Global trends in Environmental Management System and ISO14001 research

Hengky K. Salim[a], Rory Padfield[b,*], Sune Balle Hansen[c], Ali Yuzir[a], Shaza Eva Mohamad[a], Khadijah Syayuti[a], Mun Hou Tham[a], Effie Papargyropoulou[d]

[a] Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia (UTM), Kuala Lumpur, Malaysia

[b] Department of Social Sciences, Oxford Brookes University, Oxford, United Kingdom

[c] UTM Palm Oil Research Center, Universiti Teknologi Malaysia (UTM), Kuala Lumpur, Malaysia

[d] Anglia Ruskin University, Global Sustainability Institute, Cambridge, United Kingdom

[*] Corresponding Author. Email: rpadfield@brookes.ac.uk. Tel.: +44 (0) 1865 483740

Abstract

The International Organization for Standardization (ISO) 14001 Environmental Management System (EMS) standard provides a guideline for an organisation to perform a continuous improvement to their environmental performance. In light of continued concerns over global environmental impacts and climate change, the ISO 14001 standard serves to demonstrate organisational commitment to sustainable production processes. The objective of our paper is to determine the thematic and geographical trends of published EMS research with a view of developing a coordinated and holistic research framework which can be applied to facilitate the adoption of ISO 14001 in developing and developed regions of the world. Drawn from a portfolio of 509 articles from the Web of Science database, this study investigates the global trends of ISO 14001 EMS research between 2000 and 2016. The results show a considerable increase in scientific publications; from 10 articles in 2000 to 58 articles in 2016. Three themes were identified from the analysis: socio-ecological (60 %), economic implications (25 %), and environmental aspects (15 %). In addition to a concentration of articles towards the socio-ecological theme of research, it is found that the majority of the published research derived from Europe (40 %), North America (21 %), and China (11 %). Articles authored by researchers from developing countries were poorly represented in the findings. In order to address the thematic and global imbalance of EMS research, a research framework is proposed that promotes multi-stakeholders inclusion (e.g. industry, academics, government, etc.), cross-

country research collaboration and a focus on demand-driven approach for problem solving and policy-making.

Keywords: environmental management system; ISO 14001; bibliometric analysis; thematic trends; multi-stakeholder framework

1. Introduction

The exponential rise in greenhouse gas (GHG) emissions since the pre-industrial era has caused considerable impact to natural and human systems on all continents and across the world's oceans (IPCC, 2014). Considering the projected increase of the global population, fulfilling increasing economic demand will continue to be a fundamental challenge, especially in view of future resource scarcity concerns and global economic uncertainty (Bentley, 2008). Towards the end of the last century an environmentally-conscious policy agenda emerged in response to growing awareness of the problem of global unsustainable production and consumption (Grove, 1992). This policy agenda has supported the adoption of environmentally responsible business operations (Padfield et al., 2016) across various sectors, industries and countries (Papargyropoulou et al., 2012), which in turn has contributed towards improved consumption and production practices (Vergragt et al., 2014).

The concept of sustainable consumption and production (SCP) rests on the notion of tackling negative externalities by reducing resources utilisation, energy usage, waste, and pollution, whilst maintaining economic prosperity and social well-being (Bentley, 2008). SCP consists of a holistic approach which moves an organisation toward life-cycle perspective in order to improve its environmental performance across the value chain (UNEP, 2012). Sustainable production refers to the application of green technologies and environmental improvement of production processes, whereas sustainable consumption takes into account the efficient allocation of resources throughout the value chain. One way to operationalize SCP is via the adoption of an officially certified environmental management system (EMS) standard (Bentley, 2008).

The establishment of environmental management system (EMS) followed an earlier sustainability initiative established at the 1992 Earth Summit in Rio de Janeiro, which called for an international environmental standard (Massoud et al., 2010). The most widely recognised EMS standard was developed by the International Organization for Standardization (ISO) in 1996, which is the ISO 14001 standard (Nishitani, 2010). The standard consists of a systematic framework which leads to environmental regulatory compliance by setting-up measurable

environmental targets and performing a regular review on their effectiveness (Zutshi and Sohal, 2004). It utilises a set of comprehensive guidelines for an organisation to establish its environmental policies and perform continuous environmental improvement via consistent control of its operations (Naudé et al., 2011). Massoud et al. (2010) argue that EMS can be an instrument to reorient consumption and production patterns of industrial activities to secure natural resources and prevent ecological damages.

The ISO 14001 standard has been championed as one initiative to help achieve the sustainable development goals. It offers an organisation cost saving benefits from improved efficiencies and energy efficiencies whilst also supports a company to build legitimacy with overseas stakeholders, thereby expanding its products market. It allows an organisation to demonstrate its environmental stewardship to discerning worldwide customers, thus drawing wider interest towards their products (Darnall and Carmin, 2005). From a social perspective, continuous environmental improvement can directly serve as a pathway to increase the quality of life by diminishing the potential of regional environmental hazards, such as food insecurity, heatwaves, floods, droughts and health problems (Haines et al., 2006).

Geels et al. (2015) argue that EMS allows for incremental changes in production and consumption via technological fixes that improve efficiency as means to address the complex environmental challenges we are facing today, known as the 'reformist SCP position'. EMS supporters traditionally oppose calls for comprehensive transformation of societal structures, such as capitalism, materialism, and consumerism, also known as the 'revolutionary SCP position' (Geels et al., 2015). In this way EMS has gained favour with governmental and industrial actors since it does not require a fundamental overhaul of political governance processes and economic processes.

