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ANALYZING INSTITUTIONAL RESEARCH PUBLICATIONS, CITATIONS AND COLLABORATION ACTIVITIES IN SUSTAINABLE DEVELOPMENT AND ITS SUB-AREAS, WITH PARTICULAR REFERENCE TO ASIAN INSTITUTIONS

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Abstract: This paper aims to assess the research publications, citations and collaboration activities in the area of sustainable developments and its sub-areas: climate change, renewable energy, fishery and forestry. The study is conducted using the scientific literature of top ten Asian institutions in terms of publication output in sustainable development over the time period of 1999–2008. Sustainable development and its sub-areas are defined by the set of keywords, vetted by 16 domain experts. Using these keywords, we pull 17,911 papers from the Scopus database. We analyzed research landscape of the selected institutions in terms of absolute publication counts, citation counts, institute citations per paper, percent international collaborations and percent international citations. The results indicated that the institutions which are strong in sustainable development overall may not be strong in all sub-areas and that the institutions which are not strong in sustainable development overall may have significant niche strength in a given sub-area. It is also noted that the Chinese institutions appear to be strong in terms of publication output in sustainable development and its sub-areas but they do not appear to be strong in terms of scholarly impact. While the Chinese Academy of Science and Tsinghua University shows 24.55% and 15.07% of publication share in renewable energy during 2004-2008, they only show 20.12% and 8.83% for citation share. In contrast, Japanese institutions show increase in citation share, e.g. Kyoto University shows 9.26% publication share in renewable energy during 2004-2008 but its citation share is the highest among all the selected institutes (i.e. 21.15%) in the same time window. Finally, using Spearman's correlation, we compared institutes' ranking based on publication counts in sustainable development with traditional university ranking systems. We found weak correlation, $\varrho = 0.26190$ with QS ranking and $\varrho = 0.09523$ with Shanghai Jiao Tong University ranking, which suggest that the institutes may have different standing in terms of their research standing in a particular subject field than the traditional ranking systems.

KEYWORDS: Sustainable development, research productivity, citation analysis, global sustainability.

Introduction

Sustainable Development: An Interdisciplinary Research Area

The topics of "sustainability" and "sustainable development" have achieved increasing prominence in the last three decades. It is commonly acknowledged as *Our Common Future*. The sub-areas of sustainable development concern various aspects including nature, artifacts, and society (Abdullah *et al.,* 2012; Le´le´ 1991; Goodland 1995; Lapeña 2011). Research activities conducted at institutes accordingly aim at understanding diverse characteristics of complex interactions among natural, human, and social systems. An increasing number of institutes have begun to adopt research areas related to sustainable development as a strategic research focus and some have even established schools and degree programs for sustainability. Hokkaido University (http://www.sustain.hokudai.ac.jp/) has taken and initiative called "Hokudai Network for Global Sustainability" to create a network of

research and higher education institutions for Global Sustainability; Rikkyo University (http://www.rikkyo.ac.jp/) has launched the Education for Sustainable Development Research Centre (ESDRC); and Osaka University has launched a new trans-disciplinary research organization, the Research Institute for Sustainability Science (RISS) (Uwasu *et al.,* 2009).

Given the recognized critical need for institutions to develop more sustainable development paths and the rapid increase in resources now being invested in this area, it is becomes important to clearly understand the current state of research landscape in this area. However, due to inter-disciplinary nature of sustainable development, it is very challenging to measure the diversity of knowledge involved in sustainable development in institute research assessment. Moreover, we yet do not have consensus on the definition, concepts, or methodologies which should be adopted in this emerging field of science. However, using bibliographic analysis, one way to build corpus for sustainable development is to procure scientific publications which contain the term "sustainability" or "sustainable" in their titles, abstracts and keywords (Yarime *et al.,* 2010; Kajikawa *et al.,* 2007). Also, there have been efforts to provide research core and framework of sustainable development by identifying sub areas of sustainable development (Kajikawa 2008). Kajikawa *et al.,* (2007) detect following sub areas of sustainable development: Agriculture, Fisheries, Ecological Economics, Forestry (agro-forestry), Forestry (tropical rain forest), Forestry (biodiversity), Business, Tourism, Water, Urban Planning, Rural Sociology, Energy, Health, Soil, Wildlife, Education, Biotechnology, Medical, Livestock, Climate Change, Welfare and Livelihood.

