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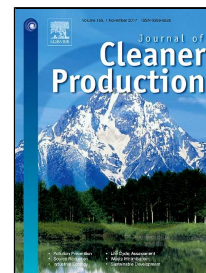
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2 **Global trends in Environmental Management System and ISO14001**
3 **research**

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13 **Abstract**

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

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

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

36 **1. Introduction**

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

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

58 The establishment of environmental management system (EMS) followed an earlier
59 sustainability initiative established at the 1992 Earth Summit in Rio de Janeiro, which called
60 for an international environmental standard (Massoud et al., 2010). The most widely recognised
61 EMS standard was developed by the International Organization for Standardization (ISO) in
62 1996, which is the ISO 14001 standard (Nishitani, 2010). The standard consists of a systematic
63 framework which leads to environmental regulatory compliance by setting-up measurable

64 environmental targets and performing a regular review on their effectiveness (Zutshi and Sohal,
65 2004). It utilises a set of comprehensive guidelines for an organisation to establish its
66 environmental policies and perform continuous environmental improvement via consistent
67 control of its operations (Naudé et al., 2011). Massoud et al. (2010) argue that EMS can be an
68 instrument to reorient consumption and production patterns of industrial activities to secure
69 natural resources and prevent ecological damages.

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

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

87 In recent decades the ISO 14001 standard has gained worldwide attention (Prajogo et al.,
88 2012); yet there is an uneven adoption of the standard when comparing developed and
89 developing countries (Neumayer and Perkins, 2004). As the early adopters, European countries
90 have experienced a significant increase in ISO 14001 adoptions; from 7,253 certified
91 companies in 2000 to 119,754 in 2015 (ISO, 2016). Asia has moved from 5,234 certifications
92 in 2000 to 173,324 in 2015, making the region the new largest adopter (ISO, 2016).
93 Nonetheless, Asia's growth in ISO 14001 certifications has been primarily dominated by three
94 of the region's most developed nations, China, Japan, and South Korea. Neumayer and Perkins
95 (2004) argue that an uneven adoption of ISO 14001 standards will result in the exclusion of
96 uncertified companies, which in turn could serve to marginalise companies from countries
97 where ISO 14001 is not commonly adopted. This is especially the case where certified

98 companies require their suppliers to be certified with a specific environmental certification
99 standard (Nishitani, 2010).

100 Bibliometric analysis is widely used by researchers to investigate past trends of a specific
101 research topic (e.g. Cañas-Guerrero et al., 2014; Hansen et al., 2015; Li and Zhao, 2015).
102 Ferenhof et al. (2014) undertook a bibliometric analysis of EMS research from the period of
103 1999 to 2013. A small number of articles (27 published papers) were obtained from the Scopus
104 and Web of Science databases and the scope of the study was limited to articles focusing on
105 small and medium-sized enterprises (SMEs). The result suggests that EMS research in SMEs
106 is still under represented, where only 2 articles had been published in 1999 with a slight
107 increase to 3 publications in 2013.

108 In light of the important role of ISO 14001 EMS in helping to achieve more sustainable
109 production and consumption practices, the objective of this paper is to undertake a systematic
110 trends analysis of EMS research articles between 2000 and 2016. In determining the thematic
111 and geographical trends of recently published EMS research, a coordinated and holistic
112 research framework is developed which can be applied in the future to facilitate the adoption
113 of ISO 14001 in developing and developed regions of the world. A framework of this nature
114 can guide academic stakeholders as well as private and public research funding agencies on the
115 specific geographies and particular themes of research most in need, and the process in which
116 research programmes can be developed in collaboration with industrial partners. Research
117 efforts supporting the widespread adoption and practice of EMS can help challenge the current
118 structures that shape global production and consumption.

119 **2. Data and Method**

120 **2.1. Article search**

121 This study employed a bibliometric analysis method to examine the trend of ISO 14001
122 EMS research from 2000 to 2016. The Web of Science (WoS) database was used to search for
123 and identify academic publications. The database provides extensive ISI-indexed academic
124 articles, with wide coverage of journals collection (over than 14,000 journals) in various topics,
125 including business and management, humanities, natural sciences, social sciences, and
126 engineering (Hansen et al., 2015).

