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National Innovative capacity in the water sector: An analysis of China and Europe

Mariú Abritta Moro^{1,2*}, Ursula S. McKnight¹, Barth F. Smets¹, Maj Munch Andersen³

¹Department of Environmental Engineering, Technical University of Denmark, Bygningstorvet 115, 2800 Kgs. Lyngby, Denmark.

² Sino-Danish Center for Education and Research. University of Chinese Academy of Sciences 380 Huaibeizhuang, Huairou district, Beijing, China.

³Department of Management Engineering, Technical University of Denmark, Diplomvej Building 372, 2800 Kgs. Lyngby, Denmark.

*Corresponding author: mamor@env.dtu.dk

Abstract

The water sector needs to increase its resource efficiency; failure to do so may have negative effects on economic development and growth. Achieving a higher level of innovative capacity within the water sector may govern a country's capacity to meet specific water challenges and ensure sustainable economic development. Traditional water technologies are reaching their stagnation point; in a transition to more sustainable technologies, eco-innovation is the core driver. Based on the national innovative capacity (NIC) as an analytical framework, we test indicators that govern the innovative capacity of the water sector in Europe versus China, representing respectively, an early mover and a late mover in the green economy agenda. Additionally, we provide an analysis of the evolution of the water technological development. We found that the innovative capacity in the water sector is strongly related to the national innovative strategy. Environmental regulations, Research and Development and international collaboration were all found to be determinants for both Europe's and China's NIC in the water sector. The level of direct investments and private Research and Development, on the other hand, were found to be a determinant for China only. However, the evolution of the NIC determinants could not provide any insight as to whether China may reach the same level of NIC in the water sector as Europe. This analysis contributes nonetheless to increasing the level of understanding in the water innovation dynamics field, providing insights related as to why Europe and China present different innovative capacities in the water sector.

Keywords: National innovative capacity, eco-innovations, water technologies, water sector, China, Europe.

32 **1.Introduction**

33 Water is essential for human life, yet in 2010, more than 13% of the world's population did not have
34 access to piped water supply and/or clean water, and water demand is predicted to increase more than 55%
35 by 2050 due to both population and economic growth (OECD, 2012a). The capacity of a country to increase
36 its efficient use of natural resources via technological development will impact its overall economic
37 development and growth in the long run (United Nations Environmental Program (UNEP), 2011).
38 Technological developments in the water sector are essential for enabling the transition to more sustainable
39 economies (OECD, 2012b), and understanding the mechanisms determining the national innovative capacity
40 in the water sector are crucial to ensure a successful transition towards greener economies.

41 There is little information on what may determine the innovative capacity in the water sector. A recent
42 study by the European Commission (2016) showed that, in Europe, the sector is highly concentrated with a
43 few large companies dominating national markets, and is less dynamic and innovative than other comparable
44 sectors. The report further suggests that there exists a high potential for innovation that is not being
45 exploited. One reason for this low level of innovation could be that investments are linked with public
46 budgets, which are influenced by economic fluctuations and government instabilities (European Commission,
47 2016).

48 This paper analyses water eco-innovation, with a special focus on testing whether the national
49 innovative capacity in water varies with a country's stage into the greening of the innovation system.
50 Specifically, we investigate whether countries in different stages of development display different water
51 innovation system characteristics, and whether the drivers for enhancing innovative capacity are therefore
52 different. The comparison between Europe and China represents a special case to be analyzed, since Europe
53 is an early mover in the green economy agenda (Andersen, 2010a), whereas China is a late mover.

54 This paper therefore analyzes the drivers of the national innovative capacity (NIC) in the water sector
55 and examines whether indicators recognized as important drivers for NIC as a whole could also be applicable

for the water sector. In addition, the role of environmental regulations and environmental indicators on the NIC of the water sector is examined. Finally, Europe and China are compared to identify differences in drivers of the innovative capacity in this sector.

2. Background

The concept of innovative capacity was formally introduced by (Suarez- Villa, 1990) as a measure of the level of invention and the innovative potential, the current and potential capabilities of a system to convert knowledge into innovation, and sustain its development (Freeman, 1995; Furman et al., 2002; Lundvall and Johnson, 1994; Schiuma and Lerro, 2008). Linked to these ideas, the concept of a national innovative capacity (NIC) was introduced (Furman et al., 2002; Porter and Stern, 1998). The NIC can be understood as the ability of a country to produce and commercialize a flow of innovative technology over the long term (Furman et al., 2002); NIC is more than the realized level of innovative output *per se*, reflecting also the drivers of the innovation process (Furman et al., 2002). According to Furman et al. (2002), the NIC is determined by the interaction of: (i) the common innovation infrastructure, which represents the framework conditions for technological development, such as the education infrastructure and the size of the economy; (ii) the cluster-specific environment for innovation, as housed in companies and knowledge institutions; (iii) the quality of the linkage between the cluster-specific environment and the common innovation infrastructure.

The framework used by Furman et.al (2002) empirically explores the determinants of country differences on the innovation intensity levels, by analyzing the relationship between the level of patenting activities and variables related to NIC, such as the common innovation infrastructure and the cluster-specific environment. The framework to analyze the NIC is based primarily on the national innovation system (Lundvall, 1998), but also on the endogenous growth theory (Romer, 1990) and the cluster-based theory (Porter and Stern, 1998). National innovation system (NIS) theory focuses on the direction and intensity of knowledge flows, technology transfer, commercialization of knowledge and economic incentives (Lundvall, 1998) which additionally enables a country comparison (Nelson, 1993, 1992). The endogenous growth theory (Romer, 1990) focus on levels of knowledge stocks and aggregate indicator levels, such as R&D and labour, and the

81 cluster-based theory of national industrial competitive advantage focuses on the micro-economic dynamics
82 and inter-actor's interactions. The Furman et al. (2002) NIC analytical framework can therefore be used to
83 contrast innovation capacities from country to country. In this context, the ability to develop cross-country
84 comparisons is extremely important for investigating why countries present different innovative capacities,
85 a question still not addressed for the water sector.

86 **2.1. National innovative capacity applied to the European context**

87 Since the pioneering work of Furman et al. (2002), the NIC analytical framework has been used in many
88 different contexts. Suarez-Villa et al. (2003) provided two types of innovative performance based on the
89 interaction between inter-organizational networks and the innovative capacity. Riddel and Schwer (2003)
90 analysed the endogenous relationship between employment growth and the NIC in the United States. Faber
91 and Hesen (2004) tested the NIC framework for 14 EU countries and added *sales of product innovations* to
92 the analysis. Archibugi and Coco (2005) analysed the differences in methodologies for NIC analysis used by
93 organizations such as the World Economic Forum, the United Nations, and the European Commission and
94 found inconsistencies among the methodologies making it difficult to develop comparisons. Natário et al.
95 (2007) analysed the evolution of the NIC among European countries, adding variables from the innovation
96 scorebook and variables related to the influence of cultural aspects and institutional differences; they found
97 positive effects on NIC associated with the efficiency of the national institutions, and a low power distance
98 national culture.