Objectives

The followings are the objectives of this paper:

1. To determine research strengths of the Asian institutions in the area of sustainable development.
2. To determine research strengths of the Asian institutions in the sub-areas of sustainable development
3. To compare institutional publication based ranking with other traditional rankings (such as QS ranking and Shanghai Jiao Tong ranking).

We conducted a bibliometric analyses in order to achieve the set objectives. Bibliometrics involves the statistical analysis of quantitative aspects of scientific publications (Moed, 2002). It has adopted quantitative performance indicators to get over the disadvantage of subjectivity in peer review and expert judgments (Van Raan &Van Leeuwen, 2004), and has been used to evaluate research performance in an increasing amount and variety of studies (Rina, *et al.,* 1998). The production of scientific literature can reflect important stages of scientific activity. The progress of science can be studies through quantitative analysis of scientific literature (Garfield, 1979; Guan, 2007). The number of publications is an indication of scientific activities, whereas, citations provide an indication of scientific influence and impact (Moed *et al.,* 1985).

Scope

Due to inter-disciplinary nature of sustainable development, reviewing its structure is not an easy task. In this paper we limit our analysis to sustainable development (as the top hierarchy) along with four important sub-areas of sustainable development detected by Kajikawa *et al.,* (Kajikawa *et al.,* 2007; Kajikawa 2008) i.e. climate change, renewable energy, fishery and forestry. We planned to include the remaining sub-areas in future. We limited the scope of institutes to the top ten institutes in Asia which have the highest publications in sustainable development in our bibliography database during 1999 to 2008. Following are the selected institutes: Chinese Academy of Sciences (CAS), Harbin Institute of Technology (HIT), Hokkaido University (HU), Kyoto University (KU), National Institute of Advanced Industrial

Science and Technology (NIAIST), National Taiwan University (NTU), Tohoku University (TU), Tsinghua University (TsU), University of Tokyo (UT) and Zhejiang University (ZU).

Scopus (http://www.scopus.com/) is the selected citation database. The bibliography data was downloaded from the Scopus database at Asian Institute of Technology Thailand, in November 2009. No doubt, this choice of database limits the scope of examination to the scientific publications listed in Scopus database only. However, Scopus is the largest bibliography database resources, covering a very wide range of academic journals in diverse fields, including English translation of titles and abstracts of non-English scientific publications.

Methodology

Data Collection

It has been an issue of debate for what could be included in the field of sustainability science. Previously, Yarime *et al.,* (2010) examine scientific articles which contain the term 'sustainability' to quantitatively study the patterns of research collaboration of institutes in sustainable development. We extended this approach to procure scientific article and collect set of related keywords for sustainable development and its sub-areas by looking at the conferences and journal titles. Furthermore, to vet the keywords, we presented the keywords to 16 relevant domain experts. The vetted keywords are then used to define the sub-areas; e.g. the following vetted keywords have been used to define the sub-area climate change: "*climatic change", "global climate change", "climate policy", "climate change", "palaeoclimate", "climate warming", "climate variability", "kyoto protocol", "climatic changes", "north atlantic oscillation", "elevated co2", "climate changes", "global warming", "phenology", "permafrost", "soil respiration", "enso", "carbon sequestration", "el niño", "carbon cycle", "greenhouse gases", "paleoclimate", "environmental change", "pleistocene", "greenhouse gas"*. Similarly, for sustainable development, sets of keywords of selected sub-areas of sustainable development are combined along with the general keywords of sustainable development i.e. "sustainability" and "sustainable". A set of publications is then pulled for each institute (for each selected sub-area), including collected keywords in their titles, abstracts and author defined keywords from Scopus citation database. Doing so, we procured 17,911 publications. With the term publication we refer to scientific publications in acknowledged scientific journals, or conference proceedings, like articles, reviews and conference papers.