127 The following keywords syntax combination were utilised to search for articles in the
128 WoS search query: “ISO 14001” OR “ISO 14000” OR “ISO14001” OR “ISO14000” OR
129 “environmental management system”. In order to avoid picking up articles related to Eco-

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

135 **2.2. Refinement and categorisation process**

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

146 (Insert Figure 1 Here)

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

161 (Insert Table 1 Here)

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

171 3. Results

172 3.1. General trends

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

184 (Insert Figure 2 Here)

185 3.2. Thematic trends

186 3.2.1. *Socio-ecological*

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

192 (Insert Figure 3 Here)

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

205 3.2.2. *Economic implications*

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

211 (Insert Figure 4 Here)

212 The economic implications studies captured various types of economic improvement
213 areas. The studies were mainly focused on the general economic benefits, which cover two or
214 more of the following topics: cost-related benefits, firm value and reputation, trade, innovation,
215 and productivity (Turk, 2009). The trend moved from one publication in 2000 to three
216 publications in 2016 with a peak of six published articles in 2015. As the trade or globalisation
217 studies experienced a gradual decline in 2010 until no further studies was conducted a few
218 years later, the cost and profitability studies started to emerge in the same period, which
219 indicates that there has been a shift of interest between these two sub-themes. Research on ISO
220 14001's implications for firm value and reputation is still under represented. The others sub-
221 theme (e.g. productivity, innovation, energy efficiency, etc.) showed a constant trend from
222 2007 to 2015 followed by a marginal increase in 2016.

223 3.2.3. *Environmental aspects*

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

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

228 (Insert Figure 5 Here)

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

242 3.3. Geographical trends

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

251 (Insert Figure 6 & 7 here)

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

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

260 **4. Discussion**

261 **4.1. Uneven geographical spread of environmental knowledge**

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

267 Despite the upward trend at a general level, there is a distinctly uneven geographical
268 distribution of publications, most notably between developed and developing regions.
269 Notwithstanding noteworthy contributions in the number of publications by a small number of
270 Asian countries (discussed below), the predominance of publications by researchers from
271 research institutes in developed regions can be explained by two main factors. Countries in
272 developed regions have in the large part driven the global policy discourse on sustainability,
273 SCP and the standardisation of sustainability (UNEP, 2012). European countries, in particular,
274 have been a leading voice in sustainability policy initiatives and regulatory reform, such as the
275 EU Strategy for Sustainable Development in 2001 and the Sustainable Consumption and
276 Production and Sustainable Industrial Policy Action Plan in 2008 (European Commission,
277 2008). Environmental regulations in these geographies are widely regarded as some of the
278 strictest in the world and, therefore, it is understandable that researchers from these regions
279 would examine ISO 14001 within an established regulatory context. On-going disagreements
280 between then World Trade Organization (WTO) and non-governmental organisations (e.g.
281 Greenpeace and World Wide Fund for Nature) over environmental performance as a trade
282 barrier (Oxley et al., 2003) will also have intensified the interest of the scientific community
283 based in the Global North. Universities and research institutes in developed countries have by
284 and large greater access to resources and capability to enable them to undertake research on
285 this topic. An example includes the EU's R&D programmes (e.g. Horizon 2020) which has
286 historically funded research on environmental management and policy related topics (European
287 Commission, 2015).

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

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

304 **4.2. The rise of ISO 14001 EMS research in China and Malaysia**

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

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

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

342 **4.3. Thematic imbalance**

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

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

356 the standard, especially since this theme is one of the least studied and still remains under
357 represented relative to the number of publications. The lack of studies in this topic implies that
358 there is limited understanding of the potential benefits from EMS implementation, thus
359 companies will likely draw scepticism and suspicion towards the perceived benefit. Increasing
360 economic implications studies will increase the visibility and clarity of the potential economic
361 benefits. This in turn can serve as a strategy to an effective voluntary EMS adoption and help
362 organisations maintain their ISO 14001 certification in uncertain economic conditions.

363 Consistent with the global trend, European countries display a disproportional large
364 amount of socio-ecological studies, whilst there are relatively low numbers of economic
365 implications studies (see Fig. 6). This likely reflects the stringency of regulatory enforcement
366 in Europe along with established monetary incentives and disincentives either in the form of
367 penalties (e.g. carbon tax, emission trading scheme) or financial support (e.g. Horizon 2020,
368 EU Funding Instrument for the Environment and Climate Action, etc.) (European Commission,
369 2017). It appears academics are more likely to focus on investigating the interaction between
370 social aspects and the natural environment, with a view of better understanding how to increase
371 organisational compliance and promote good governance.

