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HIGHER EDUCATION IN ASIA:
Expanding Out, Expanding Up

The rise of graduate education and university research

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FOREWORD

Asia's spectacular rise in enrolment rates in higher education over the past 20 years has been the subject of many reports. However, this report does *not* focus on the past to explain this trend. Instead, it looks to the future by examining the different approaches countries are taking to expand their higher education systems for the next generations. On the one hand, higher education systems are growing outwards with the construction of new campuses to enrol more undergraduate students. At the same time, they are reaching upwards with the introduction of more graduate programmes to ensure a steady supply of qualified professors and researchers.

This process of expansion demands innovation in terms of policy and reform and not just greater financial investment. For countries across the region, the aim is not just to accommodate more students. They see higher education as a means to the larger goal of improving the livelihood of individuals and the socio-economic development of their societies.

This report presents data and analysis to better understand the factors driving the expansion in undergraduate and graduate education across Asia. By looking at the system as a whole, the authors evaluate the strategies used to respond to current demand but also to build a sustainable system that can continue to grow in terms of quality and reputation. Some of these policies are considered controversial, such as the growing reliance on the private sector, which raises issues of equity in access to higher education. Concerns also arise with the unintended consequences of being guided by international rankings to attract staff, students and even from international investment. Through a series of case studies in middle-income Asian countries, the authors provide valuable insights for developing countries across the region to find their own balance as they embark on new policies and reforms of their higher education and research systems.

Another unique feature of this report is the diversity of data presented. This is the first UIS study to rely on indicators from the Institute's databases on education and research and experimental development (R&D), in addition to external data sources. This comprehensive approach better informs policy debates, such as the decision to favour applied research over basic research in some universities or the role of international collaboration in research productivity.

While the report is primarily based on cross-nationally comparable data, it also presents data from national reports and case studies. These studies will also be used by the Institute to further improve the accuracy of our data, while laying the foundations to develop new indicators in the future. The report's analysis of higher education data is based on the newly-revised International Standard Classification of Education (ISCED 2011), which serves as the best method for comparing higher education systems.

It is important to highlight the expertise of the partners contributing to this report. The authors from the United Nations University offer insight into the world-class research performance of specific universities across the region, while the experts from Elsevier critically examine the underlying mechanisms to support international research cooperation. Finally by linking trends in education data to university policy and planning, colleagues at

UNESCO's International Institute for Educational Planning (IIEP) helped us to examine the diversity of strategic approaches undertaken by countries across the region.

As a whole, this report provides the data and the analysis to help countries across the region and beyond to find their own balance in expanding 'up and out' in terms of higher education and research.

Hendrik van der Pol
Director
UNESCO Institute for Statistics

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We would also like to thank the 51 interviewees in Malaysia and Thailand who helped to produce the case studies by providing their perspective on graduate education and university research. These interviews would not have been successful without the logistical support provided by the following: in Malaysia: Faridah Idris (Universiti Putra Malaysia), Nor Saribon Binti Ramli, (Universiti Kebangsaan Malaysia), Zubaidah Binti Aman (Ministry of Higher Education), staff in the National Higher Education Research Institute and International and Corporate Office in the University of Malaya; in Thailand: Pirawaz Sahawiboonsuk (UNESCO), Nopraenue S. Dhirathiti and Phimhatai Sangsutthi (Mahidol University), Ninnat Olanvoravuth (Chulalongkorn University) and Inn Beng Lee (Elsevier).

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EXECUTIVE SUMMARY

OVERVIEW

The report examines the dynamics associated with the growth of graduate education in Asia, with particular attention to the middle-income countries of Southeast Asia (see the Reader's Guide for the list of countries analysed in this report). The analysis is primarily based on data from the UNESCO Institute for Statistics (UIS), which are complemented by data from national authorities and international organizations. The report is designed to: a) describe the extent of and reasons for the expansion of undergraduate and graduate education across the region; b) clarify the extent to which key actors perceive a tension between expanding out and expanding up; c) examine how universities gauge the quality of their graduate programmes and the actions they take to raise programme quality; d) identify research strength, rates of productivity and extent of international collaboration among countries at both the national and institutional levels; and e) highlight continuing issues that education and government leaders face as they seek to expand higher education opportunity, ensure a qualified instructional staff and promote university-based research.

Enrolment in higher education has experienced explosive growth across Asia over the last 20 years, the result of high birth rates, increasing school participation rates, and the perceived importance of advanced education in subsequent life opportunities. To accommodate these enrolment increases, higher education systems have had to **'expand out'** by constructing new universities, hiring new faculty members, and allowing and encouraging the entry of private higher education providers. Faced with escalating demand for instructional staff to serve the expanding number of public universities and the fast-emerging private universities, many countries across the region have needed to **'expand up'** by introducing graduate programmes to prepare future instructors. From the perspective of many governments, expanding graduate education has an attractive secondary benefit. Many governments see universities as centers of research that will yield positive economic returns to the country. University research is typically done at the graduate level (Master's and doctoral). Hence, expanding graduate education is viewed as a means of increasing the economic competitiveness of the country.

CHAPTER 1 analyses the convergence of pressures that have resulted in dramatic enrolment increases in undergraduate education over the last 20 years. This enrolment growth put financial pressure on many governments. In response, governments sought ways to lower the cost of instruction in public universities and shift more of the cost of higher education to students and their families. Public universities introduced new tuition-bearing programmes and auxiliary enterprises aimed at covering more of their operating costs. Some universities also sought less expensive means of instructional delivery, such as online instruction and other forms of distance education. East and Southeast Asia now lead the world in the delivery of distance education.

At the same time, to reduce student demand for access to public universities, many governments changed legislation to allow and encourage the growth of private higher education, now the fastest-growing segment of higher education in the region. However, increased access to higher education has not necessarily led to greater equity. While there is greater gender equity across university-level enrolment in many, but not all, countries in the region, there are still large discrepancies in access related to differences in family wealth. The poor remain disproportionately limited in their access to higher education.

One outcome of the enrolment growth was the need for additional qualified instructional staff and for upgraded preparation of existing instructors in order to staff the growing number of higher education institutions. To meet this demand, most middle-income countries across Asia have ventured into providing graduate education. The need for more and better-qualified instructional staff was the primary motivator for the expansion of graduate education in the region. However, national support for graduate education was also influenced by the government's interest in promoting university-based research as a route to national economic development.