99 Castellacci and Natera (2013, 2011) added the dynamic aspect of the national innovation system (Lundvall,
100 2007) improving the analytical rigor of Furman et al. (2002). They identified that the NIC dynamics are driven
101 by three *innovative capability* factors: innovative, scientific and technological input, and three *absorptive*
102 *capacity factors*: infrastructures, international trade and human capital. Proksch et al. (2017) described
103 different paths to improve the NIC in European countries, showing how the different compositions of the
104 common innovation infrastructure and the cluster-specific environment can lead to the same level of

105 innovation capacity. Their study revealed that the NIC is mostly associated with a combination of high GDP
106 per capita and the share of government expenditure on higher education, and when included with the
107 combination of high patent stock and high IP protection tends to have higher innovative output.

108 **2.2. National innovative capacity in developing countries**

109 Systemic differences exist between the innovation systems in developed versus developing or transitional
110 economies (Gu and Lundvall, 2006; Hu and Mathews, 2005; Liu and White, 2001; Radošević, 2002). The very
111 stage of development *per se* is a reflection of these differences, for instance, companies play a major role in
112 the NIS of developed countries, but not necessarily in developing countries where the government and
113 foreign actors may also play an equally important role. The NIS of developing countries are also transitioning
114 (like the economy) and therefore often lack strong innovative and R&D capabilities and display limited
115 absorptive capacity to transform knowledge into innovations (Fagerberg et al., 2007; Gu et al., 2016)

116 Hu and Mathews (2005) analysed the technological catching-up process of East-Asian countries via an
117 increase of their NIC, measured per Furman et al. (2002), highlighting the importance of public R&D on the
118 development of a developing country's NIC. Mathews and Hu (2007) furthermore demonstrated the
119 contribution of academic innovations to Taiwan's NIC, as they transitioned from a strategy of *fast follower* to
120 a strategy of *innovation-based developer*. Hu and Mathews (2008) investigated drivers behind the Chinese
121 NIC focusing on the relationship between China's patents and its relationship to the NIC evolution, and
122 concluded that both the government and the universities were major actors in promoting the NIC in China.
123 Fan(2011) analysed NIC in India and China and concluded that human resources in R&D, the financial
124 investments, and the role of the government on directing investments to the national development process
125 were crucial to the transformation of the NIC in both countries. Despite the fact that the NIC has been applied
126 in different contexts, there is still a lack of studies analysing the NIC with a focus on sustainable development.

127 **2.3. National innovative capacity and eco-innovation in water technologies**

128 Eco-innovation can be seen as the part of the process of technological and economy change in which
129 paradigmatic changes happen in an evolutionary process. Hence eco-innovation can be understood as a
130 process of technological and economic change related to the greening of the economy (Andersen, 2010b). In
131 the context of a greening economy, part of the NIC is linked with the ability of a country to produce and
132 commercialize a flow of eco-innovation technology over the long term. The eco-innovations are new or
133 modified products or services that generate positive externalities on the environment, and are intrinsically
134 connected with the policies of green growth, symbolizing a synergy between environment and innovation
135 policies (Andersen, 2006; Kemp and Andersen, 2004; OECD, 2009) and the creation of green business
136 opportunities (Andersen, 2010a; Beltramello et al., 2013). The degree of a sector's eco-innovativeness is not
137 only driven by a self-interested search for reduced production costs, increased efficiency, or enhanced
138 product performance, but is often controlled by public or private incentives and policies to set technological
139 trajectory directions (Kemp and Pearson, 2007). The elements that influence eco-innovation development
140 also differ between those related to the development of traditional innovations (Arundel and Kemp, 2009;
141 Kemp, 2010). Environmental regulations can be a major driver of eco-innovation through breaking the
142 technological *lock-in* created by uncertainties related to new technological paths (Porter and Linde, 1995).
143 With new regulations, emerging markets are created which provide competitive advantages for new (green)
144 technologies (Foxon and Kemp, 2008), thereby creating a win-win scenario subsumed in Porter and Linde
145 (1995). Eco-innovations, whose development was spurred by regulations, can then generate both economic
146 and environmental benefits, negating the oft-assumed trade-offs between private profit and environmental
147 improvement.

148 The successful development of eco-innovations, however, is not only a response to environmental
149 regulations, but is governed to a large extent (just like the development of traditional innovations) by how
150 companies and knowledge institutions interact as a system, thereby determining the capabilities required for
151 successful innovation activities (Carlsson et al., 2002; Edquist, 2006; Lundvall et al., 2009). In the water sector,
152 the lack of effectiveness with respect to the interaction among key innovative actors in the sector is seen as

153 a chief barrier for increasing the innovative capacity (De Montalvo and Alaerts, 2013). Indeed, effective
154 interactions for a successful technological development are required among water users (citizens), water
155 researchers, water providers (utilities companies) and water policy and regulatory bodies (governmental
156 institutions), and even within the government bodies, many layers of interactions exist (from cities,
157 municipalities, villages to states, provinces, regions to the national level). The high complexity inherently
158 relies on the coordination of these different levels of interactions, and good water governance is pointed out
159 as the solution for the barrier created by lack of effective interaction among actors in the water sector
160 (Alaerts and Kaspersma, 2009; De Montalvo and Alaerts, 2013).

161 Overall, issues related to increasing the NIC for the water sector can be related to the weak link between
162 the common innovation structure and the cluster-specific environment. An example of this weakness is the
163 failure to coordinate efforts between governmental levels, companies and knowledge institutions increase
164 the capabilities related to technological development of (eco) innovation. Hence, in addition to current
165 determinants for the NIC, both the governance and the environmental policy are expected to have a strong
166 impact on the innovative capacity of the water sector.

167 **3. Methods and data**

168 The methodology applied in this paper is built on earlier work regarding innovative capacity and in
169 particular on the framework for innovative capacity developed by Furman et al. (2002). The determinants of
170 NIC can thus be divided into three main categories: (i) the common innovation structure, (ii) the cluster-
171 specific innovation environment, and (iii) the quality of linkages. The overall innovative performance of an
172 economy will result from the interplay among all three (Furman et al., 2002). For example, the common
173 innovation infrastructure creates a positive or hostile environment for technological development, whereas
174 a strong or weak cluster innovation environment can enhance or hinder the strengths of the common
175 innovation infrastructure.

176 The analysis presented in this study has been based on the use of patent data. There are several studies
177 that have previously used patents as a proxy for innovation to measure innovative capacity e.g (Faber and
178 Hesen, 2004; Furman et al., 2002; Krammer, 2009; Mellahi and Wilkinson, 2010). Patents are useful in this
179 context because they provide a highly disaggregated level of information and still enable the comparison
180 across different countries. It should be mentioned that several limitations are commonly recognized when
181 using patents as a proxy for innovation, for example, not all patents may reflect an innovation and/or there
182 may be important innovations that are not patentable. The limitations of patents as a proxy for the level of
183 water innovative capacity have been extensively debated elsewhere (Archibugi, 1992; Griliches et al., 1986;
184 Pavitt, 1985), and are therefore not discussed further in this paper; we firmly believe that patent counts can
185 be successfully applied as a proxy for the level of innovation activity and to analyze changes in the
186 technological trajectory especially when considering the limited data available in the water sector (Moro et
187 al., 2018).