372 In developing regions, a gradual increase of ISO 14001 EMS research can be seen in the
373 South America region and Asia. In South America, this is likely associated with the increase
374 in research funding provided by the Brazilian government. In 2008, the state of São Paulo
375 Research Foundation developed a new funding scheme in Global Climate Change under the
376 support from the National Council for Scientific and Technological Development (CNPq),
377 Brazil. An amount of R\$ 100 million was allocated for ten years to improve sustainability via
378 various research projects (FAPESP, 2009).

379 **4.4. A framework to facilitate industrial applicability of EMS research**

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

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

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

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

417 (Insert Figure 8 Here)

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

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

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

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

448 **5. Conclusion**

449 Understanding recent patterns of EMS research, including the thematic balance of research and
450 the geographical trends of past publications will facilitate the formulation of plans for further
451 adoption of EMS around the world. Employing a bibliometric analytical technique, this study
452 found that there has been a steady increase in ISO 14001 EMS research from 7 publications in
453 2000 to 51 published articles in 2016. Within the portfolio of articles there is a focus towards
454 socio-ecological and environmental aspects themed research, whilst the economic implications

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

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

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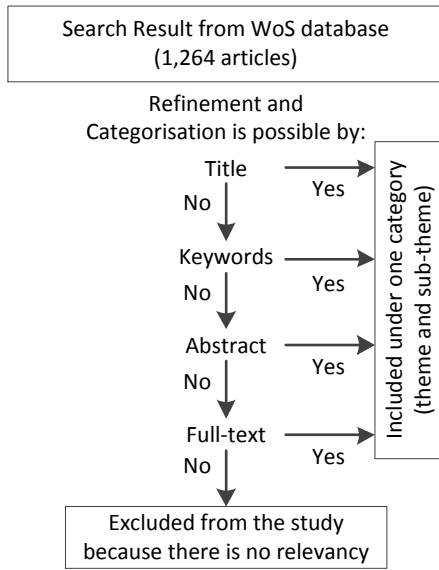
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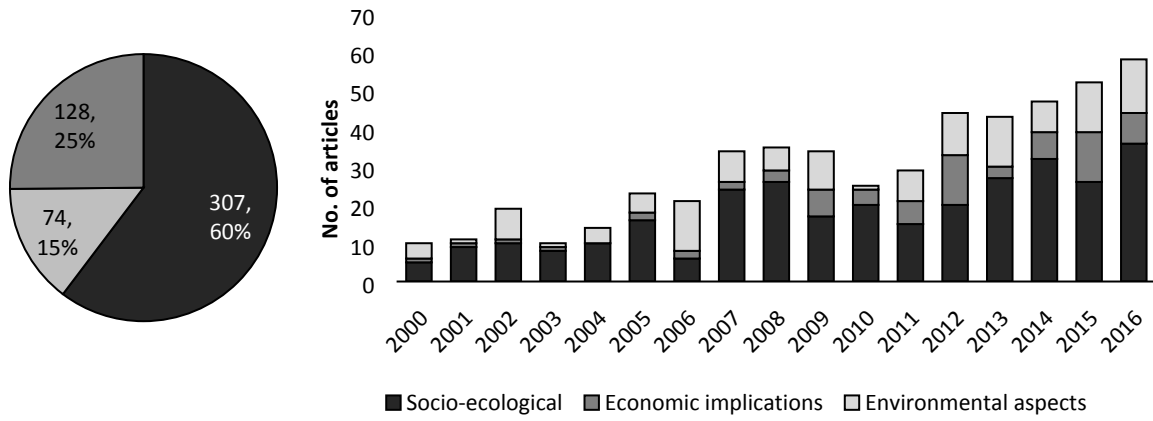
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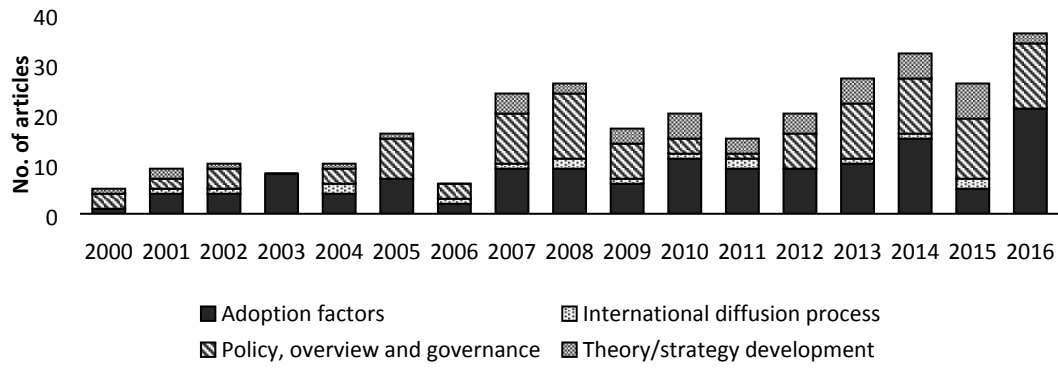
626 Fig. 1. Procedure for refinement and categorisation processes (Hansen et al., 2015)