We utilized two time windows to track the research activities of institutes. One is the Historical Time Window and the other is Recent Time Window. While Historical Time Window is used to determine research strength of a given institute in later years, Recent Time Window determines the research strength of an institute in most recent years. Historical Time Window utilizes five year window for publications from year 1999 to 2003, and for citation window, we compute median citation half-life of scientific publications (from year 1996 to 2008) in sustainable development, which turns out to be 6 years. Hence, each paper in Historical Time Window gets 6 year time period to receive citations including publication year; e.g. papers published in 2003 have citation time window till year 2008. However, for the Recent Time Window, publication and citation counts have been considered during the same time window i.e. 2004 to 2008.

Performance Indicators

We analyzed research strengths in terms of absolute publication counts, citation counts, Institute Citations per Paper (ICPP), percent International Collaborations (%I-Col) and percent International Citations (%IC). While absolute number of publication and citation counts provided actual research output and impact, ICPP is a measure of efficiency that is calculated by scholarly impact of research per publication. The %I-Col shows the internationality of an institute to develop

international research linkages and %IC show international recognition of the research conducted at the institute.

The ICPP is the ratio of "total citations received by the papers in a given sub-area of sustainable development during a given time window published during a given time window" by "total number of papers in the sub-area of sustainable development published during a given time window". The %I-Col is calculated by taking the ratio of "number of papers with at least one international co-authorship in a given sub-area of sustainable development published during a given time window" by "total number of papers in the sub-area of sustainable development published during a given time window". The %IC is the ratio of "number of citations received by papers from outside the country where an institute is located in a given sub-area of sustainable development during a given time window published during a given time window" by "total citations received by papers in a given sub-area of sustainable development during a given time window published during a given time window".

Results

Using the above performance indicators, we examined research activities of the institutes in sustainable development. Furthermore, we examined research activities of the institutes in the sub-areas of sustainable development. Finally, we compared institutes' rankings based on publication counts in sustainable development with other traditional institute ranking systems (such as QS ranking and Shanghai Jiao Tong ranking). The Table A-1 below shows publications, citations, %I-Col and %IC data of the selected institutions in sustainable development.

Research Strengths of the Selected Institutes in Sustainable Development

Figure 1 shows analysis of ICPP vs. publications of the selected institutes in sustainable development in Historical Time Window. X-axis on graph shows the number of publications produced by the institutes, whereas, y-axis shows the ICPP. The analysis shows that UT is strong in sustainable development both in terms of ICPP (11.42) and publication counts (622). The

Table A-1: Publications (P), Citations (C), International Collaborations (I-Col) and International Citations (IC) of the institutes in Sustainable development.

	Historical Time Window				Recent Time Window			
Institutes	**P**	**C**	**% I-Col**	**% IC**	**P**	**C**	**% I-Col**	**% IC**
CAS	1168	8189	27.40%	38.55%	4980	13392	29%	40%
UT	622	7104	19.45%	67.30%	1549	7343	34%	70%
TsU	373	1417	17.43%	53.85%	1437	2824	16%	47%
ZU	213	850	12.68%	37.18%	1024	2043	19%	41%
KU	368	5631	23.10%	67.39%	1010	5763	32%	64%
HIT	106	223	14.15%	26.91%	962	711	11%	39%
NIAIST	321	3993	16.82%	59.50%	852	4769	22%	63%
NTU	265	2281	23.77%	66.86%	767	2653	32%	70%
HU	279	2846	25.81%	62.58%	722	3444	33%	66%
TU	264	2229	14.02%	64.11%	629	2939	28%	68%
Average	397.9	3476.3	19.46%	54.42%	1393.2	4588.1	25.60%	56.80%

