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# Tracking scientific development and collaborations – The case of 25 Asian countries

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Section 7:
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# Tracking scientific development and collaborations – The case of 25 Asian countries

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Bibliometric indicators based on publications in international, peer reviewed journals can be used to characterize the current stage of a country's scientific development. A simple bibliometric model for different phases of development of a country's national research system distinguishes four phases: (1) pre-development; (2) building-up; (3) consolidation and expansion; and (4) internationalization (see Figures 1, 2). The model assumes that during the various phases of a country's scientific development, the number of published articles in peer reviewed journals shows a more or less continuous increase, although the rate of increase may vary substantially over the years. But a bibliometric indicator measuring the share of a country's internationally co-authored articles discriminates between the various phases in the development.

1. **Pre-development phase:** In this phase the level of research activity in a country is low. Research oriented towards the international research front is carried out by a limited number of researchers only. There is no clear research policy and structural funding of research. Activities result from initiatives by a limited number of active researchers, who may in some years seek collaborations with foreign colleagues. The publication output is low. From a statistical point of view, indicators are based on low numbers and may show large annual fluctuations. This is especially true for the percentage of internationally co-authored articles.

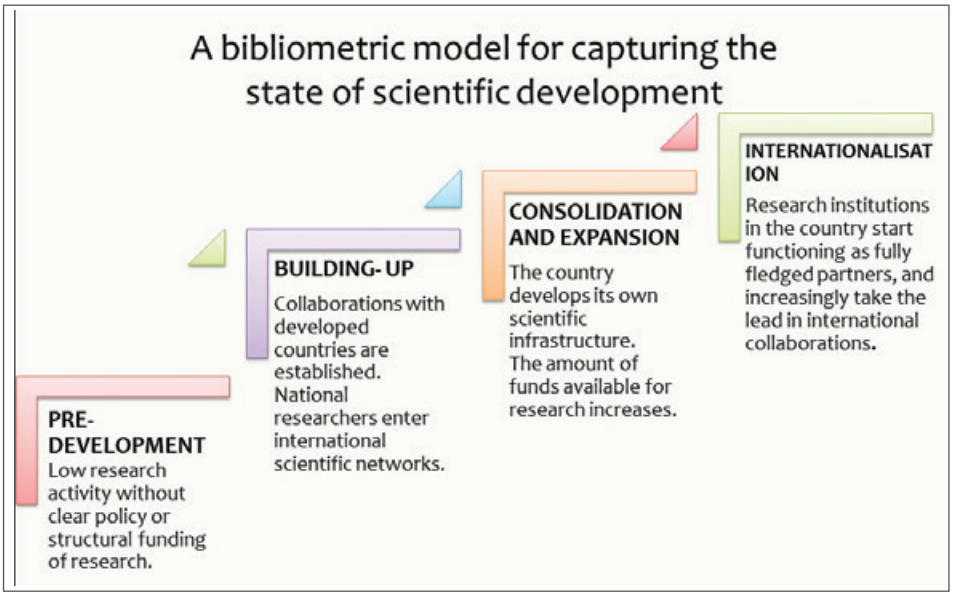


**Figure 1:** Bibliometric model for capturing the state of scientific development

2. **Building-up phase:** Researchers in the country start establishing projects with foreign research teams, often funded by foreign or international agencies, and focusing on a particular topic. They begin collaborating with colleagues from more developed countries. Internationally co-authored articles constitute one of the outputs. National researchers enter international scientific networks. The role of the country's authors in the collaboration is secondary rather than primary. The percentage of internationally co-authored articles relative to a country's total publication output tends to increase, but is often not statistically significant, due to the fact that the absolute number of annual publications from a country is low, and the internationally co-authored papers may be concentrated in particular years.

3. **Consolidation and expansion:** The country develops its own scientific infrastructure. The amount of funds available for research increases. The national research capacity increases. Nationally oriented journals internationalize and have a larger probability of being indexed in Scopus and other international scientific literature databases. More and more research papers are based on research carried out by national institutions only. The number of internationally co-authored papers increases as well, but at a rate that is lower than that of the country's total output; hence, the percentage of internationally co-authored papers declines.