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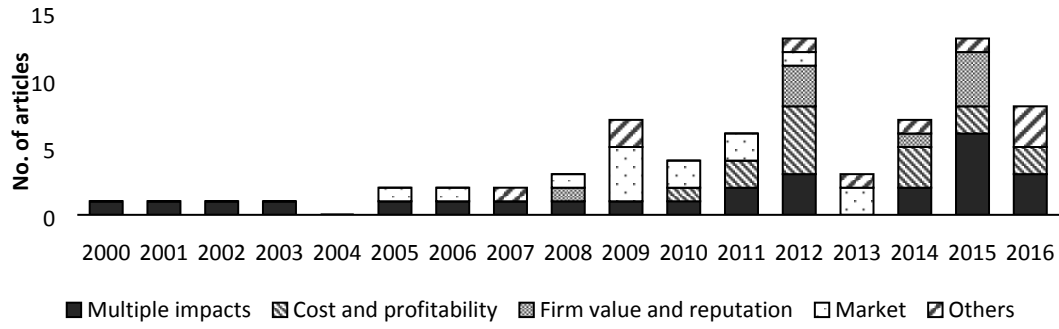
628 Fig 2. Global trends of ISO 14001 EMS research and the total number of publications from

629 2000 to 2016



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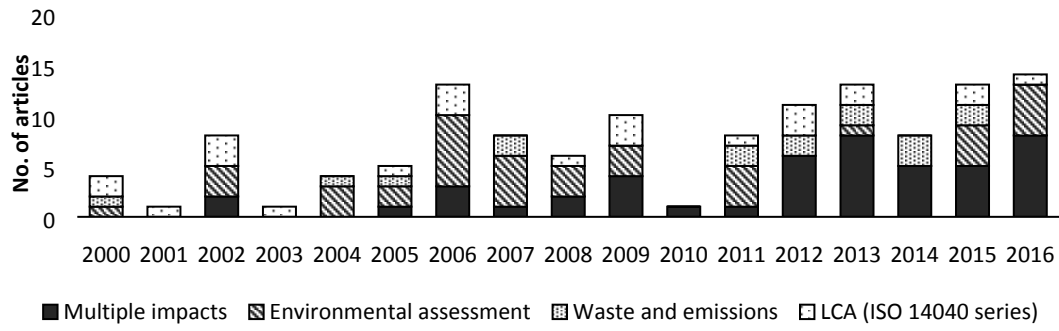
631 Fig. 3. Publications trend of socio-ecological research theme from 2000 to 2016



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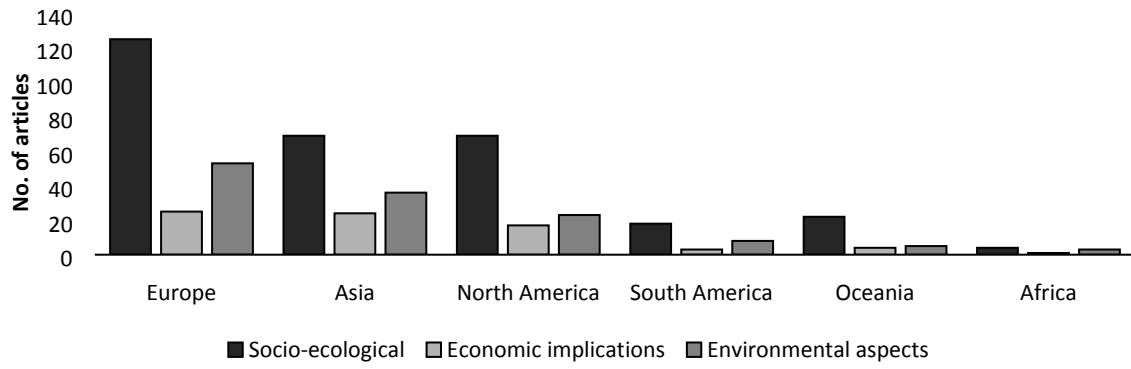
Fig. 4. Publications trend of economic implications studies from 2000 to 2016