188 **3.1 Data collection**

189 Data has been collected from the Organization for Economic Co-operation and Development (OECD) and
190 the European Patent Office (EPO), since previous work showed no differences in variance explained using the
191 data of the EPO compared to the US Patent Office (USPTO) (Faber and Hesen, 2004). Furthermore, we have
192 specifically used Triades¹ patent data covering the timeframe from 1990 until 2013, thereby allowing us to
193 additionally investigate and capture the changes over time. This database can distinguish patent families,
194 which prevents counting the same invention multiple times and ensures that only high level patents were
195 included in our analysis. To further avoid low quality patents, we selected only granted patents that were
196 filed with the EPO, USPTO, and World Intellectual Property Organization (WIPO). Moreover, the patents have

¹ According to OECD, the triadic patent families are counted according to the earliest priority date (first patent application worldwide), the inventor's country of residence and fractional counts. The OECD triadic patent families improve the quality and the international comparability of a patent indicator; home advantage and influence of geographical location are eliminated (OECD, 2009).

197 been collected using the International Patent Classification (IPC) codes, and these selected IPC codes are part
198 of the EPO environmental technologies classification.

199 The initial variables introduced by Furman et al. (2002) and further elaborated by Proksch et al. (2016) are
200 kept. However, due to the selection of regions studied here (i.e. Europe and China), the sectoral choice
201 (water) and the available data, the analysis had to be modified in order to improve the analysis of the national
202 innovative capacity framework to be applied in the water sector. The other indicators used in this study were
203 mainly collected from the OECD database in order to ensure quality level of data. A comprehensive overview
204 of the variables explored in this study is available in the Appendix (Table A.2).

205 **3.1.1 Variables to measure the NIC**

206 ***International water patents and international water patents per capita (IWPPC)***

207 The water patents are selected based on a list of specific IPC codes related to water environmental-related
208 technologies (See appendix Table A.3) and were counted based on the triadic patent families. The water
209 patents per capita is then calculated according to equation (1), where i = country and j = specific year:

$$210 \quad IWPPC_{i,j} = \frac{\sum Water\ patents_{i,j}}{\sum Population\ per\ head_{i,j}} \quad (1)$$

211

212 **3.1.2 Common innovation infrastructure**

213 ***GDP per capita***

214 Given the choice to analyze European countries and China, the common way of calculating the GDP is via
215 US dollars purchasing power parities (PPP). The PPP and related economic indicators are constructed
216 primarily for spatial comparison and for comparison between different currency areas (Eurostats, 2015).

217 ***Stock of international water patents (SIWP)***

218 If the maximum lifetime of a patent is 20 years, records from a 20-year period would allow assessment of
219 the influence of a patent stock. Also, a consistent database is available for only about two decades, enabling

us to accumulate all patents within a 23-year period for each observed point in time (1990–2014). The stock of international patents is then calculated using the formula below, where i = country and j = specific year:

$$SIWP_{i,j} = \sum Water\ patents_{i,j+1} \quad (2)$$

Aggregate employed scientific and technological (S&T) personnel and labor force

The S&T head count data measures the total number of researchers who are fully or partly employed within R&D (OECD, 2015).

Aggregate R&D expenditures

The aggregate R&D expenditures have been extracted from the OECD Database and are in US dollars. The R&D statistics are based on the main concepts and definitions of the OECD (2002), which is an internationally recognized standard methodology for collecting R&D statistics.

Strength of protection for Intellectual Property (IP)

The strength of IP rights was measured using the intellectual property rights index extracted from the intellectual property rights organization. The values vary from 0 (weak IP rights) to 20 (strong IP rights); the higher the IPRI value, the greater the IP protection within a country.

Share of government expenditure on higher education

The share of government expenditure on higher education, extracted from the OECD database, is presented as a percentage of the GDP.

Specialization degree

The specialization degree is calculated by dividing the number of water patents per total number of patents. The patents are classified according to the IPC codes. The specialization index is calculated according to equation (3), where i = country and j = specific year:

$$Specialization\ degree_{i,j} = \frac{\sum Water\ patents_{i,j}}{\sum all\ patents_{i,j}} \quad (3)$$

3.1.2 Additional variables to measure the NIC for the water sector

The driver for eco-innovation development may differ from traditional technologies, where environmental regulations are recognized as key drivers for eco-innovation (Foxon and Kemp, 2008; Gregersen and Johnson, 2009; Porter and Linde, 1995), but are not limited to a response to the regulations. Therefore, we included a set of variables in our analysis for testing whether they display a relationship (correlation) with the level of NIC in the water sector. The selection of these variables is based on a literature review of water and (eco)innovations.

Environmental Policy Stringency Index² (EPS index)

The OECD Environmental Policy Stringency index is a country-specific and internationally comparable measure of the stringency of environmental policy. Stringency is defined as the degree to which environmental policies put an explicit or implicit price on polluting or other environmentally harmful behavior. The index ranges from 0 (not stringent) to 6 (highest degree of stringency). The index covers 28 OECD and 6 BRICS countries for the period of 1990-2013. The index is based on the degree of stringency for 14 environmental policy instruments, primarily related to climate and air pollution (Botta and Koźluk, 2014). The index is comprised of both market based and non-market based indicators.

Water dependency ratio³

The dependency ratio expresses the part of the total renewable water resources originating outside the country. This indicator may theoretically vary between 0% (the country does not receive water) and 100% (country receives all its water from outside). This indicator does not consider the possible allocation of water

² The dedicated website: <http://oe.cd/OQ>

³Source: <http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en>

261 to downstream countries, but otherwise begins to give some indication of the importance/influence of
262 transboundary waters for a country/region. The dependency ratio of a country is an indicator expressing the
263 percentage of the water resources originating outside the country. (UNEP, GEODATA, 2017)

264 ***Drinking water availability***

265 This indicator reflects the percentage of the population with access to drinking water. The indicators vary
266 from 0 (no access to drinking water) to 100 (complete access to drinking water) (UNEP, GEODATA, 2017).

267 ***Water pollution levels***

268 The water pollution level is determined based on three indicators related to the nitrogen level (Emnox),
269 phosphorus level (Emso2) and non-methane organic compound level (Emnvoc). The coverage of all
270 sources/types of water pollution – typically encompassing physical changes (e.g. erosion), aesthetical
271 pollution, eutrophication, pathogenic pressure, oxygen depletion, xenobiotic chemicals, and changes in the
272 ecosystem (community dynamics) (Vezzaro et al., 2018) – wasn't possible due to limitations in data
273 availability and consistency. However, the majority of European ecological indices, especially for
274 macroinvertebrates and fish, are based on dissolved oxygen, nitrogen and phosphorous compounds –
275 targeting effects of pollution with easily degradable organic matter (Vezzaro et al., 2018), and thus the results
276 presented here are believed to present a robust first indication for the state of pollution in surface water.

277 ***Collaboration***

278 The paper uses the international collaboration index as a *proxy* for the level of interaction between
279 domestic actors and international actors. The index is. The index is calculated by OECD as measure for the
280 level of shared patents of a country available at disaggregated levels, enabling the use of the index specific
281 for water patents.

282 ***Governance***

283 The issue of water governance was pointed out as being a barrier for the development of technological
284 capacity (De Montalvo and Alaerts, 2013). As a proxy for governance, the level of direct investments has been
285 selected. We recognize the limitation of this indicator as a *proxy* for governance, since it doesn't necessarily
286 reflects the level of government leadership on promoting the development of capabilities in the water sector,
287 but due to the lack of quantitative data in the analyzed timeframe (1990-2013) and the selected objects
288 (China and Europe), this was determined to be the closest variable available, since it shows the level of
289 governmental direct investments .