4. **Internationalization:** National research capacity is further expanding; research institutions in the country start functioning as fully fledged partners and more and more often take the lead in international collaborations. Overall impact increases; the country's researcher's influence the global research agenda; the country more and more becomes one of the world leaders, at least in specific research domains. Both the number of publications and the share of internationally co-authored articles increase.

| Phase | Trend in number of publications | Trend in share of internationally co-authored papers |
|---|---|---|
| Pre-development | . | . |
| Building up | + | ++ |
| Consolidation and expansion | ++ | - |
| Internationalization | + | + |

**Notes:** "." denotes low or limited; "+" denotes an increase; "++" denotes a large increase; "-" denotes a decline.

**Figure 2:** Schematic overview of trends in bibliometric indicators per development phase. Source: UNESCO report "Higher Education in Asia – Expanding up, Expanding Out"; P. 80

| Concept | Main questions | Indicators; classifications |
|---|---|---|
| Publication output | How many articles did a country publish and how did this number develop over time? | The number of research articles, reviews and conference papers published in journals and conference proceedings indexed in Scopus during 1997-2012 |
| Disciplinary specialization | In which subject field does a country specialize? | Use of a subject classification into 26 main disciplines available in Scopus |
| Distribution by institutional sector | How important are the various institutional sectors in research? | Use of a classification into 4 institutional sectors: Higher Education; Government; Private; Health |
| Global and regional collaboration | How frequently do Asian countries collaborate with each other and with countries outside the region? | Based on the number of articles co-authored by researchers from different countries; calculation of the percentage share of a country's articles co-authored with researchers working abroad |
| State of scientific development | In what phase of its scientific development is a country? | Based on a simple model taking into account the trend in a country's annual number of publications and the percentage share of internationally co-authored articles |

**Table 1:** Main bibliometric indicators and classifications used in this study

This study analyzed data on scientific publications for 25 Asian countries (see Table 2) extracted from Scopus, a multidisciplinary database covering publications in 20,000 peer reviewed, mostly international journals. Data on all publications indexed in the Scopus database were organized by country and sorted into three adjacent time periods: (a) 1997-2001, (b) 2002-2007 and (c) 2008-2012. This yielded approximately 6.5 million records for the region as a whole over these three time periods. These publication records were sorted into 26 research disciplines implemented in Scopus. Publications were coded to denote the number of co-authorships among authors from countries in the study set and with authors in other countries outside the studied countries. Publications were further categorized by authors' type of institutional affiliations, e.g., whether they were affiliated with a higher education institution, government, a private sector organization, or were employed in the health sector. Figure 1 describes the most important indicators and document classifications applied in the following analysis.

### Trends in scientific output 1997-2012

Figure 3 shows that there are substantial differences among countries in their average number of publications per year, by up to 400 per cent. Among countries with more than 1,000 papers per year per country, the largest output is from China. However, Iran, Malaysia and Pakistan have a compound annual growth rate above 15 per cent.

| Country | Country |
|---|---|
| Afghanistan | Macao |
| Bangladesh | Malaysia |
| Bhutan | Maldives |
| Brunei | Myanmar |
| Cambodia | Nepal |
| China | North Korea |
| Hong Kong | South Korea |
| India | Pakistan |
| Indonesia | Philippines |
| Iran | Singapore |
| Japan | Sri Lanka |
| Laos | Thailand |
| | Vietnam |