CHAPTER 2 examines the dynamics associated with the expansion of graduate education in Malaysia and Thailand, the two middle-income countries that have experienced the most dramatic growth at this level of education over the last decade. A case study of these two countries was undertaken to further elaborate the reasons that governments and higher education institutions in these countries are expanding their graduate-level programmes, how the growth of graduate education is affecting the professional lives of the faculty and administrators leading those programmes, and the institutional-level issues associated with this expansion.

In these two countries, support for expanding graduate education has been largely tied to the belief that investing in higher education will lead to an educated workforce and that, as evidence of an educated workforce becomes known, it will attract international investment that will eventually pay off in national economic development. For this investment in graduate education to yield the desired payoffs, top universities not only have to be good, but they have to be widely recognised to be good by the international community. A commonly-used metric of higher education excellence is international university rankings. Consequently, the case study found that high rankings were viewed as a way to earn international respect, justify government investment in their institutions, and recruit students and faculty.

Since publication rates are a key ingredient in all international ranking systems, pushing faculty to increase their publication in top-tier international journals was viewed by many interviewees as an important strategy for gaining the desired international attention. This has led to considerable pressure on university staff to undertake more research leading to publications. A secondary hope is that the commercialisation of university-based research can be a meaningful source of income for universities, thereby reducing their need for public funding. The case study describes strategies used by research universities to encourage and reward faculty members to raise their research productivity and faculty members' response to these efforts.

CHAPTER 3 summarises international research and experience to examine the underlying premise, identified in Chapter 2, that university research can lead to national economic development. While there is considerable evidence that countries that spend more on research benefit from that investment financially, that linkage can be complicated. In many countries, most research is not done at universities but by private sector enterprises. One reason is that private sector enterprises are reluctant to out-source their research. They tend to want proprietary rights over new findings that might have commercial application. There are also a variety of contextual factors, such as unfavorable tax laws and limited access to capital, that may limit the economic return on university-based research. The general finding is that many elements of university and government research have very low direct returns and contribute to economic growth only indirectly. These indirect effects can be important and often take the form of knowledge spillovers to the private sector. University-based research can yield important benefits to national development but does not necessarily lead to the economic payoffs that governments expect.

While university rankings continue to be controversial, they are nonetheless reshaping strategic planning in universities, national higher education reforms, and the conditions of employment of many faculty members. **CHAPTER 4** compares three of the highest-visibile and most commonly-used ranking systems, examines how universities respond to rankings, and explores some of the pros and cons of such ranking systems in terms of how they affect the development of higher education.

One overlooked aspect of such rankings is that they operate at the institutional level, masking variations in programme quality within universities. The analysis presented in this section demonstrates that pockets of excellence can be found across a wide range of universities, not just in those that place near the top in world rankings. If governments are consolidating funding to support top-tier, world-class universities, they may be missing the subtler, but still substantial, contributions to high-quality research being made by a wider set of higher education institutions. One implication is that governments may benefit by targeting their research support to a wider swath of universities that may not yet have earned a position in the top overall rankings but which are doing particularly good work in niche areas.

Authors in Chapter 4 also examine the role of international collaboration in research productivity. Widely advocated as a strategy for helping universities improve research quality and output, the premise is that, as university researchers from different countries work together, they are able to increase their productivity. Authors analyse the growth in research productivity in 26 selected countries or territories across East, Southeast and South Asia, measured in terms of publication rates, and examine the extent to which those publications have been a product of within-region and wider international collaboration. Findings suggest that international collaboration is an effective way to boost both productivity and quality in university-based research. One implication is that university incentive systems may need to acknowledge more fully the value of collaboration in their reward structures.

CHAPTER 5 summarises key themes of this report and highlights issues that governments and higher education systems will need to address going forward. Every country has to find its own balance between expanding out and expanding up. The goal of this study report is to provide further data and ideas relevant to those considerations.

Chapter 1

THE RESHAPING OF HIGHER EDUCATION ACROSS ASIA

N.V. Varghese, Chiao-Ling Chien, Patrick Montjourides, Hélène Tran, Shailendra Sigdel, Hiromichi Katayama and David Chapman

1.1 INTRODUCTION AND OVERVIEW

Enrolment in higher education has experienced explosive growth across Asia over the last 20 years, the result of school participation rates, increasing demand of the society and economy for specialised human resources, and the perceived importance of advanced education in subsequent life opportunities (e.g. ADB, 2011; World Bank, 2012). To accommodate these enrolment increases, higher education systems have had to 'expand out' by constructing new universities, hiring new faculty members, diversifying delivery mechanisms, and allowing and encouraging the entry of private higher education providers. In many countries across the region, this, in turn, has required that higher education systems 'expand up'. Faced with escalating demand for instructional staff to serve the increased number of public universities and the fast-emerging private universities, countries have expanded their provision of graduate education. From the perspective of many governments, expanding graduate education has an attractive secondary benefit. Many governments see universities as centers of research that will yield positive economic returns to the country. University research is typically done at the graduate level (Master's and doctoral). Hence, expanding graduate education is viewed as a means of increasing the economic competitiveness of the country.

In important ways, *expanding up* and *expanding out* are competing agendas. Within many countries, decisions regarding the appropriate balance between government investment in top-tier research universities versus investing to upgrade a wider set of weaker institutions are controversial. In important respects, they vie for the same financial and human resources. A recent Asian Development Bank (2011) study argues that governments should direct more of their resources to second-tier (regional public) and third-tier (largely private) colleges and universities rather than concentrate resources on top-tier universities seeking to be world-class institutions. Yet, some governments in the region believe that a top-tier university is an international signal of modernity, a source of economic return to the country, and a necessary component of their higher education system.

Observers understand that expanding up and expanding out are both necessary if quality higher education is to be available to the growing number of students. There is considerably less agreement as to the appropriate balance between these agendas. While this balance may vary from country to country, the premise of this study is that there are key policy issues that all governments need to consider as they seek their own appropriate balance in the allocation of education resources. To that end, the purposes of this report are to: i) describe the extent of and reasons for the expansion of undergraduate and graduate education across the region; ii) clarify the extent to which key actors perceive a tension between expanding out and expanding up; iii) examine how universities gauge the quality of their graduate programmes and the actions they take to raise programme quality; iv) identify research strength and rates of productivity across countries at both the national and institutional levels; and v) highlight continuing issues that education and policymakers face as they seek to expand higher education opportunity, ensure qualified instructional staff, and promote university-based research.