In recent decades the ISO 14001 standard has gained worldwide attention (Prajogo et al., 2012); yet there is an uneven adoption of the standard when comparing developed and developing countries (Neumayer and Perkins, 2004). As the early adopters, European countries have experienced a significant increase in ISO 14001 adoptions; from 7,253 certified companies in 2000 to 119,754 in 2015 (ISO, 2016). Asia has moved from 5,234 certifications in 2000 to 173,324 in 2015, making the region the new largest adopter (ISO, 2016). Nonetheless, Asia's growth in ISO 14001 certifications has been primarily dominated by three of the region's most developed nations, China, Japan, and South Korea. Neumayer and Perkins (2004) argue that an uneven adoption of ISO 14001 standards will result in the exclusion of uncertified companies, which in turn could serve to marginalise companies from countries where ISO 14001 is not commonly adopted. This is especially the case where certified

97 companies require their suppliers to be certified with a specific environmental certification
98 standard (Nishitani, 2010).
99 Bibliometric analysis is widely used by researchers to investigate past trends of a specific
100 research topic (e.g. Cañas-Guerrero et al., 2014; Hansen et al., 2015; Li and Zhao, 2015).
101 Ferenhof et al. (2014) undertook a bibliometric analysis of EMS research from the period of
102 1999 to 2013. A small number of articles (27 published papers) were obtained from the Scopus
103 and Web of Science databases and the scope of the study was limited to articles focusing on
104 small and medium-sized enterprises (SMEs). The result suggests that EMS research in SMEs
105 is still under represented, where only 2 articles had been published in 1999 with a slight
106 increase to 3 publications in 2013.
107 In light of the important role of ISO 14001 EMS in helping to achieve more sustainable
108 production and consumption practices, the objective of this paper is to undertake a systematic
109 trends analysis of EMS research articles between 2000 and 2016. In determining the thematic
110 and geographical trends of recently published EMS research, a coordinated and holistic
111 research framework is developed which can be applied in the future to facilitate the adoption
112 of ISO 14001 in developing and developed regions of the world. A framework of this nature
113 can guide academic stakeholders as well as private and public research funding agencies on the
114 specific geographies and particular themes of research most in need, and the process in which
115 research programmes can be developed in collaboration with industrial partners. Research
116 efforts supporting the widespread adoption and practice of EMS can help challenge the current
117 structures that shape global production and consumption.

118 ## 2. Data and Method

119 ### 2.1. Article search

120 This study employed a bibliometric analysis method to examine the trend of ISO 14001
121 EMS research from 2000 to 2016. The Web of Science (WoS) database was used to search for
122 and identify academic publications. The database provides extensive ISI-indexed academic
123 articles, with wide coverage of journals collection (over than 14,000 journals) in various topics,
124 including business and management, humanities, natural sciences, social sciences, and
125 engineering (Hansen et al., 2015).
126 The following keywords syntax combination were utilised to search for articles in the
127 WoS search query: “ISO 14001” OR “ISO 14000” OR “ISO14001” OR “ISO14000” OR
128 “environmental management system”. In order to avoid picking up articles related to Eco-

Management and Audit Scheme (EMAS), the following syntax was added in the search query field: NOT "EMAS". All publications (original research articles and review articles) within the past 17 years (2000 to 2016) were selected. The search result was refined to the articles and conference papers published in English. The result returned 1,264 articles available for further refinement.

2.2. Refinement and categorisation process

The collected articles were refined to ensure that the articles in the search result were relevant to the topic in this study. The relevant articles were further categorised under one specific research theme and one sub-theme. The method for articles refinement and categorisation process follows a similar bibliometric procedure by Hansen et al. (2015). The process was performed through four phases: title, keywords, abstract, and content. Specifically, the first categorisation was to examine the title of the articles i.e. if the title was sufficient to be categorised under a category then it would be classified accordingly. Otherwise, the researchers examined the next selection criteria, such as keywords, abstract, and full publications in the same manner. Fig. 1 depicts the procedure flow to perform the refinement and categorisation of the articles.

(Insert Figure 1 Here)

The themes used for the categorisation follow the triple bottom line principle, including socio-ecological, economic implications, and environmental aspects (Galbreath, 2011). Socio-ecological system refers to the interaction between social aspects and the natural environment (Azar et al., 1996). This theme includes the identification of factors which influence the adoption of the ISO 14001 standard, examination of ISO 14001 diffusion process, strategy for increasing the adoption, and the policy or governance. The studies on economic implications refer to the economic benefits from the adoption of the ISO 14001 standard. The theme includes the examination of the relationship between ISO 14001 implementation and potential cost reduction or profitability, increased firm value, market expansion, innovation, and productivity. The environmental aspects theme includes the examination of the ISO 14001's effectiveness to mitigate environmental problems, methods to assess environmental performance based on the ISO 14001 principle, and life-cycle assessment (LCA) ISO 14040 series. Table 1 summarises the underlying research themes and sub-themes for the categorisation process.

(Insert Table 1 Here)

A portfolio of 642 articles was acquired after the refinement process. A further refinement process was performed to exclude articles which did not have full-text available. The process returned with 509 articles categorised into each determined research theme. Each publication was further analysed to determine the geographical location of the first author's research institution. The geographical categorisation follows the countries classification based on the economic criteria by the United Nations which classifies all countries into six regions: North America, Europe, Asia, South America, Oceania, and Africa. Due to the diversity and range of developing and developed countries in Asia, special attention was given to this region with a further breakdown by country.