290 **3.2 Data treatment**

291 First, the paper provides the descriptive statistics of the main indicators related to the level of NIC (water
292 patents per capita and water patents), common innovation infrastructure (EPS index, collaboration, direct
293 investments, total R&D expenditures, GDP per capita, patent stock, investments in higher education and full
294 time equivalents), and the cluster-specific environment (private R&D funding and the private R&D funding
295 performed by universities, total R&D and the specialization index). This first assessment of the data provides
296 the overall evolution of the indicators which may have a relation with the level of water innovative capacity.

297 Secondly, the paper develops partial regressions to analyze the significance and the specific effect of
298 selected variables, which may have a higher impact on the level of national water innovative capacity. The
299 partial regressions can be divided into three groups, where the first two groups analyze variables related to
300 the common innovation structure: EPS index, collaboration, direct investment and the investments on R&D.
301 The second group of partial regressions is related to the cluster-specific environment, using the following
302 variables: private R&D funding and the private R&D funding performed by universities.

303 Thirdly, a *log-log* regression is developed in order to analyze the effects of the common water innovation
304 infrastructure, the cluster-specific environment, as well as other elements that may contribute to the water
305 innovative capacity. The paper first analyzes the correlation matrix and tests for multi-collinearity to exclude
306 combinations of variables that may cause multi-collinearity problems; these results are available in the

307 supplementary information. Different combinations of dependent variables were tested to identify potential
308 changes to the explanatory power of the model. Additionally, the control for year-to-capture differences over
309 time was included, as well as different models to control for fixed or random effects. The fixed and random
310 effects test can also be found in the supplementary information.

311 **Table 1: Descriptive data.**

Variable		Mean	Std. Dev.	Min	Max	Observations
Water Patents	overall	2.77564	1.45217	1.1087	5.6621	N = 432
	between		1.34426	0.63879	5.48376	n = 18
	within		0.63102	0.259063	5.38216	T = 24
IWPPC	overall	0.12348	1.6479	11.5129	1.9732	N = 432
	between		1.53758	4.86415	1.28741	n = 18
	within		0.69109	6.77223	2.48136	T = 24
WPstock	overall	4.8565	1.71974	1.3863	8.6673	N = 432
	between		1.40389	2.606117	7.70545	n = 18
	within		1.04488	0.864079	7.30808	T = 24
specdgree	overall	3.89962	0.90584	5.8713	1.5349	N = 432
	between		0.7306	4.5773	1.70966	n = 18
	within		0.56147	-5.7949	1.329	T = 24
EPS index	overall	5.05017	0.58383	3.2189	6.0243	N = 432
	between		0.32481	4.240562	5.5336	n = 18
	within		0.49091	3.831026	6.12851	T = 24
pop	overall	2.8869	1.42411	1.2724	7.2319	N = 432
	between		1.46312	1.392787	7.16151	n = 18
	within		0.04003	2.76651	3.03781	T = 24
UniRD	overall	2.70252	1.52007	4.0378	11.1044	N = 432
	between		1.1879	1.2386	4.31819	n = 18
	within		0.98732	0.19308	10.3295	T = 24
PrivRDUni	overall	1.209	1.75066	-9.1809	0.0973	N = 432
	between		0.84363	-2.88387	0.41944	n = 18
	within		1.54631	-8.95666	1.21457	T = 24
GDPcap	overall	10.0233	0.64636	6.8856	11.1132	N = 432

	between		0.54267	8.180221	10.5154	n = 18
	within		0.37284	8.456046	11.2636	T = 24
fulltime equiv.	overall	11.1819	1.28751	8.0277	15.0776	N = 432
	between		1.27895	9.504338	13.9985	n = 18
	within		0.33057	9.069903	12.261	T = 24
GovRD	overall	8.87129	1.46801	0.8893	12.6645	N = 432
	between		1.36104	6.524971	11.1732	n = 18
	within		0.63364	0.8523	10.6224	T = 24
fullRD	overall	8.68602	1.43746	5.1006	12.7193	N = 432
	between		1.35976	6.2298	10.966	n = 18
	within		0.56216	4.847091	10.764	T = 24
water quality	overall	4.59175	0.0543	4.2008	4.6126	N = 432
	between		0.04949	4.394117	4.6052	n = 18
	within		0.0251	4.398436	4.75424	T = 24
Collaboration	overall	3.31463	1.44746	0	6.7158	N = 432
	between		1.20629	1.481488	5.77768	n = 18
	within		0.84715	0.649679	5.34348	T = 24
emnox	overall	6.19503	1.22012	4.544	9.9843	N = 432
	between		1.24704	4.712967	9.58213	n = 18
	within		0.12869	5.769897	6.6066	T = 24
emso2	overall	6.19503	1.22012	4.544	9.9843	N = 432
	between		1.24704	4.712967	9.58213	n = 18
	within		0.12869	5.769897	6.6066	T = 24
emmvoc	overall	6.28927	1.33168	4.022	10.0464	N = 432
	between		1.34927	4.37915	9.8301	n = 18
	within		0.2236	5.777836	6.95274	T = 24
IPrights	overall	0.55556	0.49748	0	1	N = 432
	between		0.51131	0	1	n = 18
	within		0	0.555556	0.55556	T = 24
water dependency	overall	0.33333	0.47195	0	1	N = 432
	between		0.48507	0	1	n = 18
	within		0	0.333333	0.33333	T = 24

312

313 4. Results and Discussion

314 The analysis of the NIC in the water sector needs to take into account those elements that impact the
315 overall national innovative capacity, since the water innovation system can be considered a sub-system of
316 the national innovation system. Additionally, an analysis of NIC in the water sector needs to incorporate
317 specific elements that impact water innovations. The first step is therefore to analyze the evolution of these
318 important indicators over time in order to identify differences between Europe and China that may lead to
319 different levels of water innovative capacity. The second step of the analysis can then be used to verify the
320 relation between the level of water innovative capacity with the evolution of indicators related to common
321 innovation infrastructure, the cluster-specific environment and the quality of the linkages. Finally, the third
322 step identifies how the interaction between these indicators may impact the overall level of the water
323 innovative capacity.

324 **4.1. Descriptive data analysis**

325 The complexity involved in the process of technologic development goes beyond the technology itself to
326 the whole system of technological development involved in this process (Geels, 2004, 2002; Kemp and
327 Arundel, 1998). Understanding the systemic aspect essential to understand the development of eco-
328 innovation. The many actors involved in the technological development process have different skills essential
329 for innovative activities, since the agents do not innovate in isolation, but do so in a context of a system of
330 networks made of direct and indirect relationships (Freeman, 1995; Lundvall, 1992, 2007; Nelson, 2006). The
331 most fundamental indicator to measure the levels of innovative activities *per output* are patents. A higher
332 level of patenting per capita means a region has developed the ability to increase the development of water
333 eco innovation, ensuring a sustainable path.

334 Figure 1 expresses the most basic form of innovative output: the evolution of water patents per capita and
335 the evolution of water patents. Figure 1A and B indicates that the overall level of patenting activities in China
336 is increasing but at a much lower level than Europe. The European national innovative capacity presents a
337 low level of changes implying a lack of dynamism in the water sector. This preliminary result highlights the

338 infrastructural characteristics of the water sector. Figure 1C shows patenting per capita in Europe and China;
 339 it is clear that the overall level of patenting activities is significantly lower in China. Figure 1D shows the
 340 patenting in Europe, the average for European countries and China where it can be seen that, despite the
 341 fact that patenting activities in China are at a much lower level compared to Europe, it is at a similar level
 342 with respect to the European average. The analysis of the evolution of the innovative output *per se* is not
 343 enough to understand why there are different levels of innovative capacity. The different levels of variables
 344 such as the regulatory framework, investments, and other elements related to the common innovation
 345 framework may increase or hamper the innovative capacity.