**Table 2:** List of countries included in the analysis

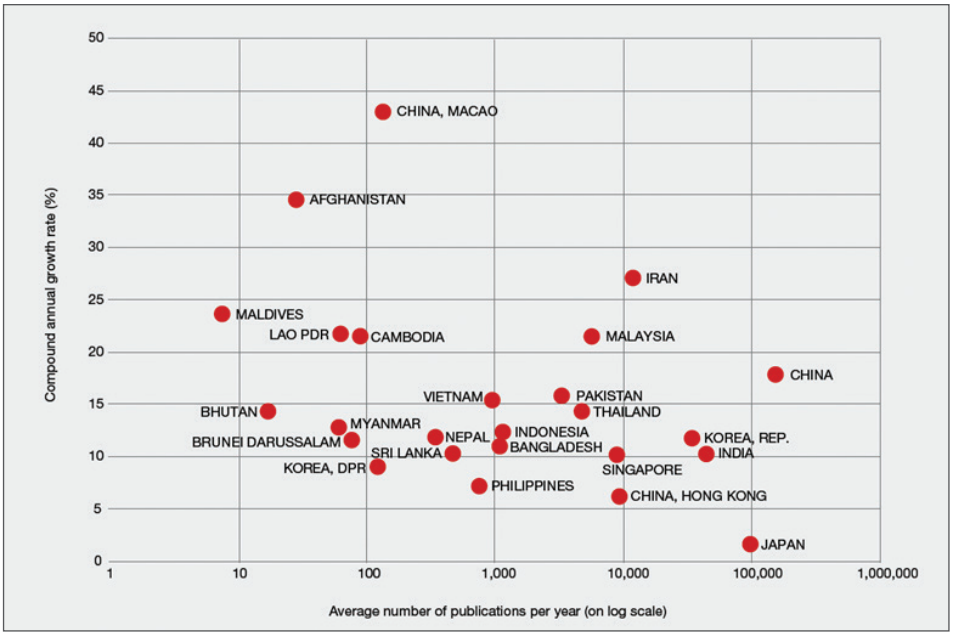


**Figure 3:** Number and annual growth rate of publications indexed in Scopus 1997-2012.
Note: The horizontal axis gives the average number of publications indexed in Scopus per year over the time period 1997-2012 on a logarithmic scale. The vertical axis gives the compound annual growth rate (CAGR) in the number of publications over the same time period. If P1 and P2 denote the number of publications from a country in 1997 and 2012, respectively, CAGR is defined as 15(P2/P1) - 1.
Source: UNESCO report "Higher Education in Asia – Expanding up, Expanding Out", P.85

### Scientific output in relation to PhD students enrolment and FTEs

The data below compare two bibliometric indicators – the number of published articles and the number of publishing authors in a year – with two non-bibliometric indicators, namely the number of FTE researchers in a country and the number of doctoral degrees awarded by that country. Figure 4 indicates that the number of publications generated within a country increases in almost linear fashion with the number of doctoral degrees. This suggests that doctoral students play a key role in the production of a country's publication output in international, Scopus indexed journals.

Likewise, the number of authors from a country publishing research articles (at least in Scopus) increases with the number of FTE researchers (Figure 5). Further, research intensive countries, i.e., countries that have a large number of FTE researchers per inhabitant, tend to have a higher share of researchers in the business sector than less research intensive countries. Since researchers in the business sector tend to publish less in international journals, this factor may explain why the increase in the number of publishing authors has a somewhat weaker relationship to FTE researchers in the country.