3. Results

3.1. General trends

From the screening process a total of 509 journal articles in ISO 14001 EMS research was obtained. It was observed that the publication trend has experienced a considerable increase over the study period, from only 10 publications in 2000 to 58 publications in 2016. It can be argued that the publications trend will almost certainly increase in the foreseeable future whilst there is a growing interest in sustainability (Agan et al., 2013). In terms of total publications per category, socio-ecological studies consistently made up the largest number of published articles, accounting for 307 publications (60 %) within the studied period, whereas environmental aspects accounts for 128 published papers (25 %). The least studied topic is economic implications, which only accounts for 74 articles (15 %). Fig. 2 depicts the publications trend of ISO 14001 EMS research during the studied period and the total number of publications in each research theme.

(Insert Figure 2 Here)

3.2. Thematic trends

3.2.1. Socio-ecological

The temporal distribution of socio-ecological system publications is consistent with the overall trend of ISO 14001 EMS research, which has increased from five articles in 2000 to 36 articles in 2016. The overall trend of this topic follows the global upward trends as shown in Fig. 2. This implies that there is a large and growing interest in the socio-ecological research theme. Fig. 3 depicts the trend of socio-ecological studies in ISO 14001 EMS research.

(Insert Figure 3 Here)

192 The vast majority of socio-ecological studies focus on the adoption factors which have
193 experienced an upward trend over the study period. This includes the identification of
194 organisational factors such as drivers (Massoud et al., 2010) and barriers (Hillary, 2004), the
195 role of stakeholders (Zutshi and Sohal, 2004) and institutional factors (Zhu et al., 2013) which
196 increase the extent or deter the adoption of ISO 14001 standard. Research on policy, overview,
197 and governance were prevalent despite a decline in 2011. This topic engages with various type
198 of studies, for example, an overview of ISO 14001 concept (Karapetrovic and Willborn, 2001)
199 and the establishment of organisational environmental policies and programmes after EMS
200 implementation (Zailani et al., 2012). Notwithstanding the low number of publications in these
201 sub-themes, theory or strategy development and international diffusion process sub-themes has
202 followed an unclear trend over the study period, which equates to a high level of uncertainty in
203 projecting future trends.

204 *3.2.2. Economic implications*

205 The economic implications studies accounts for a small fraction of the total number of
206 publications. The trend follows the global increase (Fig. 2) from one publication in 2000 to 13
207 publications in 2012. The trend is followed by a steep decline in 2013 and only a full recovery
208 in 2015. The number declined again in 2016, thus making the projection of future trends highly
209 uncertain. Fig. 4 shows the overall trend of economic implications research theme.

210 (Insert Figure 4 Here)

211 The economic implications studies captured various types of economic improvement
212 areas. The studies were mainly focused on the general economic benefits, which cover two or
213 more of the following topics: cost-related benefits, firm value and reputation, trade, innovation,
214 and productivity (Turk, 2009). The trend moved from one publication in 2000 to three
215 publications in 2016 with a peak of six published articles in 2015. As the trade or globalisation
216 studies experienced a gradual decline in 2010 until no further studies was conducted a few
217 years later, the cost and profitability studies started to emerge in the same period, which
218 indicates that there has been a shift of interest between these two sub-themes. Research on ISO
219 14001's implications for firm value and reputation is still under represented. The others sub-
220 theme (e.g. productivity, innovation, energy efficiency, etc.) showed a constant trend from
221 2007 to 2015 followed by a marginal increase in 2016.

222 *3.2.3. Environmental aspects*

223 The trend of environmental aspects studies is relatively consistent with the increase in
224 the global trends as seen in Fig. 2, despite declines in 2003 and 2010. There were four articles

published in 2000 which increased to 14 publications in 2016. Fig. 5 shows the overall trend of environmental aspects research.

(Insert Figure 5 Here)

Environmental improvement on multiple impacts was the most widely studied sub-theme. These studies address whether or not the adoption of ISO 14001 could effectively mitigate various environmental problems by examining environmental performance indicators using Likert scale (Campos et al., 2015) and environmental management practices using structural equation modelling method (Prajogo et al., 2014). The quantification of GHG emissions to measure the reduction of emissions, waste and pollution in ISO 14001-certified companies (Hertin et al., 2008) is also included this sub-theme. The trend shows a gradual increase until 2013, a slight decline in 2015 followed by an increase in 2016. This implies that the interest in this sub-theme has been relatively constant across the study period. Studies in methods for environmental assessment studies have fluctuated during the study period. This topic includes the quantification methodology based on the ISO 14000 series guidelines (Chen et al., 2004). Similarly, along with the low number of publications in environmental improvement studies, specifically on waste, emissions, and LCA, the trends were unclear.

3.3. Geographical trends

Fig. 6 shows the trend of ISO 14001 EMS publications classified according to the geographical region. Consistent with the high contributions from European countries, this region has shown a major increase over the study period, implying that this region has the greatest interest and research capacity to study sustainability and environmental standardization. Despite contributing the second largest number of articles, the majority of publications in Asia were derived from Chinese, Malaysian and Japanese research institutions (see Fig. 7). Notwithstanding the slow growth and low number of publications in the Oceania region, the other regions have contributed less towards ISO 14001 EMS research.