This study focused mainly on the middle-income countries of Southeast Asia but included data and some narrative concerning higher education systems in countries in South and East Asia (see the Reader's Guide for the list of countries analysed in this report). Graduate education in the high-income countries in the region is well developed and widely discussed elsewhere. The low-income countries of this region generally have not ventured very far into the provision of graduate education. Data from countries in other parts of Asia provide useful points of comparison. It should be noted that the focus of this study is on Bachelor's, Master's and doctoral programmes, and does not include attention to the wider array of tertiary education that includes technical or vocational-oriented schooling.

1.2 THE EXPANSION OF HIGHER EDUCATION AND ITS CONSEQUENCES

A statistical portrait helps capture the extent of the growth in undergraduate and, more recently, graduate education across the region. This section describes enrolment growth at the Bachelor's level, which was the original impetus for higher education systems to expand into graduate education. It reviews some of the key consequences of that expansion, giving particular attention to the impact of system expansion on public financing of higher education, the role of private higher education in absorbing the growing demand for access, and the implications of increased access on equity. Finally, this section profiles the growth of graduate enrolment and the concomitant government interest in university-based research, with particular attention to the middle-income countries of Southeast Asia.

1.2.1 Expanding out

Over the past four decades, global higher education enrolment increased from 32.6 million in 1970 to 182.2 million students in 2011, 46% of which was in the East and South Asia region in 2011 (UIS, 2013). This phenomenal expansion was fueled by a convergence of demographic trends, public preferences, policy decisions and external economic circumstances (ADB, 2011). Among the key factors driving this growth were higher participation rates in basic education and higher progression rates in primary and secondary schools. More students were entering and graduating from secondary school and seeking to continue their education.

Most middle- and low-income countries in the region have made much progress in widening access to Bachelor's degree programmes. (An international classification of higher education across countries can be seen in **Box 1**.) **Figure 1** shows the long-term trends in participation in Bachelor's programmes (measured by the gross enrolment ratio, see **Box 2**). In China, Lao People's Democratic Republic, Malaysia, Nepal and Sri Lanka, the gross enrolment ratios for Bachelor's programmes have increased over 10 times over the past four decades. Nepal has leaped in having many more students complete the Bachelor's level, from only about 1 out of 100 in 1980 to 14 out of 100 in 2011.

To measure the increased output of undergraduate education, **Figure 2** shows a comparison of gross graduation ratios for Bachelor's degree (first degree) programmes in 2000 and 2011 (calculated using the number of students graduating from first degree programmes in a given year relative to the population of the typical age of graduation from first degree programmes). Thailand leads middle-income countries in improving its gross graduation ratio for first degree programmes, from 15% in 2000 to 31% in 2008.

Over the course of the last two decades, many countries in Southeast and East Asia have moved from previously elite systems to massification. Trow (2006) describes higher education system growth as following three phases – elite, mass and universal access phases – based on the proportion of the relevant age group enrolled in higher education

BOX 1. Classifying higher education programmes

The *International Standard Classification of Education (ISCED) 1997*, a framework developed by UNESCO, classifies tertiary[1] education programmes into two levels (or four types of programmes) in order to address the diversity of programmes within countries, as well as differences in structures across countries. In the ISCED 1997 framework, tertiary education programmes consist of ISCED 5B, ISCED 5A first degree, ISCED 5A second or further degree, and ISCED 6:

ISCED 5B programmes are mainly designed so that students acquire the practical skills and know-how needed for employment in a particular type or certain class of occupations or trades. These programmes have a minimum full-time equivalent of two years of study (but, in practice, often run up to three years) and typically provide graduates with a specific labour market qualification. After successful completion of programmes, students are usually awarded an associate degree or diploma.

ISCED 5A programmes are largely theoretically-based and are intended to provide sufficient qualifications for gaining entry into advanced research programmes and professions with high skills requirements. They have a minimum cumulative theoretical duration (at the tertiary level) of three years' full-time equivalent study, although typically they run four or more years. ISCED 5A programmes include first degree programmes[2] and second (or further) degree programmes.[3]

ISCED 6 programmes lead to the award of an advanced research qualification, such as a PhD degree.

To reflect significant changes in education systems worldwide since 1997, a revised framework – ISCED 2011 – has been published. A major reason to update the manual was to better reflect the tertiary education structure (Bachelor's, Master's and doctorate) that is found around the world but has been more recently introduced across Europe following the Bologna Process in 1999. ISCED 2011 classifies four levels of tertiary education (extended from two levels in ISCED 1997). **Table 1** shows the correspondence between ISCED 2011 and ISCED 1997. The first international education data collection based on the new classification will begin in 2014.

Table 1. Correspondence between ISCED 2011 and ISCED 1997

ISCED 2011	ISCED 1997
ISCED level 5 – Short-cycle tertiary education	
ISCED level 6 – Bachelor's or equivalent level	ISCED level 5
ISCED level 7 – Master's or equivalent level	
ISCED level 8 – Doctoral or equivalent level	ISCED level 6