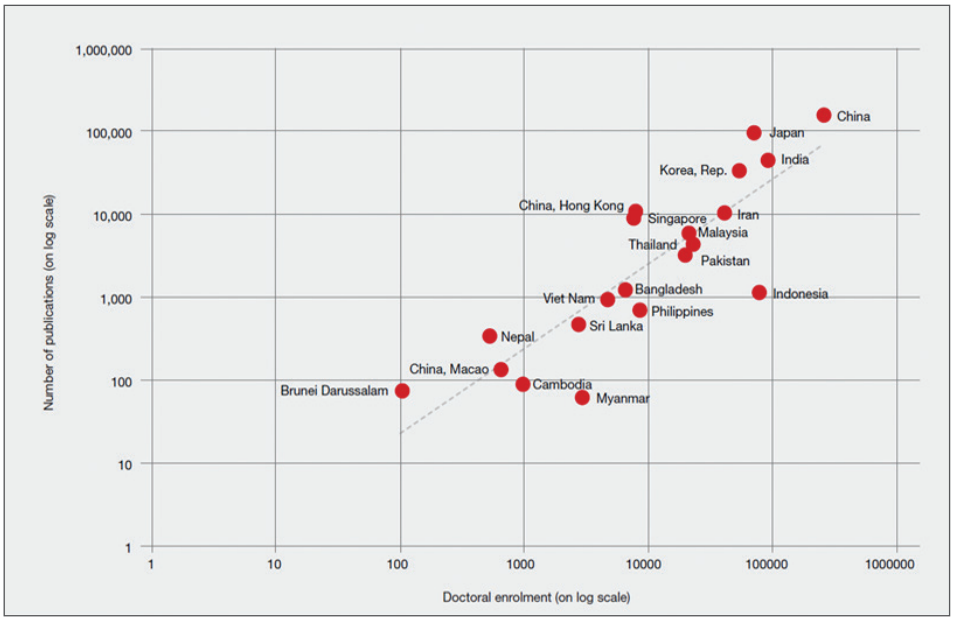


**Figure 4:** Number of publications indexed in Scopus in relation to doctoral enrollment by country (UNESCO, 2006). Note: Publication counts relate to the average number of publications from a country per year during 1997-2012, and the number of doctoral degrees to the most recent year for which data are available (mostly 2011). The dashed line represents the best fit of a power law relationship of the type $y=\alpha.x^{\alpha}$. Plotting this functional relationship on a double logarithmic scale, it yields a straight line. The exponent $\alpha$ in the relationship is called the scaling parameter or exponent, and is in a double log plot represented by the slope of the straight line. If $\alpha=1$, y increases linearly with x. If $\alpha>1$ y increases superlinearly with x, indicative for a cumulative advantage. If $\alpha<1$ y increases sublinearly with x, indicative for a cumulative disadvantage. The R2 value is a measure of the goodness of fit of the power law relationship. It ranges between 0 (no fit) and 1 (perfect fit). Source: UNESCO report "Higher Education in Asia – Expanding up, Expanding Out", P.82

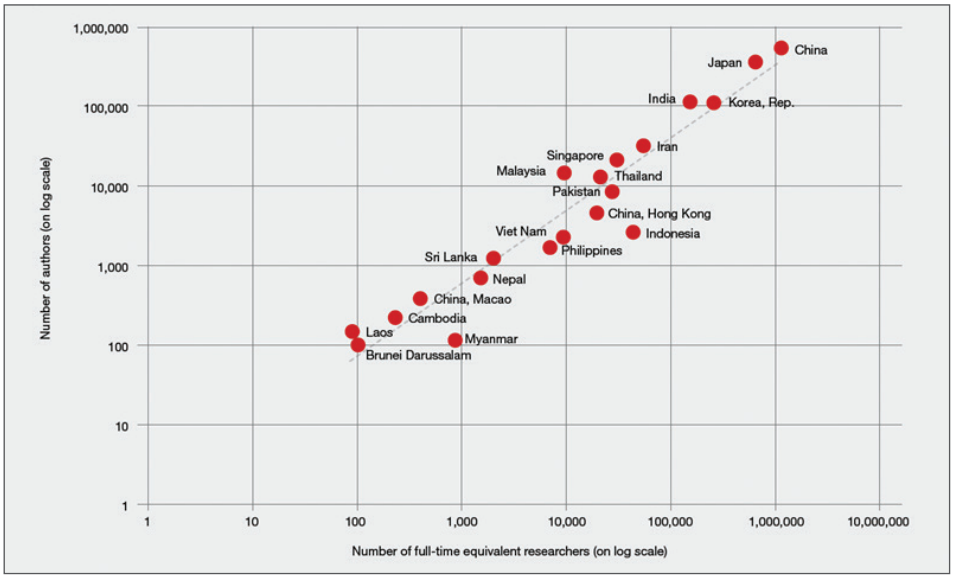


**Figure 5:** The relationship between the number FTE researchers (UNESCO, 2006) in a country and the number of authors of publications indexed in Scopus. Note: Author counts relate to the average number of publishing authors from a country per year during 1997-2012, and FTE research to the most recent year for which data are available (mostly 2011). For the meaning of the dashed line and the parameters in the functional relationship see the legend of Figure 1. For the full country name corresponding with a country code see Table 1. Source: UNESCO report "Higher Education in Asia – Expanding up, Expanding Out", P.83

### International co-authorships

The trend in the percentage of internationally co-authored papers for 13 countries between 2003 and 2011 is presented in Figure 6. Three out of five high income countries such as China, Singapore and Japan, show a positive trend in international co-authorship. Seven out of nine of middle income countries such as India and Indonesia, show a significant decline in the percentage of internationally co-authored articles, and none shows a significant positive trend. A negative decline could be a sign of the consolidation and expansion phase in scientific development which is apparently dominant in middle income countries.

### Trends in scientific collaborations

Figure 7 shows that there are tight co-authorship clusters within the region. Japan has a central role in the collaborative co-authorship scheme of the region. Japan's research focus on Medicine, Biochemistry, Physics and Engineering enables it to become a central hub of collaborations, bringing together research from different areas in the region. In addition there is a formation of three clusters of research collaboration within the region. The first cluster includes China, Hong Kong (Special Administrative Region of China), Singapore and Macao (SAR of China), which constitute the East Asian region. As shown China also serves as a link between Hong Kong (SAR of China), Macao (SAR of China) and Singapore to other members of the region such as Japan, India and Thailand. The China / Hong Kong (SAR of China) / Singapore/ Macao (SAR of China) cluster focuses on the areas of Engineering, Physics and Astronomy as well as Computer Science for the most part. The second cluster, which includes India, Malaysia, Bangladesh, Pakistan and Afghanistan, constitutes the South Asian region and focuses on Medicine, Agriculture, Chemistry and Engineering. The third cluster, which includes Thailand as its center, closely connects Indonesia, Sri Lanka, Brunei, Nepal, Laos, Cambodia, Vietnam, Myanmar and Laos and together constitutes the South Asian region. This cluster focuses mostly on Agriculture, Medicine and Earth sciences. Finally the map shows that the Republic of Korea and China play an essential role in bridging between Democratic People's Republic of Korea and other countries.