(Insert Figure 6 & 7 here)

Asia and North America regions have an even balance of research despite the high number of socio-ecological themed articles. Oceania and South America regions share similar features, where a balanced research can be seen towards the economic implications and environmental aspects studies, whilst socio-ecological studies are relatively high. Africa shows a relatively even balance of articles; however, the figure depicts a low share in the total number of publications. Such a trend is likely explained by the limited resources and capacity of

institutions in Africa to undertake such research than by low interest in EMS and related environmentally themed research topics.

4. Discussion

4.1. Uneven geographical spread of environmental knowledge

The upward trend of research articles between 2000 and 2016 implies that ISO 14001 EMS will continue to play an important role in achieving SCP in developed and developing regions of the world. This trend demonstrates a sustained effort from the scientific community to further our understanding of the EMS standard and the factors that determine its adoption in different locations.

Despite the upward trend at a general level, there is a distinctly uneven geographical distribution of publications, most notably between developed and developing regions. Notwithstanding noteworthy contributions in the number of publications by a small number of Asian countries (discussed below), the predominance of publications by researchers from research institutes in developed regions can be explained by two main factors. Countries in developed regions have in the large part driven the global policy discourse on sustainability, SCP and the standardisation of sustainability (UNEP, 2012). European countries, in particular, have been a leading voice in sustainability policy initiatives and regulatory reform, such as the EU Strategy for Sustainable Development in 2001 and the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan in 2008 (European Commission, 2008). Environmental regulations in these geographies are widely regarded as some of the strictest in the world and, therefore, it is understandable that researchers from these regions would examine ISO 14001 within an established regulatory context. On-going disagreements between then World Trade Organization (WTO) and non-governmental organisations (e.g. Greenpeace and World Wide Fund for Nature) over environmental performance as a trade barrier (Oxley et al., 2003) will also have intensified the interest of the scientific community based in the Global North. Universities and research institutes in developed countries have by and large greater access to resources and capability to enable them to undertake research on this topic. An example includes the EU's R&D programmes (e.g. Horizon 2020) which has historically funded research on environmental management and policy related topics (European Commission, 2015).

The uneven global geographic spread of research articles brings this paper to an important point; the concentration of research articles – and thus by default knowledge and

experience of ISO 14001 – is held by researchers from countries where environmental reforms are comprehensive and associated environmental challenges are, by and large, manageable and in-check. In developing countries where environmental regulations are less robust and where achieving high levels of sustainability remains a considerable challenge, research to develop knowledge into ISO 14001 is not developing at the same rate. Such a finding is important within the context of recent global sustainability and climate change legislation where developing countries have taken a supportive role in reducing GHG emissions as shown by the high number of signatories to the COP21 Paris Agreement (United Nations, 2016); there is clearly willingness to reduce environmental impacts, including GHG emissions in many developing countries. Ultimately, it is argued that countries in the developing world are the ones most in need of research programmes into ISO 14001 to allow a fast and efficient transition to SCP on a national scale. A key finding from this research is, therefore, that greater effort is required to support R&D programmes on ISO 14001, and EMS more broadly in developing countries.

4.2. The rise of ISO 14001 EMS research in China and Malaysia

Whilst ISO 14001 research is largely dominated by developed countries, there are two noteworthy exceptions. As shown in Fig. 7, China and Malaysia dominate EMS research in Asia and it is argued that this corresponds with an increase in sustainability related regulations and investment in R&D capabilities. Since the 2000s China has developed a national plan (informally known as the 'Green Leap Forward') which focuses on investment in renewable energy and environmental protection (Percival, 2011). The plan includes the reorientation of China's Five Years Plan (FYP) into an ambitious environmental improvement as the centre of its national strategy (Friedman, 2006) and enforcing industries to meet environmental standard (KPMG, 2016). Likewise, Malaysia has pushed ahead with various national environmental policies since the 2000s, such as the National Policy on Climate Change (NRE, 2016) and National Policy on Biological Diversity (Nagulendran et al., 2016). The 3rd Malaysia Industrial Master Plan also contributes to the enforcement of industrial compliance by increasing the adoption of green technologies and practices (Adham et al., 2013). At COP2009 in Copenhagen Malaysia Prime Minister Najib announced Malaysia would target a voluntary reduction of up to 40 % in terms of emissions intensity of GDP by the year 2020 compared to 2005 levels (Manzo and Padfield, 2016).

Investment in R&D has also played a part in the emergence of China and Malaysia's as key sites of EMS related research. In China, the Natural Science Foundation of China (NSFC)

Research Grants Council of the Hong Kong Special Administrative Region (RGC) will likely have played a role in driving the growth in environmental research. Each year the NSFC has distributed approximately US$ 7.2 billion for research in science, technology, and education (NSFC, 2016), and RGC has spent HK$ 841 million on business studies and social sciences research in 2016 (RGC, 2015). The case was prevalent to the government's interest towards ISO 14001 certification to mitigate environmental problems since the pilot project in 1996. It allows the Chinese government to establish local environmental protection bureau, consultation, and certification bodies in advance, thus creating a solid foundation on the rapid development of ISO 14001 standards adoption (Li, 2008). This also aligns with the bilateral Europe-China Trade Agreement, where China is required to maintain its legitimacy by enabling a widespread adoption of EMS standard to comply with European environmental trade policies. In Malaysia, investment in R&D by Ministry of Higher Education (MOHE) Malaysia has driven research excellence and increased the number of publications in high tier journals. Rapid expansion of research infrastructure, including the increased number of research funding, laboratory facilities, and investment in skilled researcher through the National Higher Education Strategic Plan (NHESP) initiative (Jailani, 2012) has facilitated this trend. The Malaysian National Policy on the Environment (NPE) emphasizes the need to increase R&D activities in environmental sound technologies and EMS in collaboration with industries and academics (Adham et al., 2013).