346

347
 348 **Figure 1: Evolution of the measures for innovative output in (A) water patents per capita and (B) water patents for**
 349 **China (■), Europe (●) and the European average (○), as well as their respective (C) means and (D) deviations.**

350 Some of the most important investments and policy choices that support innovative activity have broad
 351 impact throughout an economy—these are the common innovation infrastructures. The differences in
 352 common innovation structure can therefore provide information regarding the different levels of innovative

353 capacity between the two regions. The water sector is highly regulated with a mix of private and public actors
354 involved in the process of knowledge creation. These actors in turn are influenced by the government
355 directions in terms of regulatory frameworks, budget levels and overall public involvement. The amount of
356 money invested in R&D is also a reflection of the innovation input performed by a country.

357 Figure 2 provides an overview for selected elements from the common innovation infrastructure and its
358 evolution over time. Figure 2A shows that Europe and China have been improving the ability of their
359 environmental regulations to drive innovations; China was lagging behind but it clearly changes from around
360 2011 when stronger water regulations were established as they recognized the need to shift towards a more
361 sustainable path. In contrast, for Europe a fairly continuous growth can be seen underlining the region's
362 position as a first mover into the green economy agenda. In any case, this result highlights that both regions
363 are using regulations to drive eco-innovation. Figure 2B shows the collaboration index, which indicates the
364 level of patenting collaboration with other countries for each region. This indicator is comparable in Europe
365 and China until around 2000, at which point a substantial increase in the collaboration index for China is
366 suggestive that they had adopted a strategy of learning-by-interacting and trying to assimilate external
367 knowledge. In Figure 2C, the evolution of China with respect to Europe can be seen where both regions
368 present positive growth with respect to direct investments (as % GDP), but the direct investment in Europe
369 is consistently at a higher level than in China. Finally, Figure 2D presents the evolution of total R&D
370 expenditure where Europe presents a consistent and strong investment in R&D, and China starts at a lower
371 level but catches-up with Europe showing a transition from a low level of investments to a high level of
372 investments that may reflect changes on the national innovative capacity in the water sector.

Figure 2: Evolution of the common innovation infrastructure in China (■) and Europe (●) for the (A) evolution of the environmental stringency policy index (ESP); (B) evolution of the collaboration in patenting activities index; (C) evolution of the direct investments (as % of GDP); and (D) evolution of the aggregate R&D expenditures.

Figure 3 provides an overview of other selected elements from the common innovation infrastructure.

Figure 3A presents the evolution of the GDP per capita, where it can be observed that the level of GDP per capita in China is lower compared to Europe, indicating the different stages of development in each of these two regions. Figure 3B shows the evolution of the water patent stock which is constantly increasing in Europe, but is almost constant for China indicating their lack of innovative activities within the water sector. This result also highlights the European position, specifically as one of the innovative leaders in this (OECD, 2014). Figure 3C shows the evolution of full-time equivalents (i.e. aggregated employment in science and technology) where a fast evolution can be seen for China, reaching and then surpassing European levels from 2010 moving forwards. Figure 3D shows the remarkable evolution on investments in higher education in China, which is indicative for a structural change with respect to education. These results taken together show that China is changing substantially over time compared to Europe, which is expected since the country

388 has been through deep structural changes allowing them to have reached European levels for some of the
 389 indicators studied here (e.g. total R&D expenditure; total investments in higher education), surpassed Europe
 390 in some (e.g. collaboration; full-time equivalents) and are still lagging behind in others (e.g. ESP index; direct
 391 investments; GDP per capita; water patent stock).

392

393 **Figure 3: Evolution of the common innovation infrastructure in China (■) and Europe (●), including the (A) evolution**
 394 **of the GDP per capita; (B) evolution of the water patent stock; (C) evolution of full-time equivalents; and (D) evolution**
 395 **of the investment in higher education.**

396 However, the common innovation structure alone doesn't determine the level of innovative capacity of a
 397 nation. The interaction among the actors in the innovation system can have a high impact on the level of
 398 innovative activities. For example, the water sector relies on public investments and the development of
 399 research from universities and companies. Therefore, the composition of public/private R&D expenditure
 400 has been analyzed to evaluate the evolution of the elements related to cluster-specific environments
 401 (Figure 4). Figure 4A shows the evolution of the water specialization index, where it can be seen that the

level in Europe and China does not exhibit large fluctuations over time and that China's index is slightly higher. Figure 4B shows the evolution of private R&D used by universities; we observe that the level of PPP in China is similar to the European levels. Figure 4C shows the evolution of private R&D as a percentage of all R&D where the levels are slightly higher in China today than in Europe, but this shift took place after 2004. Finally, Figure 4D shows the evolution of R&D activities performed by universities per total R&D, indicating that European universities are more engaged in R&D activities than Chinese universities.

Figure 4: The evolution of the cluster-specific environment in China (■) and Europe (●), including the (A) evolution of the water specialization index; (B) evolution of the private R&D performed by universities; (C) evolution of the private R&D investments as a percentage of all R&D; and (D) evolution of R&D performed by universities per total R&D performed.

The overall evolution of the main indicators related to NIC reflect the different stages of development for the selected regions: China presents an ongoing change to its innovation system structure, where, in this

stage, the role of the government tends to be stronger in guiding and influencing these changes (Gu and Lundvall, 2006; Hu and Mathews, 2008). In contrast, Europe presents a more stable evolution of its indicators showing an innovation system that is more mature and structured. These results may give an indication for the evolution (and stage) for the main (aggregated) indicators related to water innovative capacity, but they do not provide information related to any potential relationships existing between them and the selected output for water innovative capacity (i.e. water patents per capita and water patents). The following section therefore evaluates the relationships that may exist among the selected indicators at the level of the national innovative capacity.

4.2. Partial regressions analysis

The relationship among the framework conditions and the interaction among actors can lead to a high or low innovative capacity. The ability of a country to succeed in the development of innovation can reflect its position in the global value chain. In order to analyze the relationship of patenting activities and selected indicators from the framework conditions and the relationship among companies and universities, we used partial regression for the main indicators that according to the literature might affect the water innovative capacity more than the other tested indicator from Furman et. al. (2002) The ability for environmental regulations to drive eco-innovation is widely known in the literature see: (Horbach et al., 2017; Kemp, 2010; Porter and Linde, 1995) and may also be the case for eco-innovations in the water sector, therefore the ESP index is tested on the partial regressions. Other factors might be equally or more important to explain the development of eco-innovation, some of which may also be sector-specific, including the role of differences and similarities in technological regimes, sectoral institutions, demand, and market structures (Oltra, 2008) as well as the ability to interact in order to create knowledge (Lundvall, 2007). In this context, the level of the collaboration index states the learning by interacting activities, in a globalized world, can be a *proxy* for the level of interaction.

