFQM as well as ISO 9001 and EFQM in combination show no significant effect. This is a first evidence that the influence of the quality of a standard measured by the level of requirements on the average citations is doubtful. Consequently, row 4 reports no significance for publications addressing either EMAS or EFQM. At the same time, this implies that publications addressing standards with a low user rate have no significant influence on the average forward. Albeit, the combined group (ISO 14001 and EMAS as well as ISO 9001 and EFQM) has a significant influence.

The publications addressing a standard with lower requirements alias the once with a high user rate (ISO 14001 or ISO 9001 or ISO 14001 in combination with ISO 9001) have a significant effect. An explanation is that the brand awareness of the practitioner's community leaps to the scientific community [68]. Overall, the overdispersion is approved, since the alpha test is significant for all models at a 1% level. Hence, the application of a negative binomial model was the proper choice.

Table 5 examines the influence of standards within four different scientific domains. Therefore, we split the entire data set into four journal domains and we calculated for each domain the influence of publications addressing standards versus the matching set. The results show that the standards have no effect within journals in the domain of applied science and in natural science. A significant effect is apparent for economic & social science, health science and natural science. Thereby, a publication addressing standard(s) obtains on average −0.49 fewer citations within health science. However, a publication in a journal of economic and social science can expect 0.37 more average citations than those without addressing a standard [25,63]. In conclusion, through the condensed treatment of the data in the baseline model the different effects standards within the journal domain blend to insignificance. Consequently, the results related to P2 show that the research field matters. Likewise, to the former models, also for Table 5 the assumption of the negative binominal model holds, because of the significant test for alpha.

Table 4. Negative binomial model based on publications addressing standards and most related articles.

	Negative Binomial Model (Base a)	**Negative Binomial Model (Base b)**	**Negative Binomial Model (E1-a)**	**Negative Binomial Model (E1-b)**
	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line
Publication addressed at least one standard	0.2830664 **0.2080828** *** 0.033777			
1 standard addressed		0.201242 **0.1488751** *** 0.0347635		
2 standards addressed		0.8659457 **0.6406104** *** 0.0733075		
ISO 14001			0.8319272 **0.6291314** *** 0.0535179	
EMAS			0.0330867 **0.0250213** 0.1724702	

Table 4. *Cont.*

	Negative Binomial Model (Base a)	**Negative Binomial Model (Base b)**	**Negative Binomial Model (E1-a)**	**Negative Binomial Model (E1-b)**
	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line
ISO 9001			−0.118706 **−0.0897695** ** 0.0406277	
EFQM			0.0101019 **0.0076394** 0.0771363	
ISO 14001 & EMAS			1.18444 **0.957137** *** 0.5893234	
ISO 14001 & ISO 9001			0.7792873 **0.5893234** *** 0.0897267	
ISO 9001 & EFQM			0.3460878 **0.2617233** 0.2198989	
Low quality standard				0.2753112 **0.2032519** *** 0.0352738
mixed				1.000888 **0.7389176** ***
High quality standard				0.1157681 0.00982449 **0.0069917** 0.0725305
Journal Domain Dummies	Yes	Yes	Yes	Yes
Age	Yes	Yes	Yes	Yes
Number of authors	Yes	Yes	Yes	Yes
Observations	7704	7704	7704	7704
Pseudo R2	0.0119	0.0139	0.0205	0.0132
Log likelihood	−12358.994	−12334.588	−12251.512	−12342.785
Test of alpha = 0	**1.445008** *** 0.0372545	**1.428959** *** 0.0370117	**1.374856** *** 0.0361903	**1.433877** *** 0.0370927

*** Significance at the 1% level. ** Significance at the 5% level. * Significance at the 10% level.

Table 5. Negative binomial model based on publications addressing standards and most related articles separated by journal domain.

	Negative Binomial Model	**Negative Binomial Model**	**Negative Binomial Model**	**Negative Binomial Model**
	Applied Science	**Economic and Social Science**	**Health Science**	**Natural Science**
	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line	Average Marginal Effects in top line **Coefficient in 2nd line** SE in bottom line
Publication addressed at least one standard	0.0163321 **0.0176254** 0.0735041	0.3675815 **0.3510436** *** 0.0446981	−0.4930336 **−0.324584** *** 0.1087593	0.0300039 **0.1691395** * 0.0871832
Journal Domain Dummies	No	No	No	No
Age	Yes	Yes	Yes	Yes
Number of authors	Yes	Yes	Yes	Yes
Observations	2118	3796	736	984
Pseudo R2	0.0244	0.099	0.0192	0.0355
Log likelihood	−2820.6433	−6444.5868	−909.88623	−1801.389
Test of alpha = 0	**1.752871** *** 0.0942778	**1.228042** *** 0.0446913	**0.8973339** *** 0.1095971	**1.27657** *** 0.0870357