4.3. Thematic imbalance

In terms of research theme, this study found that the socio-ecological studies make up the highest number of publications, although the topic has been less studied in developing countries (see Fig. 6). It is argued that this case was prevalent as a result of difficulties to access industries and the degree of sensitivity on environmental issues, provided that many environmental problems and regulatory incompliance can still be found in the majority of organisations in developing countries (Singh and Rajamani, 2003). International diffusion process was the least studied sub-theme in this category. Likewise, this is perhaps associated with the difficulties to obtain primary data from industries in developing countries in order to explain the diffusion mechanism of the ISO 14001 standards.

The rapid growth of socio-ecological studies does raise a question on the achievement of the overall framework in SCP. Whilst socio-ecological topic will likely to result in the improvement of compliance towards environmental regulation and increase the diffusion of ISO 14001 standards adoption, this issue points towards the uncertain economic outcomes of

355 the standard, especially since this theme is one of the least studied and still remains under
356 represented relative to the number of publications. The lack of studies in this topic implies that
357 there is limited understanding of the potential benefits from EMS implementation, thus
358 companies will likely draw scepticism and suspicion towards the perceived benefit. Increasing
359 economic implications studies will increase the visibility and clarity of the potential economic
360 benefits. This in turn can serve as a strategy to an effective voluntary EMS adoption and help
361 organisations maintain their ISO 14001 certification in uncertain economic conditions.
362 Consistent with the global trend, European countries display a disproportional large
363 amount of socio-ecological studies, whilst there are relatively low numbers of economic
364 implications studies (see Fig. 6). This likely reflects the stringency of regulatory enforcement
365 in Europe along with established monetary incentives and disincentives either in the form of
366 penalties (e.g. carbon tax, emission trading scheme) or financial support (e.g. Horizon 2020,
367 EU Funding Instrument for the Environment and Climate Action, etc.) (European Commission,
368 2017). It appears academics are more likely to focus on investigating the interaction between
369 social aspects and the natural environment, with a view of better understanding how to increase
370 organisational compliance and promote good governance.
371 In developing regions, a gradual increase of ISO 14001 EMS research can be seen in the
372 South America region and Asia. In South America, this is likely associated with the increase
373 in research funding provided by the Brazilian government. In 2008, the state of São Paulo
374 Research Foundation developed a new funding scheme in Global Climate Change under the
375 support from the National Council for Scientific and Technological Development (CNPq),
376 Brazil. An amount of R$ 100 million was allocated for ten years to improve sustainability via
377 various research projects (FAPESP, 2009).

378 **4.4. A framework to facilitate industrial applicability of EMS research**

379 Akter et al. (2012) argue that certain industries, especially SMEs are less inclined to
380 address their environmental impacts due to poor understanding of the resulting economic
381 benefits of direct environmental action – such as the adoption of an EMS – to their business.
382 Our study indirectly supports that thesis having revealed a disproportionate focus of published
383 articles aligned towards social-ecological and environmental categories and relatively few
384 examining the economic implications (i.e. industrial applicability) of EMS. In a bibliometric
385 study of palm oil sustainability research, Hansen et al. (2015) revealed a large and growing
386 volume of academic articles published since 2000 but within that pool few studies with direct
387 industrial applicability. Such a finding implies the research community have tended to focus

more towards academic questions and the resulting academic outputs (i.e. peer reviewed articles) than the critical problems and issues of most concern to industries. For instance, in Malaysia there is a relatively high intensity of ISO 14001 EMS research (see Fig. 7) yet this does not reflect directly on the adoption rate of ISO 14001 standards (ISO, 2016).

Following the holistic framework proposed by Hansen et al. (2015) and the call by Velazquez et al. (2000) and Padfield et al (2014a) for a closer interaction between academics, government, and industries, a framework of EMS research targeted specifically at developing countries is proposed centred on strong collaboration between academic research and non-academic stakeholders and with input from actors from across the supply chain, including those in developed and developing countries (see Fig. 8). Multi-stakeholder participation is especially important in order to promote a robust scientific consensus on the importance of EMS by enabling constructive and collaborative discussions among various stakeholders (Hansen et al., 2015; Padfield et al., 2014b). Collaborative actions between multiple stakeholders can promote a demand-driven approach for scientific problem solving and policy-making that will lead to greater industrial applicability of EMS.

As indicated in Fig 8, cross-country collaboration occurs between one or more researchers in the Global North *and* with a counterpart in the Global South. The researchers seek input from industries based in their respective geographies on topics and potential projects that could benefit from EMS research; the assumption here is that industry is more likely to open up to researchers with links to a 'local researcher institution' than an external institute. The researchers aim to gain input from government and non-governmental stakeholders on regulatory (e.g. policy reform) and broader societal issues (e.g. environmental and social impacts) related to the research. Knowledge insights are shared amongst both sets of researchers which informs their approach to a clearly defined research project. As set out in this research paper, EMS research projects of this nature are likely to fall under one of the following themes: socio-ecological, economic implications or environmental implications. Research outputs are shared with the non-academic stakeholders with the aim of industrial applicability and policy uptake.