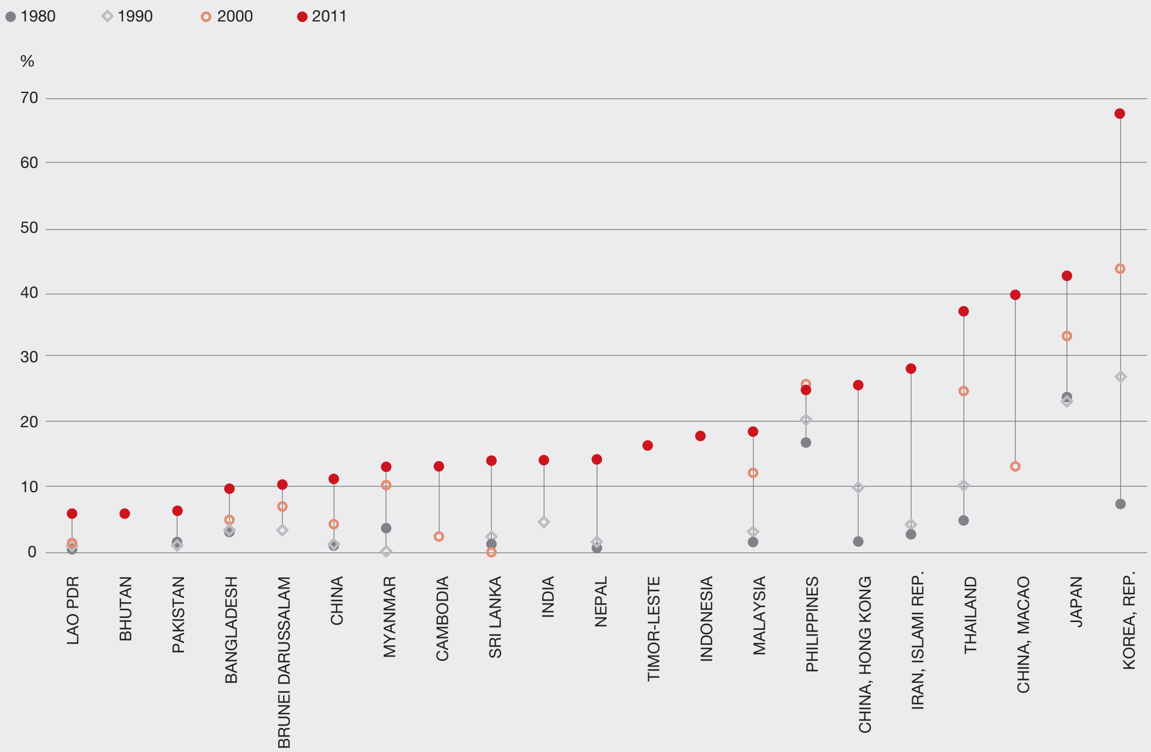
Notes: 1. This report uses 'higher education' in the same sense as 'tertiary education' is used in the ISCED manual.
2. In the countries studied in this report, first degrees are all Bachelor's degrees.
3. In the countries studied in this report, second degrees are nearly always Master's degrees, though in countries where it exists, post-graduate non-PhD programmes are also classified as second degrees.

institutions. In his characterisation, the elite phase is when a country's enrolment ratio for higher education (gross enrolment ratio, GER) is below 15% of the relevant age group. The massification phase is when the GER is between 15% and 50%. Finally, the universalisation phase is when the GER is above 50%. The progress of countries along this continuum reflects long-term trends in GERs spanning 35 years since 1975. As higher education systems move along this continuum, the issues they face change. For example, as enrolments grow, they tend to become more diverse, resulting in new instructional challenges for faculty members, at a time when some of these instructors are coming under intensified pressure to undertake research.

Rippling consequences of expanding access

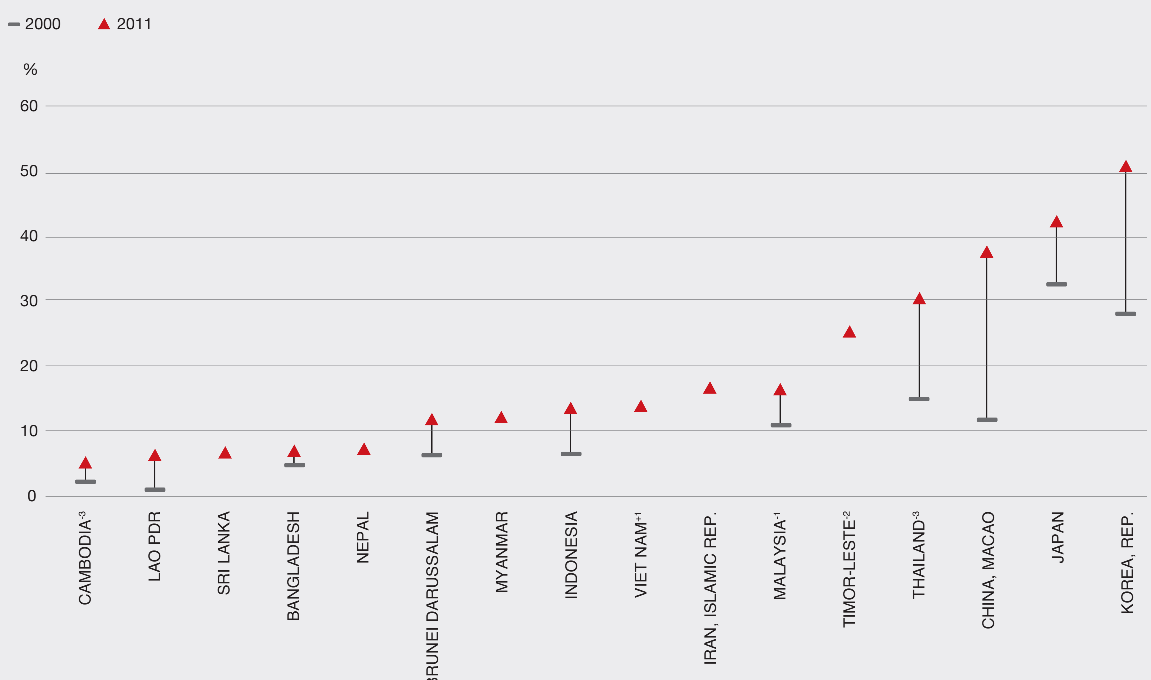
Success in expanding access triggered a series of challenges in serving the increased number of

Figure 1. Gross enrolment ratios for Bachelor's programmes by country or territory, 1980-2011



Source: UNESCO Institute for Statistics **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f1

Figure 2. Gross graduation ratios for Bachelor's programmes by country or territory, 2000 and 2011



Notes: [-3] Data refer to 2008; [-2] Data refer to 2009; [-1] Data refer to 2010; [+1] Data refer to 2012.
Source: UNESCO Institute for Statistics **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f2

Box 2. Measuring participation in higher education

Across Asia, most higher education systems offer a wide range of programmes and pathways, allowing students to obtain a Bachelor's degree in three to five years or to complete an advanced research degree (e.g. PhD) in five or six years. In light of this variation, this study calculates the gross enrolment ratio for Bachelor's programmes on the basis of a standard age range of five years that follow the typical age of completion of secondary education. Similarly, the participation rate (gross enrolment ratio) in graduate programmes (Master's and doctoral) used in this study is calculated using the population ten years after the typical age of completing secondary education.