- Table is sorted based on publications in Recent Time Window.*

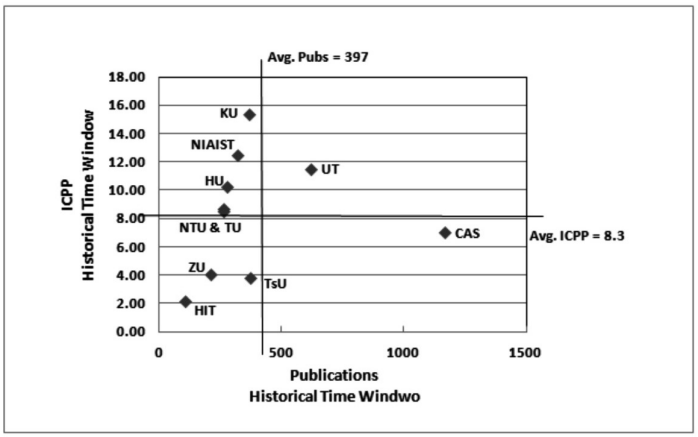

Figure 1: ICPP vs. Publication Output of the Institutes in Sustainable Development in Historical Time Window.

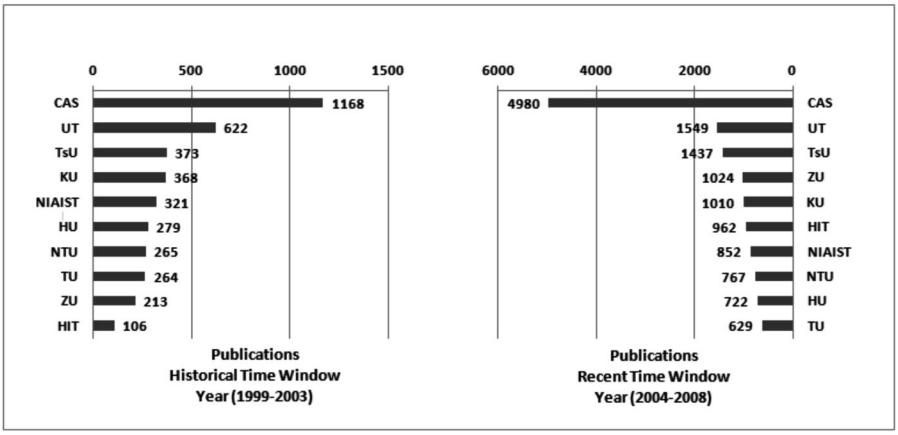

Figure 2: Publication Output of the Institutes in Sustainable Development in Historical and Recent Time Windows.

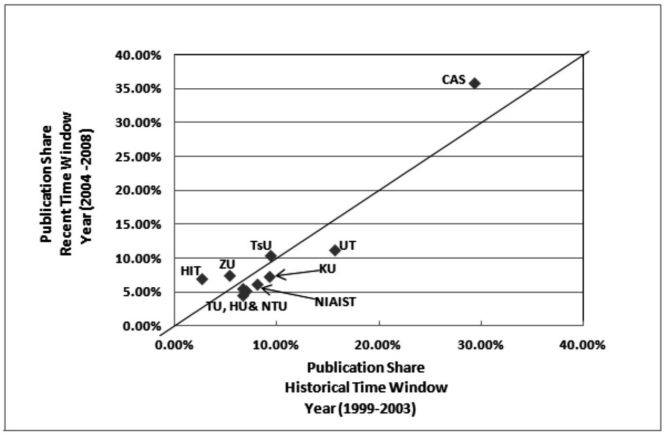

Figure 3: Publication Market Share of Selected Institutes in Historical and Recent Time Windows.

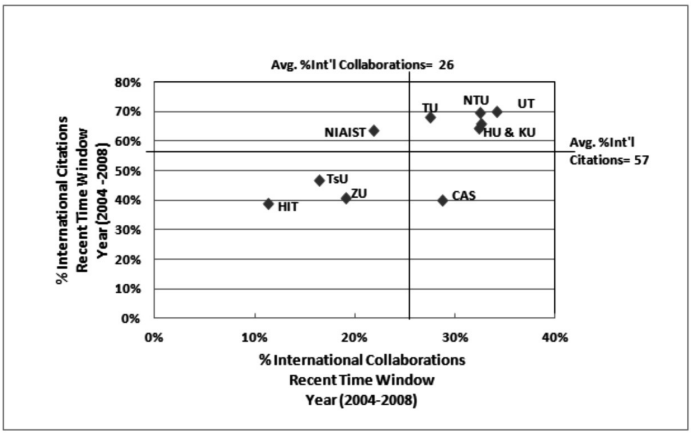

Figure 4: % International Collaborations vs. % International Citations of Selected Institutes in Recent Time Window.