(Insert Figure 8 Here)

The framework places importance on cross-country research collaboration between academic and non- academic institutions in the Global North and Global South. Cross-country research collaboration is regarded as an effective way to facilitate knowledge exchange and access to advanced scientific infrastructure for developing economies (Kim, 2006). Such a partnership model allows tacit knowledge transfer between two or more developing and

developed countries, thus increasing the capability to intensify ISO 14001 EMS research in developing economies. Developing strong linkages and partnerships between research institutions and industrial actors in the Global North with those in Global South is not without difficulty but would reconfigure existing relationships between these actors and the way environmental problems can be addressed, especially within developing countries.

The relevance of the proposed framework extends beyond ISO and EMS research discussions; it contributes to wider SCP and ecological modernisation debates. This research proposes a middle ground between the 'reformist' and 'revolutionary' SCP position', also known as the 'reconfiguration' position (Geels et al., 2015). By engaging with existing EMS literature and going a step further to propose a new collaborative research framework the current structures shaping production and consumption can be challenged .

The research collaboration proposed here can be mutually governed by the participation of multiple stakeholders to ensure that the scientific consensus addresses the prospects of industrial applicability of ISO 14001 standard in the Global South (Costello and Zumla, 2000; Hansen et al., 2015). Resource allocation, research infrastructures can be either provided by either developed or developing countries, whereas the industrial and environmental regulatory contexts are provided by the non-academic stakeholders from the Global South counterpart. In this sense, academics can be the central actors in offering stakeholders with a scientific consensus of socio-ecological, economic, and environmental aspects to provide greater clarity within the context of SCP. The proposed framework, in turn, could develop domestic industries in the Global South beyond national and regional markets, whilst developed countries can benefit from the improved productivity of natural resources in the Global South. The experience of China, and to a lesser extent Malaysia, could also be studied in detail to examine the factors that have led to the adoption of ISO 14001 and the interplay between academic and non-academic institutions to facilitate this adoption.

5. Conclusion

Understanding recent patterns of EMS research, including the thematic balance of research and the geographical trends of past publications will facilitate the formulation of plans for further adoption of EMS around the world. Employing a bibliometric analytical technique, this study found that there has been a steady increase in ISO 14001 EMS research from 7 publications in 2000 to 51 published articles in 2016. Within the portfolio of articles there is a focus towards socio-ecological and environmental aspects themed research, whilst the economic implications

theme remains largely under represented. It is argued that limited knowledge in economic implications of EMS will continue to hamper the industrial applicability of ISO 14001 research. An uneven geographical distribution of research was also highlighted in this study, with the largest contributors of research residing in developed countries. The noted exception to this broad trend is in Asia, particularly in China and Malaysia, where there has been significant growth in publications over the study period. Strengthening national level environmental legislation and investment in environmental related R&D is a likely contributing factor to the rise in EMS research in both countries.

Acknowledging the need to address the environmental challenges in developing countries it is proposed that a widespread adoption of EMS in these geographies is one potential solution. This article proposed a framework to facilitate industrial applicability of EMS research in developing countries centred on strong collaboration between academic research and non-academic stakeholders and with input from actors from across the supply chain, including those in developed and developing countries. A multi-stakeholder approach could serve as a pathway to devise demand-driven technical and policy solutions to policy makers and practitioners. Increased cross-country research collaboration between developing and developed countries would likewise allow developing countries to strengthen their capability for sustainability whilst developed countries benefit from increased access to sustainably produced raw materials.

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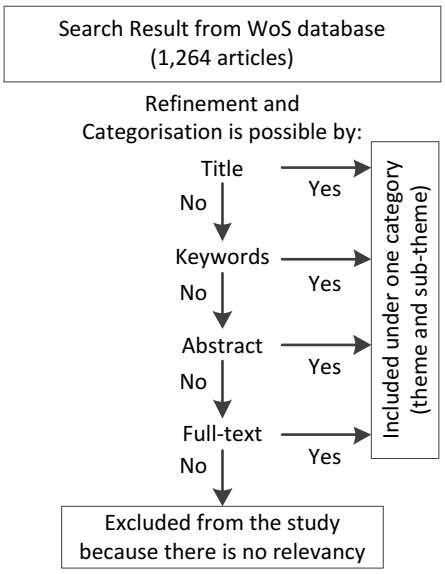