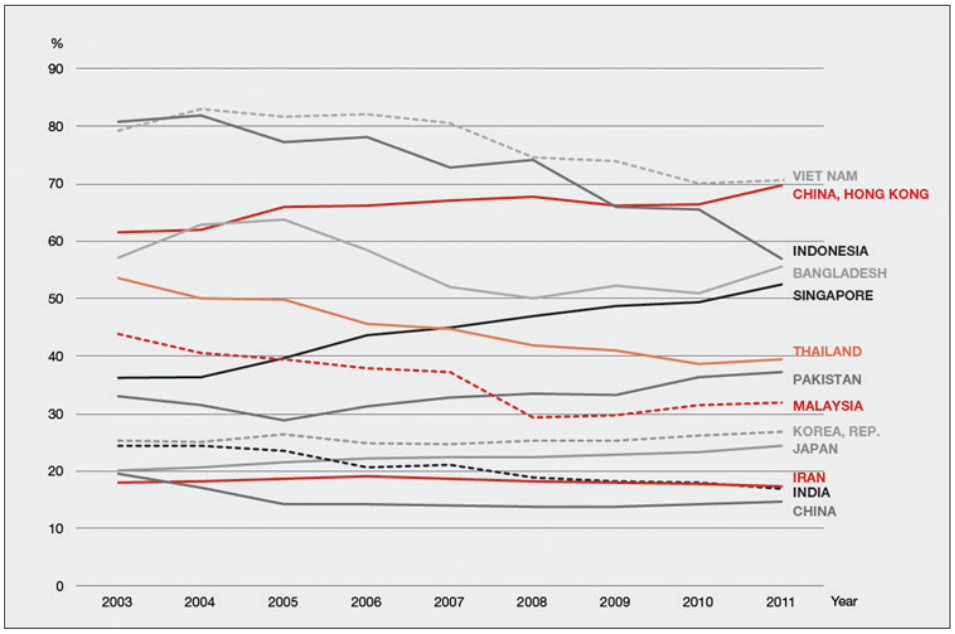


**Figure 6:** Trends in percentage of internationally co-authored articles in selected countries 2003-2011
Source: UNESCO report "Higher Education in Asia – Expanding up, Expanding Out", P.84

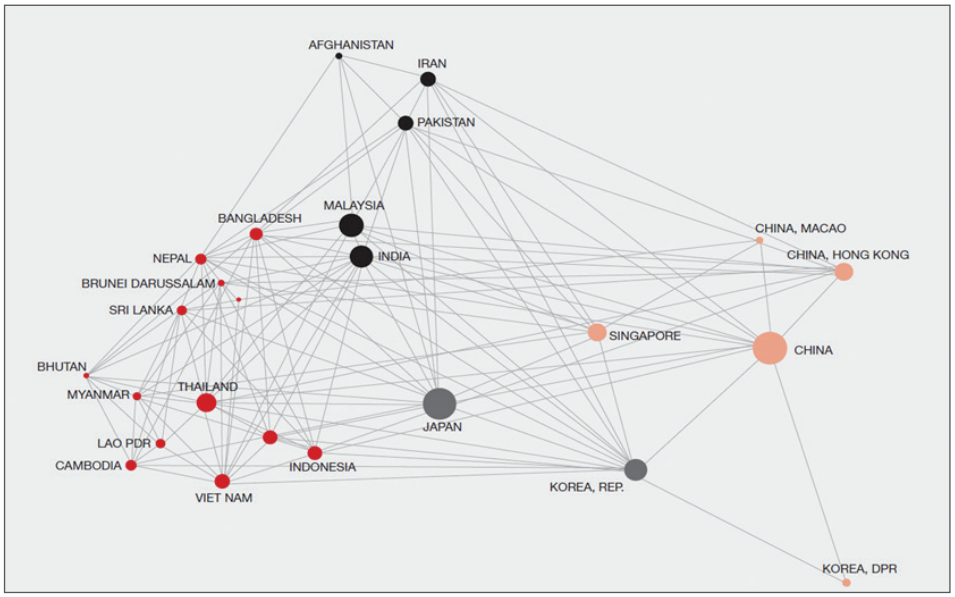


**Figure 7:** Regional scientific collaborations. Source: UNESCO report "Higher Education in Asia – Expanding up, Expanding Out", P.88