UT stands above average ICPP and publication counts among the selected institutions (avg. publications = 397, avg. ICPP = 8.3). While KU has the highest ICPP value (i.e. 15.30) against 368 publications, CAS is leading in terms of publication output (i.e. 1168).

Figure 2 shows publication output of the institutes in the Historical and Recent Time Windows in sustainable development. CAS, UT and TsU appear to be top institutes in terms of publication output in both time windows. Interestingly, ZU and HIT have significantly increased their research output in recent years. HIT has moved from 10th rank to 6th whereas, ZU has moved from 9th rank to 4th in terms of publication output.

Figure 3 shows publication share analysis of the selected institutes. X-axis on graph shows share of publications produced in Historical Time Window, and y-axis shows share of publications in Recent Time Window. While CAS, TsU, ZU and HIT have increased their publication share in recent years, UT, KU, NIAIST, TU, HU and NTU have decreased their publication share. CAS is leading with large difference in publication share among the selected institutes.

Figure 4 shows %I-Col and %IC of selected institutes in Recent Time Window in sustainable development. The UT is ranked 1st both in terms of %I-Col (i.e. 34%) and %IC (i.e. 70%). While NTU, HU, KU and TU have strong international research visibility, TsU, ZU and HIT are below the average %I-Col and %IC.

Research Strengths of the Selected Institutes in Sub-Areas of Sustainable Development

This sub-section shows the analysis of research activities of the institutes in the selected sub-areas of sustainable development: climate change, renewable energy, forestry and fishery. Table A-2 below shows publications and citations data of the selected institutes.

Figure 5 shows publication output of the institutes in climate change and fishery in Recent Time Window. The horizontal bars stand for the publication share, whereas actual publication counts are written next to abbreviation of each institute on the vertical axis of the graph. We see that research activities of the institutes are distributed differently. CAS, HU, UT and NTU are prominent in Fishery with 25.98%, 20.11%, 15.12% and 14.06% publication share respectively, in contrast with climate change, where CAS alone is dominating with 55.16% publication share among the selected institutes. Interestingly, a number of institutes which are not in top tier in sustainable development as whole appearing to be very strong in some niche of sustainable development. For instance, HU, which stands at 9th position (see Fig. 3) in sustainable development in recent years from 2004 to 2008, stands at 2nd rank in Fishery (next

Table A-2: Publications (P), Citations (C) of the Institutes in Selected Sub Areas of Sustainable Development.

Institutes	Climate change Recent Time Window		Renewable energy Recent Time Window		Forestry Recent Time Window		Fishery Recent Time Window	
	P	C	P	C	P	C	P	C
CAS	1717	5390	668	2136	952	1971	146	446
HIT	18	7	156	155	9	1	9	7
HU	281	1339	57	158	201	570	113	316
KU	183	554	252	2246	235	765	49	227
NIAIST	145	822	376	2044	38	176	16	145
NTU	108	455	150	381	70	173	79	171
TU	126	918	167	1149	64	160	21	64
UT	408	2746	279	901	208	582	85	247
ZU	53	52	206	510	61	86	33	45
Total	3039	12283	2311	9680	1838	4484	551	1668