The standard age range of five years is then used as the denominator to calculate enrolment ratios. It is important to note that the gross enrolment ratio is useful to compare the volume of participation in Bachelor's programmes or in graduate (Master's or doctoral) programmes. However, there are limitations when comparing the actual population coverage across countries due to the diversity in the duration of higher education programmes and the lack of typical ages of people who participate in Master's or doctoral programmes.

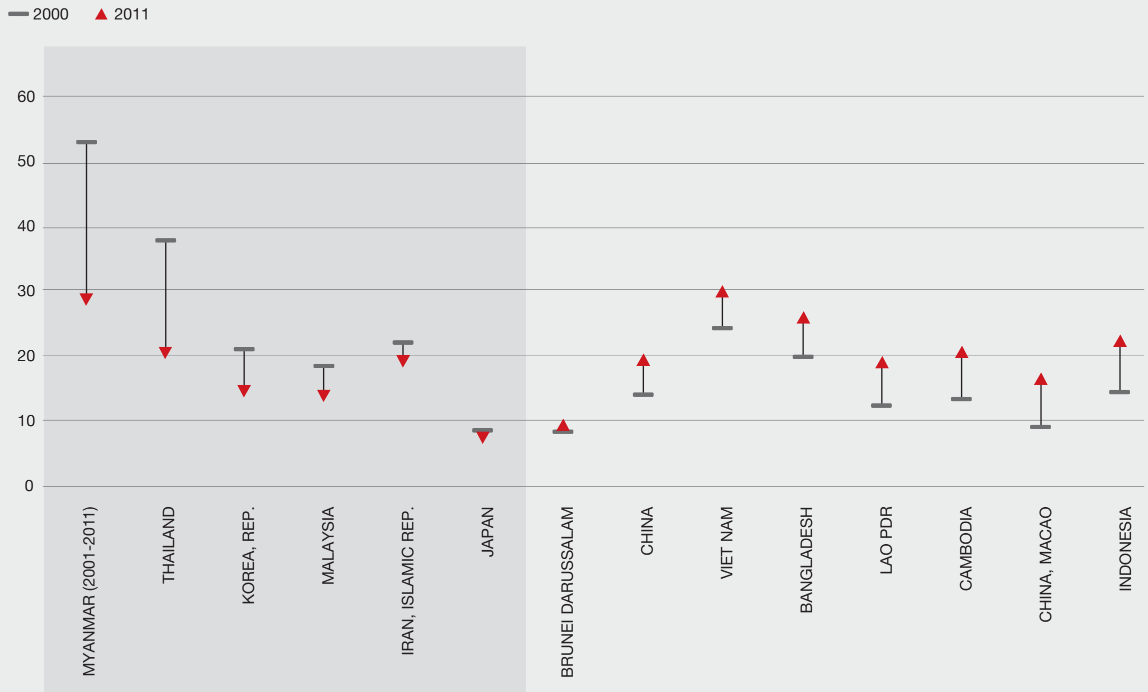
students. It put considerable financial pressure on higher education systems and many countries were hard-pressed to accommodate the rapidly-increasing numbers of students. University budgets did not increase to keep up with enrolment. This led to erosion in faculty salaries, the hiring of less-qualified instructional staff, and a decline in conditions of service (ADB, 2011). Across many countries, student-instructor ratios grew, while the quality of library and laboratory facilities eroded. Consequently, in many countries the quality of higher education declined (ADB, 2011).

Figure 3 shows student-instructor ratios in higher education and the change in ratios between 2000 and 2011. It is worth noting that within a country the student-instructor ratios vary across different fields of education. In several countries or territories (Bangladesh, Brunei Darussalam, Cambodia, China, Macao Special Administrative Region of China, Indonesia, Lao People's Democratic Republic and Viet Nam), the student-instructor ratio has increased considerably, which adds to teaching loads in ways that may threaten the quality of education. A decade ago in Indonesia, for example, each instructor needed to teach on average only 14 students; this has now increased to 22 students. By contrast, both Malaysia and Thailand have decreased their student-instructor ratios. Currently, Thailand has a student-instructor ratio of 20:1, down from 38:1 a decade ago.

While enrolments and unit costs have increased, public funding has not kept pace, adding a further financial strain on universities (Johnstone, 2009, p. 2). In most countries, despite enrolment growing rapidly, public expenditure per higher education student did not increase as gross domestic product (GDP) grew. This decline in public funding for higher education is caused by a combination of two factors. The first is the unprecedented growth of the student population; the other is a view that has gained increasing acceptance among policymakers that higher education yields greater private (than public) benefits and thus should be financed primarily by the direct beneficiaries instead of public funds. **Figure 4** shows public expenditure per higher education student in purchasing power parity (PPP) dollars. In six out of seven middle- or low-income countries (where data are available), public funding for higher education per student declined over the last decade.