The partial regression results show that both China and Europe's water patenting activities respond to a positive increase in the level of the ESP index, suggesting that regulations positively impacts the level of

441 innovative capacity as shown in Figure 5. The same trend is also observed for the collaboration index, where
 442 a positive change in the level of collaboration also positively impacts the level of water patenting activities
 443 see table 2. This result shows that a countries national innovative capacity in water can benefit from stronger
 444 water policies and high level of collaboration. These results are expected and extensively discussed in the
 445 literature of NIC, but we now confirm that the water sector follows the same trend. Moro et al. (2018) stated
 446 that the level of patenting activities follows the evolution on water policy and regulations, indicating that
 447 China is incorporating aspects of the green agenda in their development strategy, with the water sector being
 448 one of the prioritized sectors to benefit from the governmental investments.

449
 450 **Figure 5: Evolution of water patents per capita in Europe (●) and China (■) as a function of the ESP index (A;B) and**
 451 **as a function of international collaboration index (A;D).**

453 Table 2 presents the results from the partial regressions. The results show that both indicators (ESP and
 454 collaboration indices) positively affect the level of water patents per capita. The ESP index has a greater

importance for Europe than for China, suggesting that regulations may be one of the reasons why these two regions display different water innovative capacity levels. In contrast, the level of collaboration presented a similar magnitude in both regions. This suggests that, despite the high level of collaboration in China compared to Europe, the latter still presents higher innovative levels (see Fig. 1). This results shows that other variables might be more important for determining the innovative capacity in the water sector, or that the isolated effect of the collaboration might not be enough to increase the innovative capacity in this sector, since the innovative levels in Europe are higher than in China despite the fact that China presents higher levels of collaborations (level of shared water patents of a country). An alternative explanation might be that the indicator reflective of collaboration may not necessarily reflect interactive learning, but it can also be related more to an “imitation” mode of innovation from the Chinese side, that relies on foreigner knowledge rather than to develop internal capabilities to perform innovation. In any case, the analysis should be expanded, including other variables, besides regulations and collaborations.

Table 2: Summary regression statistics linear regressions results (I).

Independent Variable	Dependent variable: water patent per capita			
	China	Europe	China	Europe
ESP index	0.0505 (0.00774)	0.411 (0.0524)		
Collaboration index			0.00743 (0.00102)	0.00744 (0.000822)
R ²	0.670	0.733	0.692	0.778

Figure 6A and B displays the evolution of water patenting activities in China and Europe as a function of the government direct investments, as well as a function of aggregate investment in R&D (Figs.C; D). The direct investment results showed no significance for Europe, which may reflect a different stage of development (see table 3). The results show that water patenting activities also respond positively to an increase in total R&D, where the positive effect of R&D on water patenting activities was expected.

474

475

Figure 6: Evolution of international collaboration index over time (1990-2013) in China(■) A Europe (●) B and Evolution of water patents per capita as a function of the level of international cooperation in patenting activities in China(■) C; Europe (●) D.

In Europe, the water patenting activities did not display a significant relationship with the direct investments, as the partial regressions was not significant, whereas in China the direct investment has a positive impact on the level of water patenting activities (Table 3). This result indicates that the role played by government is more important in China than in Europe for driving water innovation. This finding is in line with Hu and Mathews (2008b, 2005) which states that developing countries have different national innovation system characteristics compared to developed countries, meaning that the role of government is more important for overcoming barriers for their national innovation system development, in the water sector the governance problems have been pointed out as barrier for further technological development (De Montalvo and Alaerts, 2013) In this context the paper uses the role of direct government investment as a proxy for governance, the indicator may not be the best fit to reflect the positive impact of good water

governance, but nevertheless, it reflects the basic structural differences between Europe and China, where the government has a bigger role on promoting investments and innovations.

Table 3: Summary regression statistics linear regressions results (II).

Independent Variable	Dependent variable: water patent per capita			
	China	Europe	China	Europe
Direct investment	1.371 (0.406)	*		
Total R&D			0.000224 (0.0000238)	0.00649 (0.000709)
R ²	0.510	-	0.792	0.783
* = Not significant				

The framework conditions provide the general environment for technological development, but the cluster-specific environment reflects the micro-environment where the actual innovation process takes place. Therefore, the water national innovation system relies on the good interaction of the actors involved in the process of water innovation creation and diffusion to improve the water innovative capacity. This micro-environment is too complex to be properly analysed due to a lack of quantitative data in the water sector that could enable an international comparison. Instead, this paper focuses on aspects of the R&D development in order to preliminarily analyse the cluster-specific environment and the quality of the linkages.

Figure 7A and B presents the percentage of private R&D as total R&D, which reflects the level of entrepreneurship in a country. Figures 7C and D present the level of private R&D performed by universities, which shows the level of interaction between private and public innovators. The results show that these indicators have no significance for Europe, but they present ambiguous results for China (see Table 4). The private R&D has a positive effect on the patenting activities in China, whereas the private R&D performed by universities has a negative impact on the level of water patenting activities. This suggests that in order to reach a higher level of water innovative capacity, the private innovators have to play a major role in the development of water innovations in China. The negative impact of private R&D performed by universities is relatively small (0.0099), suggesting that changes on the level of private R&D performed by universities has

511 little impact on the level of innovative capacity. This is an unexpected result, since the private R&D performed
 512 by universities is a *proxy* for the quality of interaction among companies and universities, and the importance
 513 of this relationship in promoting technological development has been widely highlighted in the innovation
 514 system literature (Nelson and Rosenberg, 1993).

515 Figure 7: Evolution of water patents per capita as a function of (A) total R&D and (B) private R&D investments
 516 performed by universities for China(■) and Europe (●).
 517
 518

519 Table 4: Summary regression statistics linear regressions results (III).

Independent Variable	Dependent variable: water patent per capita			
	China	Europe	China	Europe
Priv. R&D	0.00140 (0.000214)	*		
Priv.R&D Uni			-0.00990 (0.00159)	*
R ²	0.510	-	0.807	-
* = Not significant				

521 The results from the partial regression reflect that different elements will affect the water innovative
522 capacity in Europe and China, where particularly the direct role of the government is more relevant in China
523 than in Europe. Environmental regulations, as a driver for eco-innovation, is dominant in both regions. This
524 indicator reflects both the indirect influence of the government, reducing uncertainties related to which
525 technological trajectory should be followed and offering incentives to adopt a sustainable path, as well as
526 the direct influence (direct government investment) related to the role a government plays in providing funds
527 for investing in water-related innovation activities. Clearly differences exist regarding government
528 “strategies” in both regions where the Chinese government has a more straightforward approach, i.e.
529 investment in infrastructure, such as railways, energy infrastructure and water infrastructure. The next
530 section provides an analysis of how the combinations of these elements affect the water innovative capacity.

531 **4.3. Water innovative capacity analysis**

532
533 The combination of the different elements on the framework conditions, the level and nature of interaction
534 among innovative actors and their relation with the innovation environment can influence the innovative
535 capacity. Countries that developed the ability to promote efficient regulations often lead to a higher level of
536 eco-innovation development (Andersen, 2004; Horbach et al., 2011; Kemp and Pontoglio, 2011). Besides
537 regulations, the propensity of a country to interact with others to generate new knowledge may also lead to
538 higher levels of innovative capacity (Gregersen and Johnson, 1997). The amount of government expenditure
539 is also related to higher levels of innovative capacity, the more investments on R&D higher are the changes
540 to increase the technological development. The argument in this paper, therefore, is that water innovative
541 capacity is intrinsically related to a country’s national innovative capacity due to the fact that the investments
542 and evolution of the sector will follow the evolution and stage of development of the nation; the demand
543 and investments in the sector will also follow those trends to a certain degree.