- Table is sorted based on institutes' abbreviation.*

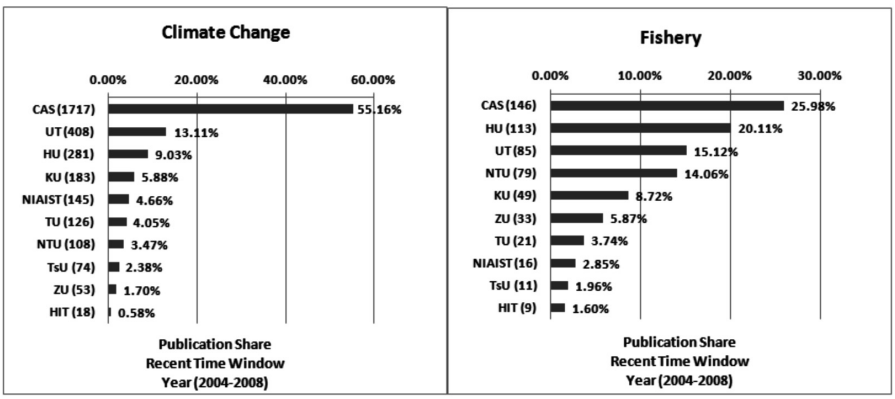

Figure 5: Publication Output of the Institutes in Climate Change and Fishery in Recent Time Window.

to CAS). Though, HU is not among the top tier institutes in sustainable development as a whole, but it stands at 2nd in Fishery with 20.11% publication share.

Figure 6 shows publication and citation share analysis of selected institutes in sub-area renewable energy in Recent Time Window. Surprisingly, KU stands above all in terms of citations, with 21.15% citation share. Though, KU has only 9.26% publication share in selected time window, but impact of these publications is very high.

Traditional University Ranking and Research Strengths of the Institutes in Sustainable Development

Finally, we compare institutes' ranking based on publication in sustainable development with traditional university ranking systems (such as QS and Shanghai Jiao Tong University ranking).

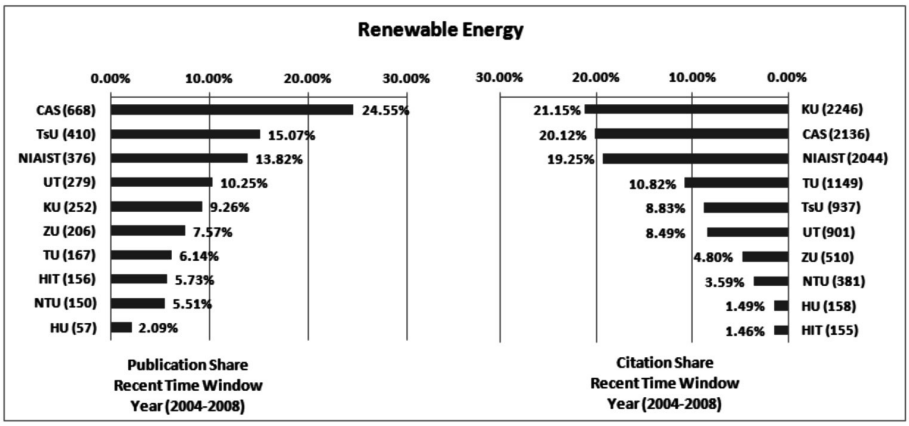

Figure 6: Publication & Citation Share Analysis of Institutes in Renewable Energy in Recent Time Window.

Table 1: Institutes Standing in Traditional University Ranking Systems Compared With the Research Strengths in Sustainable Development.

Institute	Publication based ranking in sustainable development Year (2004-2008) Region: Asia	QS Asian University Ranking 2008	Shanghai Jiao Tong University Ranking (Asia & Pacific) 2008
CAS	1	--	--
UT	2	3	1
TsU	3	15	23-41
ZU	4	32	23-41
KY	5	5	2
HIT	6	201+	69-100
NIAIST	7	--	--
NTU	8	22	17-22
HU	9	20	17-22
TU	10	13	7