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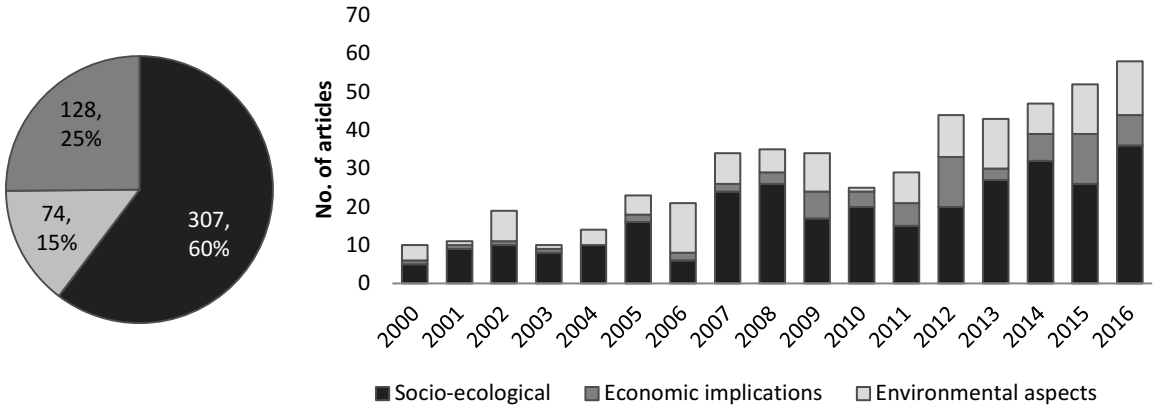
625 Fig. 1. Procedure for refinement and categorisation processes (Hansen et al., 2015)



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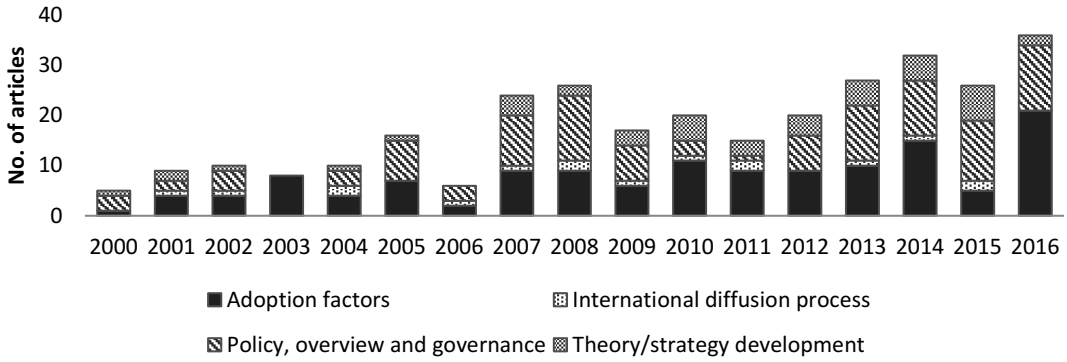
627 Fig 2. Global trends of ISO 14001 EMS research and the total number of publications from
628 2000 to 2016



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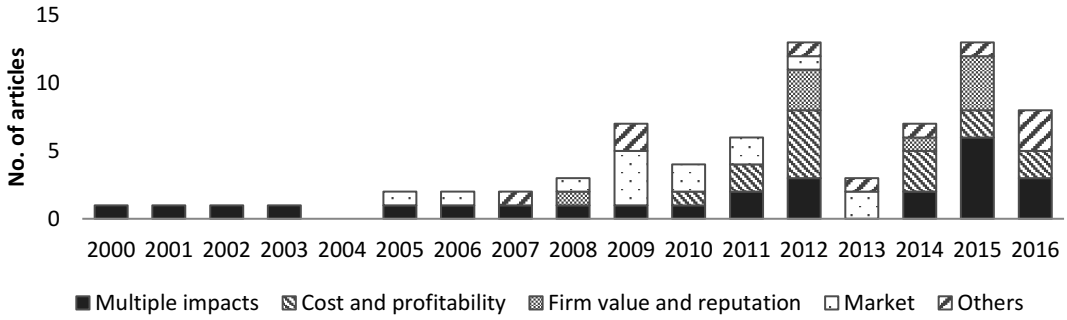
630 Fig. 3. Publications trend of socio-ecological research theme from 2000 to 2016



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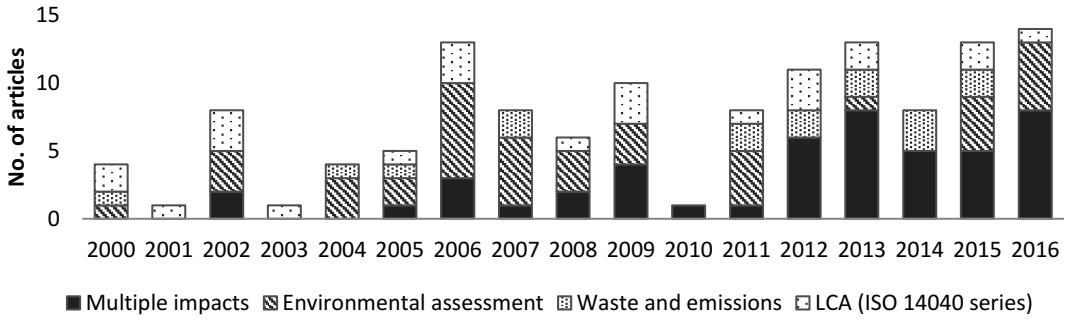
632 Fig. 4. Publications trend of economic implications studies from 2000 to 2016