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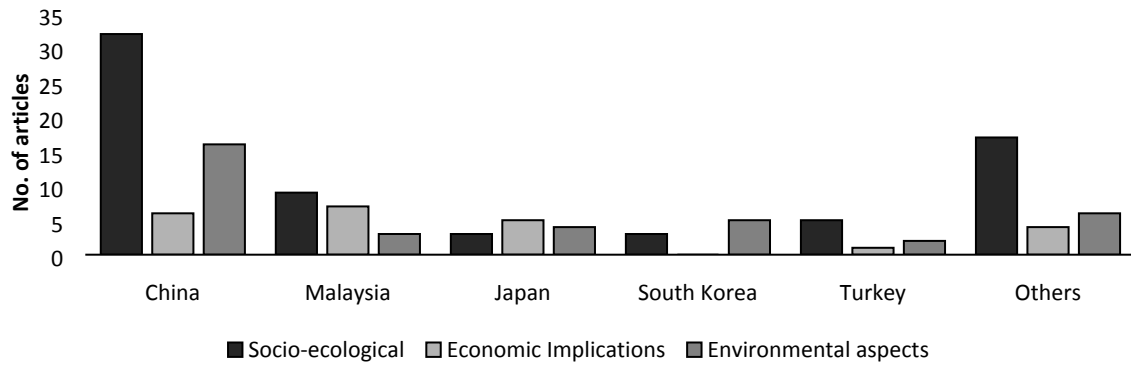
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Fig. 5. Publications trend of environmental aspects studies from 2000 to 2016



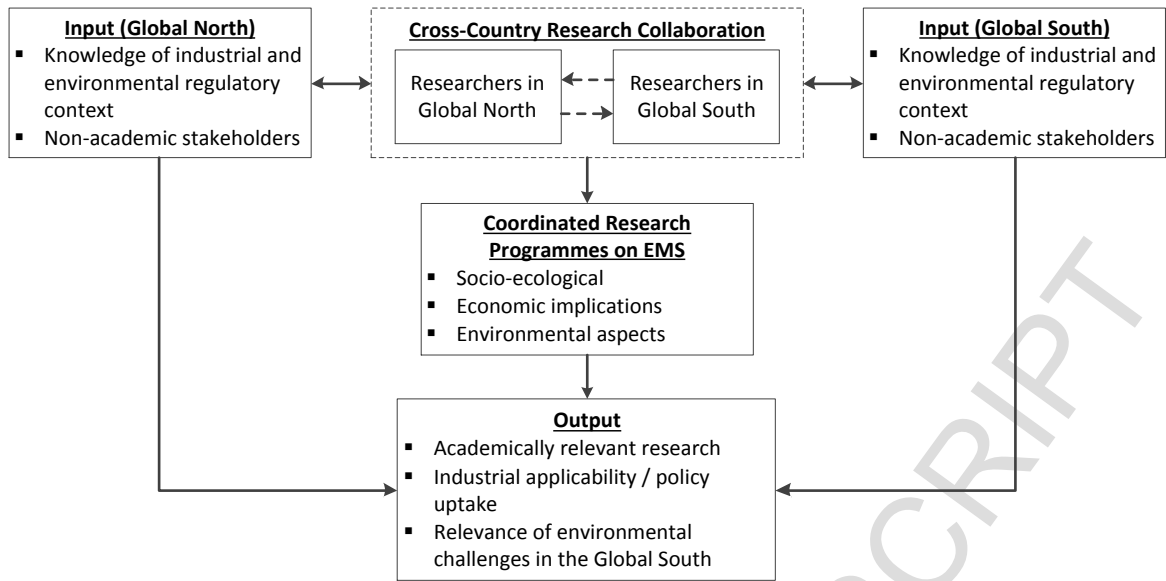
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637 Fig. 6. Distribution of ISO 14001 EMS research by geographical region



638

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



640

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

642 on EMS research

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648 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)

649 ^a Life Cycle Assessment

650