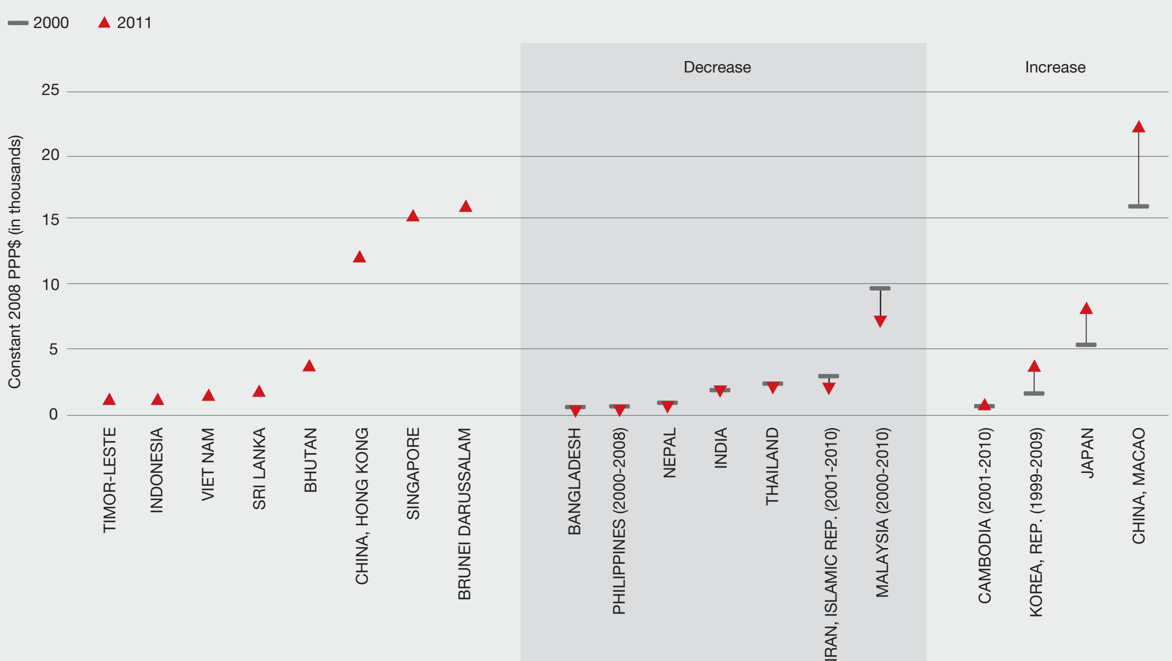
A common way to gauge a government's commitment to higher education is to examine public spending at this level of education in relation to other levels. As illustrated in **Figure 5**, the share of public expenditure allocated to higher education ranges from less than 10% in the Maldives to over 33% in India, Macao Special Administrative Region of China, Malaysia and Singapore. When comparing the share over time in 9 out of 14 countries where data are available, the share of public funding allocated to higher education has increased. The increase

Figure 3. Student-instructor ratio in higher education institutions in selected countries or territories, 2000 and 2011



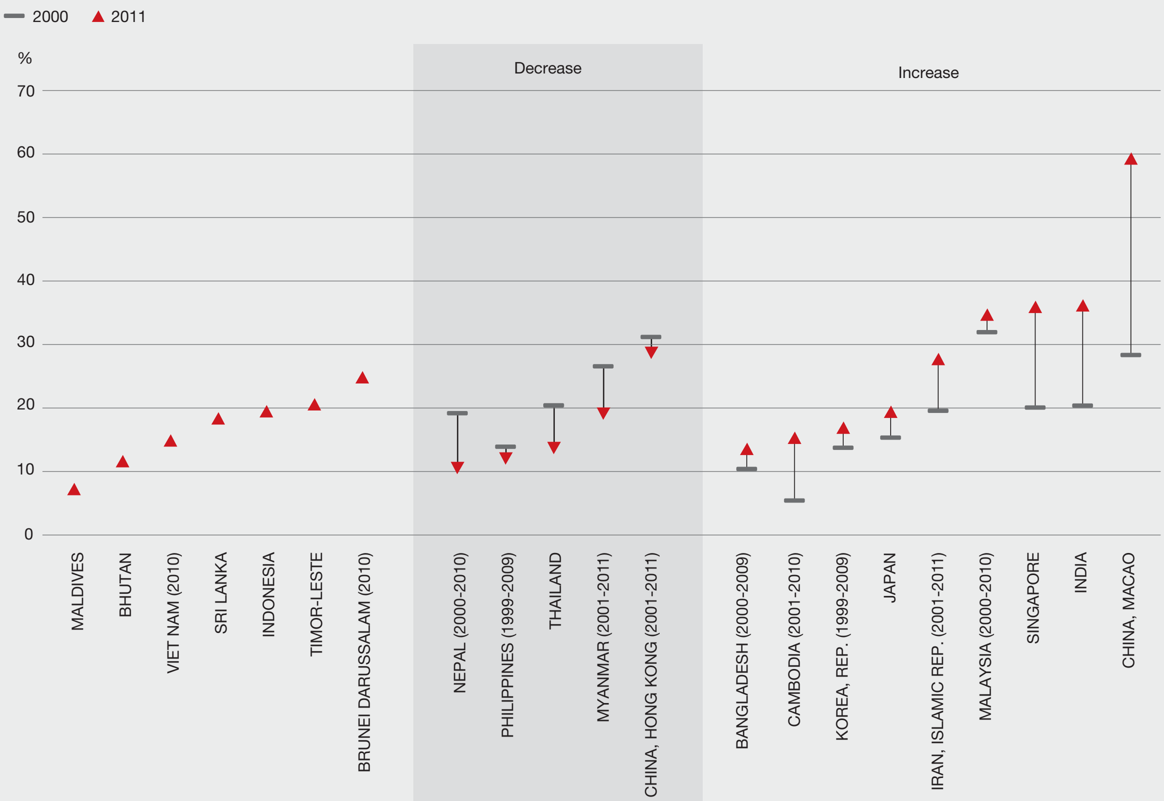
Notes: Both full-time and part-time students and instructors are included. Ideally for cross-national comparison, full-time equivalent (FTE) enrolment and FTE instructors should be used. Due to a lack of disaggregated FTE data, total headcounts of students and instructors were analysed.
Source: UNESCO Institute for Statistics, October 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f3

Figure 4. Public expenditure per higher education student by country or territory, 2000 and 2011 or most recent year available



Note: The first group of countries does not have 2000 data for comparison.
Source: UNESCO Institute for Statistics and Statistical Table B5 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f4

Figure 5. Public expenditure on higher education as a percentage of total public education expenditure by country or territory, 2000 and 2011



Note: The first group of countries does not have 2000 data for comparison.

Source: UNESCO Institute for Statistics and Statistical Table B5 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f5

can be explained by growing enrolment at this level and strengthened public funding to universities to conduct research activities, which will be discussed in Chapters 2 and 3. Even with these increases, funding per higher education student has declined.

While country situations differ, there has been remarkable similarities across the region in the strategies governments are using to accommodate the explosive growth of university enrolment (ADB, 2011). Governments generally employed a combination of strategies intended to improve system efficiency, lower (or at least contain) public expenditure to higher education and develop new sources of funding for higher education (ADB, 2011). Governments and higher education systems sought ways to lower the cost of instruction in public universities and to shift more of the cost to students and their families. Some universities introduced more fee-based courses, such as special adult education, English, computer training and executive leadership courses.