Table 5 presents the results of the summary regression⁴ statistics using water patents as the dependent variable. The overall results show that the GDP per capita doesn't have a correlation with the level of national innovative capacity, a result which partially differs from OECD (2016) which states that rich countries will have the means to develop water innovations, whereas poorer countries cannot thereby creating a "north-south" market of water technologies. Importantly, this result shows that the level of GDP itself does not reflect an advantage on the development of water technologies, such that other elements should be taken into account. Furthermore, the water regulations present a positive impact on the level of water innovative capacity, a result which is again in line with the literature discussing environmental regulations as drivers for eco-innovation (Eco-Innovation Observatory (EIO), 2016; Li, 2009; Porter and Linde, 1995).

Table 5: Summary regression statistics for panel data, linear regression (I), random effects (II), fixed effects (III).

Dependent Variable: <i>Water patents</i>						
Variable/ Model	1-(I)	1-(II)	1-(III)	2-(I)	2-(II)	2-(III)
ESP index	0.1839922 (0.914417)	0.2377456 (0.1018744)	0.2441214 (0.1040255)	*	0.2130214 (0.0983315)	0.2196979 (0.1019533)
Population	*	*		0.5036978 (0.0553652)	0.624628 (0.0805713)	*
PrivRDUni	-0.0478009 (0.0191503)	*	*	-0.0543254 (0.0189194)	*	*
Water quality	11.48144 (1.222003)	7.583321 (1.732189)	6.507264 (1.684098)	11.89321 (1.114567)	8.508264 (1.243553)	7.840374 (1.29764)
Collaboration	0.4227477 (0.0557899)	0.1837857 (0.0708037)	0.1484677 (0.0573136)	0.377241 (0.0531431)	0.1637871 (0.0520746)	0.1332878 (0.0561764)
GDP capita	*	*	*	*	*	*
IpRights	1.127842 (0.1009794)	1.308016 (0.3102294)	*	1.240217 (0.0821995)	1.43248 (0.174973)	

⁴ A "dummy" was used for China in order to capture their effects and also the control for years, both didn't present significance on the model, suggesting that the overall elements that impacts the level of water innovative capacity are similar in both regions, the lack of significance on the control for the years suggests that the elements that impact the water innovative capacity didn't change over the last 20 years.

Water	-0.3047857	*	*	-0.3493336	*	
dependency	(0.0984026)			(0.0750098)		
emnox	-0.0743148	*	*			
	(0.178652)					
Emso2		*	*			
emmvoc	0.212037	*	*			
	(0.0776557)					
Constant	-52.33118	-38.77396	-34.55679	-54.06323	41.62003	-38.7604
	(4.873448)	(6.169259)	(7.298714)	(4.589805)	(4.910751)	(6.237679)
R²	0.81	0.80	0.56	0.81	0.80	0.48
*= not significant p < 0.05						

554

555 The water quality indicators (drinking water coverage as a *proxy*) display a positive impact on the overall
556 level of water innovative capacity. This result reflects the focus given to developing water-infrastructure and
557 the level of the country's development, indicative that the innovative capacity increases along with the
558 development of water infrastructure which is related to the stage of development for a given economy.
559 Water quality is furthermore related to the stage of the country's development, mainly suggesting that richer
560 countries have more money to spend on infrastructure which will affect their water innovative capacity. This
561 result is again in line with the discussion about the level of innovations in the water sector being linked with
562 local budgets which may suffer fluctuations from external instabilities (European Commission, 2016).

563 The level of IP-rights also displays a positive effect on the level of water innovative capacity, additionally
564 reflecting the innovation environment and infrastrucutre of a country. The collaboration index also presented
565 a positive impact on the water innovative capacity, showing that higher levels of knowledge interaction and
566 creation can lead to a higher innovative capacity. This result reflects, to a certain degree, the Chinese strategy
567 for choosing to interact with the international community to accumulate knowledge. The population level
568 has a positive impact on the water innovative capacity, where this result can be understood in two ways: on
569 the one hand it reflects more labour force, and on the other, it indicates the (potential) increase in pressure

570 (demand) for (decreasing) available water resources, thus leading a country to look for smarter solutions for
571 their water resources management.

572 The second set of regression uses water patents per capita as a dependent variable. Table 6 presents
573 the results from the summary regression statistics for the panel data, linear regression (I), random effects
574 (II), and fixed effects (III) using water patents as a dependent variable.

575 **Table 6: Summary regression statistics for panel data, linear regression (I), random effects (II), and fixed effects (III).**

Dependent Variable: Water patent per capita						
Variable/ Model	1-(I)	1-(II)	1-(III)	2-(I)	2-(II)	2-(III)
ESP index	1.355904 (0.1279181)	0.2069292 (0.0159246)	0.1860151 (0.0704305)	1.482451 (0.1201043)	0.5034895 (0.0683097)	0.4769381 (0.0680526)
PrivRDUni	0.1349525 (0.0377718)	0.0581606 (0.0159246)	0.0569154 (0.0157703)	1187504 (0.0389078)	0.0661487 (0.0198169)	-0.0274403 (0.0306691)
Collaboration	0.1395332 (0.0552231)	0.3887867 (0.0413189)	0.3980715 (0.0414419)			
Specialization	5199135 (0.0797084)	0.5899158 (0.0857986)	0.5907831 (0.0436408)			
Index						
Uni RD	*	*	*	*	*	*
Gov RD				-0.1228536 (0.0474104)	0.1822262 (0.0519497)	0.205288 (0.052979)
Constant	52.33118 (4.873448)	-0.0983115 (0.8386192)	-0.0198415 (0.3130033)	-6.197229 (0.6634751)	-4.126341 (0.5254801)	-4.126341 (0.5254801)
R²	0.33	0.20	0.19	0.27	0.14	0.12
* = not significant p < 0.05						

576

577 The regression results indicate that the specialization index presented previously had a positive effect on
578 the level of the water innovative capacity, see also Table 5. These results further indicates that regulations
579 are the prime driver for eco-innovation development (Arundel and Kemp, 2009; Porter and Linde, 1995). The

580 Private R&D performed by universities also impacts the level of water innovative capacity, showing that the
581 higher level of interaction among the actors in the water innovation system (especially in China) positively
582 affects the level of national water innovative capacity further indicating the importance of intra-country
583 interactions on knowledge creation and diffusion. The collaboration index also positively affects the level of
584 water innovative capacity suggesting that not only the intra-country interaction is important for the process
585 of innovation development, but also international interaction can affect the level of innovative capacity.