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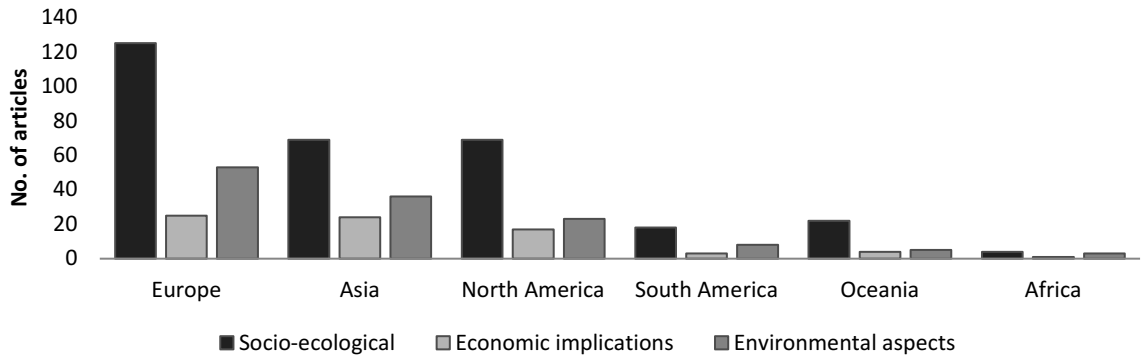
634 Fig. 5. Publications trend of environmental aspects studies from 2000 to 2016



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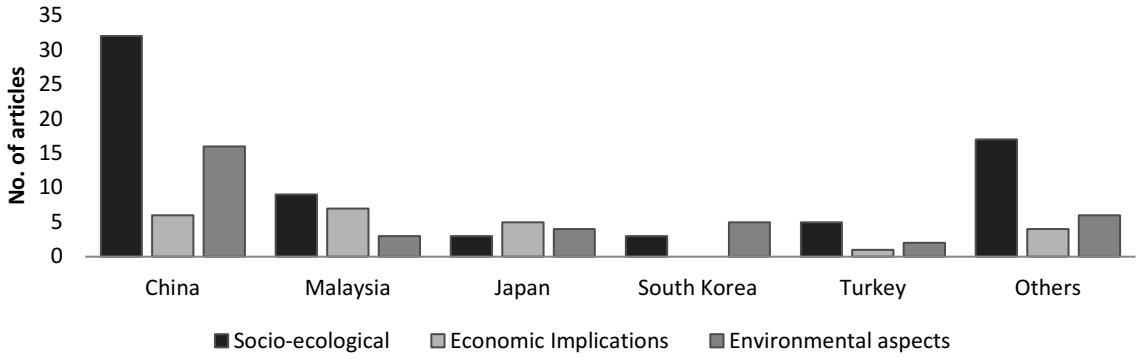
636 Fig. 6. Distribution of ISO 14001 EMS research by geographical region



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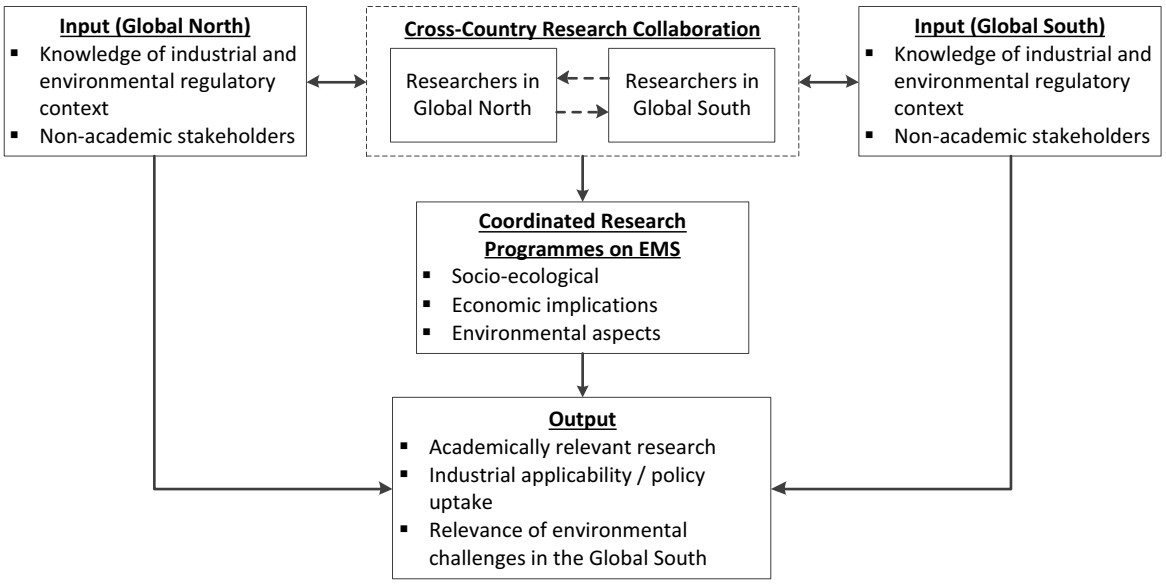
638 Fig. 7 Distribution of ISO 14001 EMS research in Asia



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640 Fig. 8. Proposed research framework for multiple stakeholders and cross-country collaboration
641 on EMS research

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647 Table 1. Themes and sub-themes for paper categorisation process

Themes	Sub-Themes
Socio-ecological	a) Adoption factors
	b) International diffusion process
	c) Policy, overview, and governance
	d) Theory/strategies development
Economic Implications	a) Economic benefits (General)
	b) Economic benefits (Cost and profitability)
	c) Economic benefits (Firm value and image)
	d) Economic benefits (Market)
	e) Economic benefits (Others)
Environmental Aspects	a) Environmental improvement (Multiple impacts)
	b) Environmental improvement (Solid waste)
	c) Environmental assessment (Method)
	d) LCA[a] (ISO 14040 series)

648 [a] Life Cycle Assessment

649