Another approach was to allow and encourage public universities to find more of their own funding. Many changed their admissions policies to allow some private-pay students. For example, the Cambodian government introduced fees in 1996. In Indonesia, public universities became legal entities in 1999, empowering them to introduce cost-recovery measures (Susanto and Nizam, 2009). Lao People's Democratic Republic introduced fees in national universities in 2011, and Malaysia enacted legislation in 1995 to adopt corporate practices in public universities (Lee, 1998; 1999; 2004). In the 1990s, Thailand enacted legislation to permit universities to mobilise their own resources (Suwantragul, 2009) and in 2005, Viet Nam allowed universities to take full control of their own budgets (International Comparative Higher Education Finance and Accessibility Project, 2013).

In some countries, cost reduction strategies often involved greater use of online and other technology-based instruction in which larger numbers of students could be enrolled at a lower per-student cost. Indeed, Asia leads the way in using distance education as a means to extend access while controlling costs in higher education. Across the region, more than 70 universities now deliver instruction exclusively through distance education (ADB, 2011). Some of these initiatives are extremely large. In China, the Central Radio and Television University directly serves about 2.6 million active students and, indirectly, another 3.5 million through its network of Provincial Open Universities (ADB, 2011). The Universitas Terbuka Indonesia serves nearly 650,000 students, most of whom are teachers enrolled in in-service training programmes (Zuhairi, 2010).

Across the region, many governments allowed and encouraged the expansion of private higher education in an effort to shift students away from the heavily-subsidised public sector. The advantage to government was that private colleges and universities could charge tuition, thereby providing greater post-secondary access without increasing the demand for public funds. Some countries had a private higher education sector already in operation. Since the 1990s, many countries in Asia, which hitherto had only public institutions, started establishing private institutions of higher education. Some countries, such as Indonesia, Japan, the Philippines and the Republic of Korea, had a strong tradition of private higher education where the majority of students attend private institutions. In 2011, nearly four-fifths of the students in the Republic of Korea and Japan, nearly three-fifths of the students in Cambodia, Indonesia and the Philippines, and two-fifths of the students in Bangladesh and the Islamic Republic of Iran were enrolled in private institutions *(see **Figure 6**)*.

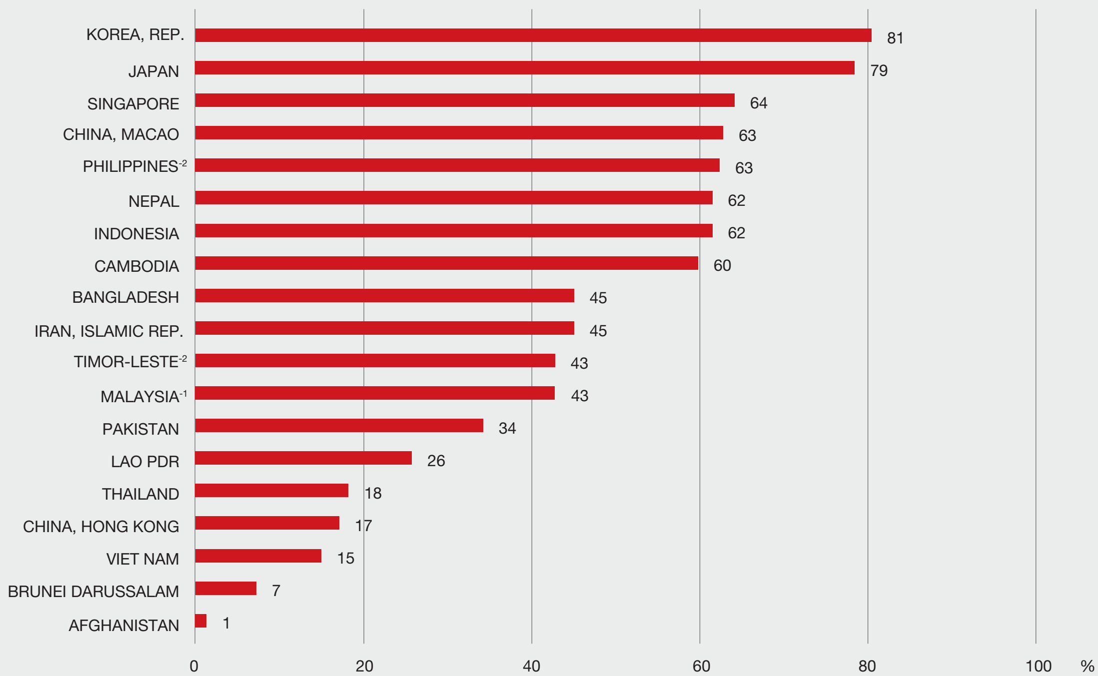
For some countries, however, the establishment of private institutions was a new initiative. Private universities were not permitted in Cambodia until 1997 (Chealy, 2006). Lao People's Democratic Republic legalised private universities in 1995, Malaysia in 1996, Thailand in 2003, and Viet Nam in 2005. Only in 2002, China introduced laws permitting private higher education institutions to operate (Li and Yang, 2013). Across the rest of the region, the share of student enrolment in private colleges and universities varies from 1% in Afghanistan to 80% in the Republic of Korea.

Over the last 15 years, private higher education has been the fastest-growing sector of higher education. Government promotion of private providers in higher education and the growth of private higher education are much more significant in Asia than in other regions of the world (Levy, 2010). Across Asia nearly 40% of higher education students are enrolled in private institutions. The numbers of public and private institutions now and then are illustrated in **Table 2**.

Additionally, foreign universities set up branch campuses in selected Asian countries in order to not only absorb demand that cannot be met by local higher education institutions, but also attract international staff and students to these branch campuses, (British Council, 2012). The latter is of particular interest for Malaysia and Singapore, because both have ambitious international student targets. Currently among all countries in Asia, Singapore has the largest number of international branch campuses (16), followed by China (13) and Malaysia (9) *(see Table 2)*.