586 The remarkable differences from the determinants of national innovative capacity to the water innovative
587 capacity is related to the GDP per capita, suggesting that rich countries with a high level of innovative capacity
588 will not necessarily also have a high level of *water* innovative capacity. The water innovative capacity relates
589 with the direction of regulations, along with investments and levels of interaction among the domestic actors
590 *vis a vis* to the levels of interaction with international actors. Other elements, such as publications, openness
591 and market share, presented a high level of correlation and therefore weren't integrated into the models.
592 These results are in line with the body of evolutionary literature, which states that a successful technological
593 development in a globalized economy is related to the level of investments and the capacity of interaction
594 among the actors (Lundvall et al., 2002; Lundvall, 2007; Nelson, 2006). In addition, the development of water
595 eco-innovation is not only related with stronger water regulations, but also with the level of investments and
596 the capacity of interaction present among the actors within the innovation system. This further highlights
597 that water eco-innovations are ultimately related to investments, which are shaped by the synergy between
598 innovation policies and environmental regulations (Andersen and Faria, 2015; Kemp and Soete, 1992; Nill
599 and Kemp, 2009; Porter and Linde, 1995)

600 Conclusions

601 This paper tested a set of indicators to analyse the water innovative capacity in Europe and China. Based
602 on the work developed by Furman et al. (2002), the paper tested variables related to the common innovation
603 structure and industrial cluster-specific environment, and developed an adapted model for water

604 innovations. The paper additionally added the (i) environmental policy stringency index, (ii) the level of
605 international collaboration on patenting activities and (iii) water-related indicators in order to include key
606 sectoral-specific elements driving the innovative capacity in the water sector in the analysis. The challenges
607 related to this analysis goes beyond the lack of specific quantitative data for the water sector, but points
608 additionally to a literature gap regarding what drives knowledge creation and diffusion in the water sector,
609 where this paper attempts to provide a first (more qualitative) step.

610 The results showed that China has evolved its innovation infrastructure over time to levels similar to
611 Europe. There are still differences related to the role of government and the level of interaction among actors
612 when creating innovation. Notably, environmental policy and governmental R&D were found to be crucial
613 for the development of water innovation, which was in contrast to previous results from other. The level of
614 specialization was also found to be relevant for the national innovative capacity. Overall, the results indicate
615 that China is progressing towards a higher level of water innovative capacity; however, the Chinese water
616 innovative capacity is still at a much lower level than Europe. The reason for this difference seems to be
617 related to the level of maturity of the innovation system and the stage of development across the two
618 regions. With the rising number of water challenges particularly in China, improving the water innovative
619 capacity will be crucial for sustaining economic development and growth. This paper contributes to
620 understanding the determinants of the innovative capacity in the water sector and it highlights the
621 importance of focusing on water infrastructure development, as well as the micro-environment for water
622 innovations. These results nevertheless indicate that Europe performed better than China, due to the
623 evolution of both the water infrastructure and the micro-environment.

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785 **Appendix**786 **Table A 1:List of countries used in the regression**

Country		
Austria	Germany	Norway
Belgium	Greece	Poland
Bulgaria	Hungary	Portugal
China (People's Republic of)	Ireland	Romania
Croatia	Italy	Slovak Republic
Czech Republic	Latvia	Slovenia
Denmark	Lithuania	Spain
Estonia	Luxembourg	Sweden
Finland	Malta	United Kingdom
France	Netherlands	

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788 **Table A 2:Description of the variables used in this paper**

Variable	Definition	Source	Year Frame
Innovative Output			
Patents	Green International water patents	PATSAT/ OECD	1990-2013
Patents _{Pop}	International patent per million persons		1990-2013
Quality of the common innovation infrastructure			
GDP <i>per capita</i>	GDP in thousands of ppp-adjusted market prices	OECD	1990-2013
Patent stock	Cumulative Patents		1990-2013
Population	Total inhabitants	OECD/UN	1990-2013
FTE _{S&E}	Aggregate employed S&T	OECD	1990-2013
R&D	Aggregate R&D expenditures (US Dollars)	OECD	1990-2013
Openness	Openness to international trade = exports (US Dollars)	OECD	1990-2013
IP	Strength of protection for IP	International property rights index	1990-2013
ED share	Share of government on higher education (on secondary and tertiary education divided by GDP)	Eurostat	1990-2013
Strength of environmental Regulation	Environmental policy stringency index	OECD	1990-2012
Governance	Direct investment as % of GDP (US Dollars)	OECD	1990-2013
Cluster-specific environment			
Private R&D funding	Expenditure on R&D of business enterprise-sector divided by total expenditure on R&D (US Dollars)	OECD	1990-2013

Specialization	Environmental Water technologies divided by total Water patents		1990-2013
Quality of linkages			
Universities R&D performance	Percentage of R&D performed by high education as percentage of total R&D expenditure US dollars)	OECD	1990-2013
Private R&D funding performed by Universities	Private R&D performed by high education as percentage of total Private R&D expenditure (US dollars)	OECD	1990-2013
Collaboration	International Collaboration index	OECD	1990-2013
Contributing and related outcome factors			
LABOR	Number of full-time equivalent persons employed in the labor force	OECD	1990-2013
CAPITAL	Non-residential Capital stock (US Dollars)	OECD	1990-2013
MARKET Share	Share of exports on total (worldwide) trade in water technologies	OECD	1990-2013
Journal	Number of scientific publications	Web of Science	1990-2012
Water quality	Percentage of improvements on drinking water quality	UNEP GEODATA	1990-2013
Water dependency ratio	Index of level of external water resources a country depends on.	UNEP GEODATA	1990-2013
Emnox	Nitrogen emissions	UNEP GEODATA	1980-2008
EmSo2	Phosphorus emissions	UNEP GEODATA	1980-2008
emmvoc		UNEP GEODATA	1980-2008

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	WP	Wpcap	specdgree	ESPindex	pop	uniRD	PrivRDUni	GDPcap	GovRD	waterqua	Collab~e	emnox	emso2	emmvoc	iprights	waterdep
WP	1															
Wpcap	0.5495	1														
specdgree	-0.1088	0.1377	1													
ESPindex	0.4067	0.5063	-0.1687	1												
pop	0.3954	-0.5376	-0.2725	-0.1525	1											
uniRD	-0.03	-0.0005	-0.1948	0.1034	-0.0186	1										
PrivRDUni	0.0982	0.1711	-0.1498	0.1106	-0.0698	0.0826	1									
GDPcap	0.3941	0.7866*	-0.1836	0.7485*	-0.4681	0.1796	0.2342	1								
GovRD	0.751*	0.0249	-0.4453	0.2423	0.7333*	0.0368	0.0742	0.0929	1							
waterqua	0.1788	0.7551*	0.0739	0.4087	-0.6331	0.1184	0.3381	0.7708*	-0.1884	1						
Collaborate	0.813*	0.2651	-0.3747	0.4769	0.5326	-0.0394	0.1427	0.356	0.8159*	0.0184	1					
emnox	0.4561	-0.4572	-0.2874	-0.1492	0.9729*	0.0409	-0.087	-0.4034	0.7636*	-0.5629	0.5325	1				
emso2	0.4561	-0.4572	-0.2874	-0.1492	0.9729*	0.0409	-0.087	-0.4034	0.7636*	-0.5629	0.5325	1	1			
emmvoc	0.4499	-0.417	-0.2136	-0.1928	0.9202*	0.0298	-0.1158	-0.4036	0.7174*	-0.5506	0.4661	0.9478*	0.9478*	1		
iprights	0.5935	0.6683*	-0.2502	0.3201	-0.1585	-0.0282	0.0688	0.4799	0.3357	0.2772	0.4437	-0.0845	-0.0845	-0.0277	1	
waterdep	-0.0247	0.1057	0.0339	0.0379	-0.1414	-0.2743	0.1975	0.0125	-0.0982	0.144	0.1045	-0.2707	-0.2707	-0.2721	0.1581	1