*** Significance at the 1% level. ** Significance at the 5% level. * Significance at the 10% level.

5. Discussion

This research studied the relation between international management standards—ISO 9001 as well as ISO 14001 and their 'European counterparts' EMAS and the EFQM Excellence model—and the academic literature. Firstly, we studied how scientists use standards in their research. We distinguished between three main functions of standards in publications: (1) object of study, (2) standards serve

as sources for reliable definitions and as role models, or (3) to identify samples of companies or organizations.

Secondly, we studied the knowledge diffusion ability of international management standards towards the academic literature. Average forward citations of publications were used as an indicator for the relevance and interest of the scientific community in certain topics. We used publications addressing at least one of the standards and a set of comparable publications to examine if publications addressing international management standards have a higher relevance (alias higher average forward citations) than the comparable sample. By the means of a negative binominal regression, we could also calculate the effect within different journal domains.

The explanatory research approach showed that publications addressing standards have a significant effect on the citation behavior of the academic literature. This means for example that a paper on environmental management, which addresses the ISO 14001 receives higher average forward citations than another one on the same topic, which does not address the standard. A more precise insight into the research question revealed different effects. The results of the separation of the publications by standard type show that ISO 14001 is most likely to trigger follow-up research, measured by the impact on average forward citations. It follows that articles dealing with a certain research question related to environmental or management system issues are more likely to be referenced if they referring to ISO 14001. Thus, publications on ISO 14001 seem to attract the interest of more researchers than comparable publications. As possible reasons serve the popularity of the standards, measured by their number of certifications and the influence of the SSO, i.e., ISO. In combination with EMAS or ISO 9001, the average forwards citations are even higher. In other words, it seems that ISO 14001 and the other standards are mutually reinforcing their attractiveness for researchers. ISO 9001 alone however, has the opposite effect on the average forward citations, i.e., publications addressing ISO 9001 have on average less forward citations than comparable ones. In addition, the decreasing number of publications addressing ISO 9001 reflects the minor interest in publications. It seemed that pre-millennial the reference of ISO 9001 was inflationary. For EMAS and EFQM we found neither of the aforementioned effects. Thus, especially ISO 14001 as international management standard is capable to foster the knowledge transfer of the standard inherent topic and to stimulate new research, but not the European counterparts. However, a closer look at the journal domains exposed that only within the field of economics and social sciences, international management standards turned in to a significantly positive effect. In contrast, health science presented a negative effect of international management standards on the average forward citations compared with the matching set. This highlights the predominant impact of international management standards on economics and social sciences. Within this domain, standards are a source of knowledge, which seem to stimulate the scientific discussion successfully.

The results show how international management standards foster the academic research progress and how they can lead to knowledge sourcing benefits. Thereby, our research mainly contributes to the scientific community and Standard Setting Organizations. Consistent with the findings of Blind and Gauch [5] and Raven and Blind [25], SSOs should reconceive their function within the academic community to foster the research progress of the standard inherent topics. In this vein, the ISEAL alliance (network of sustainability standard setting organizations) elaborated a 'Research Agenda' to guide research about sustainability standards [69]. Likewise, other SSOs could provide agendas to trigger research. Our research also implies and confirms the importance of standards for the scientific community. This refers to standards as a research object in general but also as a source of practical and comprehensive knowledge and trends. Hence, researchers should monitor and if possible even participate in the standardization process in order to gain as well as spread knowledge.

However, this study analyzes only four management standards and thus limits the generalizability of the results. Due to this case study like approach, the comparison between the effect of international and European standards can only provide a first presumed tendency. For a more convincing comparison between different standard types and topics, more standards have to be examined.

For results that are more robust, future studies should also use supplementary methods, like interviews and questionnaires with researchers. In this way, questions related to the motivations to address standards within their research could be analyzed. In addition, we did not take other factors -such as the stakeholders involved in the standardization process- into account. Hence, subsequent studies should involve further factors.

Further research should deepen the investigation of the functions of international management standards within the academic context. Therefore, researchers could examine whether the impact on the academic literature can serve as an indicator for the success and legitimation of a certain standard. In the same line, the spillover effects of the policy and properties of SSOs to the academic research process within the standard inherent topic should be analyzed.

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