### International scientific collaboration

Figure 8 shows the international scientific collaborations between Asian countries and the global community. There are four distinct "pockets" of international collaborations in the region. The United States, Canada, Germany, Spain and Italy form close collaborative relations with China, India, The Republic of Korea and Singapore. Secondly, the United Kingdom has a major role in connecting other European countries such as France, Belgium and Switzerland with SEA countries that display lower scientific output with the international community. The United Kingdom also serves as a bridge between Laos, Cambodia, Myanmar, Nepal, Bangladesh, Bhutan and others and the European scientific community. Australia forms a third circle of collaborations, bridging among Indonesia, the Philippines, Malaysia, Sri Lanka and Brunei. The map also shows that the Russian Federation is somewhat of an outlier, forming single collaborations with the Republic of Korea, Japan, India, and Pakistan.

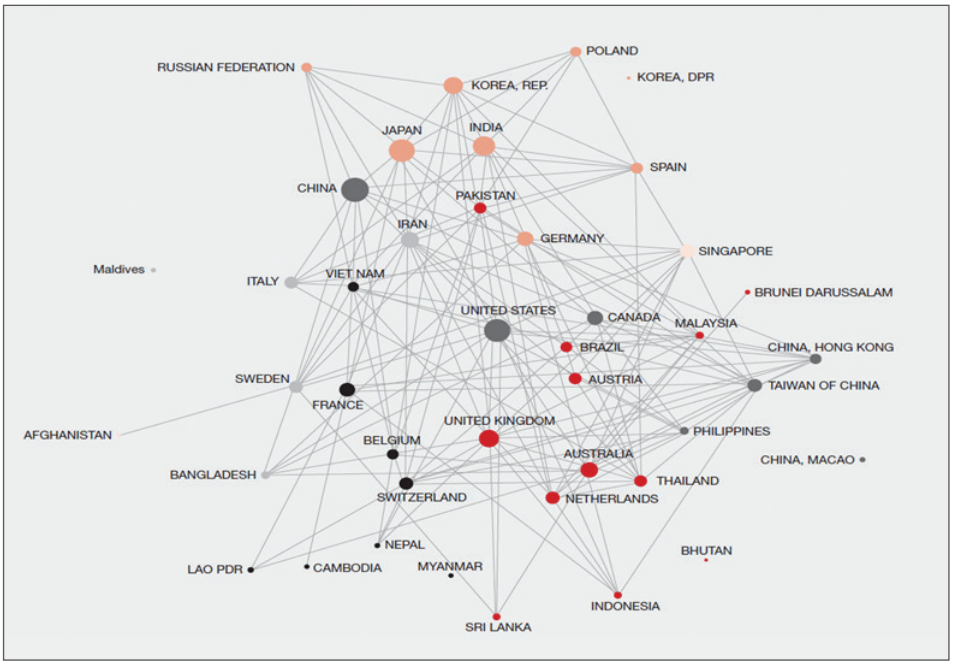


**Figure 8:** International Scientific collaborations between Asian countries and the global community. Source: UNESCO report "Higher Education in Asia – Expanding up, Expanding Out", P.89

### Conclusions

1. **Scientific output:** the region has seen a significant increase in its scientific output from 1997 to 2012. There are, however, large differences between individual countries within the region. China has a leading role in scientific output and growth. However, attention should be given to countries such as Malaysia and Pakistan which have a compound annual growth rate above 15 per cent in this time period.

2. **Regional and international collaborations:** The most evident progress seen through the bibliometric analysis is both the increasing scientific collaborations between the countries of the region and a significant growth of international collaborations between the countries of the region and the international scientific community. The regional co-authorships networks show that smaller countries entering the scientific arena, such as Nepal, Bhutan and Sri Lanka, increasingly collaborate with larger countries in the region, thus gaining expertise and increased output. These countries also used their collaborators as a bridge to the international scientific community. Larger countries such as China, Japan, Thailand and others, show increased international collaborative ties in the form of co-authorships and are functioning as hubs for smaller countries in their international scientific endeavors.