-- = Data not available

We found that the institutes may have different standing in terms of their research output in a particular subject field than traditional ranking systems (see Table 1). For instance, in year 2008, Hokkaido University is ranked at 20th in QS Asian ranking (http://www.topuniversities.com/) and is ranked between 17 and 22 in Shanghai Jiao Tong University Asian/Pacific Ranking (http://www.arwu.org/). Though, Hokkaido University is not among top 10 universities in Asian region in both ranking systems, but it stands 9th position in terms of publication output in sustainable development from year 2004 to 2008. In addition, we also compute Spearman's correlation between publications based ranking and other traditional rankings. We skipped the rows if ranking data is not available. The correlation analysis further supports the fact that institutes may have different standings in niche research areas than the traditional ranking

systems. A weak correlation $\rho = 0.26190$ is observed between publication based ranking and QS ranking. Similarly, even a weaker correlation $\rho = 0.09523$ is observed between publication based ranking and Shanghai Jiao Tong University ranking.

Conclusion and Discussions

In this paper, we presented a bibliometric study to investigate research strengths of ten Asian institutes in sustainable development and its selected sub-areas using Scopus database over the time period of 1999–2008. The present study has generated a large amount of empirical data and information related to research performance of institutions in Sustainable development and is summarized as follows:

- Chinese Academy of Science shows significant research strengths in Sustainable development and its sub-areas.
- Among the Chinese Universities, Zhejiang University and Harbin Institute of Technology have significantly increased their publication output in recent years in Sustainable development.
- University of Tokyo appears to be very strong in terms of research internationally.
- In climate change, Chinese Academy of Science is significantly strong with more than 50% of publication share among the selected institutes.
- In fishery, research strengths (in terms of publication output) are distributed among several institutes: Chinese Academy of Science (25.98%), Hokkaido University (20.11%), University of Tokyo (15.12%) and National Taiwan University (14.06%).
- In renewable energy, Kyoto University shows high research strengths in terms of citation counts (i.e. 21.15% citation share among the institutes). Note that the Kyoto University shows only 9.26% publication share.

Based on the analyses conducted and the information we gain, the following points can be concluded:

1. Among the selected institutions, Japanese institutes show significant research strengths in Sustainable development and lead in Asia in terms of citations which clearly indicates maturity of Japanese research in the field.
2. Chinese institutions show high publication output in Sustainable development overall and its sub-areas, but less citation counts. This may call upon China to improve its research quality to gain more scholarly impact.
3. Chinese institutions do not appear strong in terms of research internationality. This may call upon China to take appropriate actions to increase international research linkages and finally to gain more international scholarly impact.
4. The analyses also indicated that institutions which are strong in sustainable development may not be strong in all sub-areas and that institutions which are not strong in Sustainable development overall may have significant niche strengths in select sub-areas. Such analyses can be useful in order to help government research agencies to understand how to more effectively knit together the various niche strengths in a country, to help institutes to find strategic partners that can complement their strengths, and to help institutes to make important resource allocation decisions.
5. We also highlighted the fact that institutes may have different standings than the traditional ranking systems (such as QS or Shanghai Jiao Tong University Ranking) when it comes to the research strengths in a particular field. This may call upon research administrators to carefully monitor institute research performance.
6. In countries where research growth is high, it is often the case that the institutes which are not generally perceived as being in the top two or three are becoming the strongest

centers for research in certain areas. Moreover, the relative research standing of institutes is changing so rapidly, particularly in niche areas, one cannot rely upon general perceptions to identify centers of research strength. The presented analyses in this paper help to identify the research areas of Sustainable development in which institutes are already competitive or can be with some investment. To effectively build research excellence in a subject area, an institute must be in the top tier in that area. This is necessary in order to be successful in the global competition to attract top researchers and top students, who by nature gravitate toward the strongest research environments.

7. Finally, this study is very useful in decision making in research administration and planning, to enable policy makers in different organizations and funding agencies to evaluate their decisions on the awarding of grants to individuals and institutions in sustainable development and related areas.

In future we plan to examine research activities of institutes in Sustainable development at global level and include more indicators such as size of institute, number of researchers in an institutes and funding data. In order to conduct bibliometric analysis related to sustainable development field and its sub-areas, approach to collect set of keywords appears to be very useful. This approach is flexible and can be used to conduct such analysis for any niche research area.

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