A widely-used classification system categorises private higher education institutions into elite and semi-elite, religious/cultural, and non-elite and demand-absorbing (Bjarnason et al., 2009). The non-elite and demand-absorbing institutions are the largest and the fastest-growing segment of private higher education in Asia. Private colleges and universities across Asia tend to be small, non-elite and demand-absorbing. Most rely on student fees as the major source of income.

Figure 6. Enrolment in private higher education institutions as a percentage of total higher education enrolment by country or territory, 2011 or most recent year available



Note: -2 Data refer to 2009; -1 Data refer to 2010.
Source: *UNESCO Institute for Statistics and Statistical Table B1* **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f6

Equity and equality issues

Ample evidence indicates that having a university degree is an important factor in increased lifetime income and quality of life (e.g. Carnoy et al., 2012; World Bank, 2012). One of the major accomplishments of governments and universities across Asia has been to dramatically increase the opportunities for citizens to access higher education. Numbers tell the story. Most countries' GERs for higher education have improved considerably. One consequence of the enrolment growth is that Asia now accounts for nearly one-half of the world's higher education enrolment. To the extent that increasing access to higher education offers a wide social benefit and signifies social responsibility, universities across Asia have much to be proud of.

A recent Asian Development Bank (ADB) (2011) study of higher education in the region observed that, while access to higher education has expanded dramatically

Table 2. Number and type of higher education institutions in selected countries, 2012 or the most recent year available

Country	Public	Private	of which branch campuses of foreign universities
CAMBODIA	34	57	1
CHINA (2011)	1,887	836	13
INDONESIA	83	2,818	–
KOREA, REP.	61	350	2
LAO PDR	22	77	–
MALAYSIA	20	491	9
PHILIPPINES	220	1,636	–
SINGAPORE	5	31	16
THAILAND	98	71	2
VIET NAM (2011)	187	28	1

Notes: – denotes quantity nil.
Sources: Cambodia, Indonesia, Lao People's Democratic Republic, the Republic of Korea and Singapore: World Bank (2012); China: Educational Statistical Yearbooks of China 2011; the Philippines: Commission on Higher Education (2013); Thailand: Office of Higher Education Commission, Ministry of Education (2013); Viet Nam: the Ministry of Education and Training (2013). Data on branch campuses of foreign universities: Cross-Border Education Research Team in the State University of New York Albany (2013)
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t2

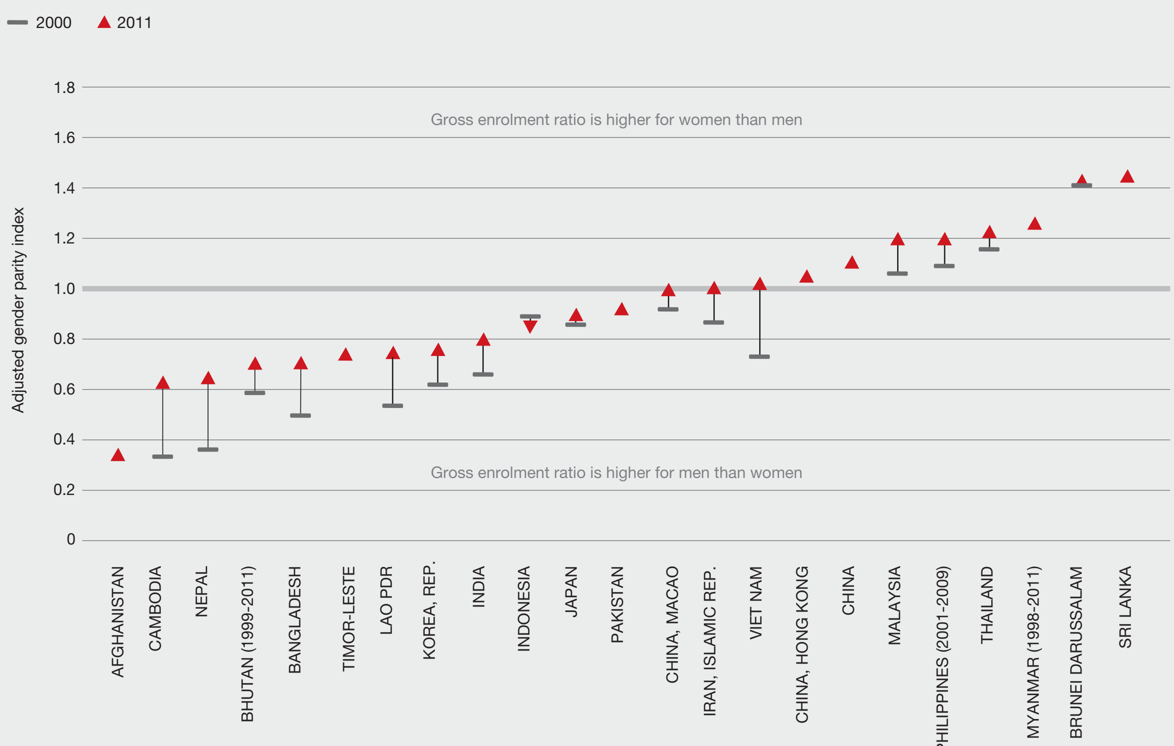
over the last decade, equity has not. In many countries, there continues to be evidence of inequities in how inputs to higher education are allocated and how benefits are distributed. Two dimensions of equity that tend to receive a lot of attention concern gender and socio-economic status. Do women and men have the same opportunity to pursue a higher education? Do the poor have the same educational opportunity as those from more affluent families?

In fact, enormous progress has been made across Asia to improve gender equity in access to higher education. Specifically, over the last decade female participation in higher education has improved significantly. In countries where the female GER for higher education is much lower than the male GER, the gender parity indexes – although still low – have moved towards parity *(see **Figure 7** and **Box 3**).* Overall, in about one-third of countries across Asia, women now outnumber and outperform men (Jacobs, 1996; Buchmann et al., 2008).

Despite improved access to higher education, proportionally less women move up the educational ladder. **Figure 8** presents the gender composition of enrolment at different stages of higher education in the 26 Asian countries or territories studied in this report. On average, women account for 47% of students in Bachelor's programmes. However, the share of women declines to 37% in doctoral programmes.

Less progress has been made in reducing wealth inequities in access, particularly related to family wealth. Young people from rich families are more likely to attend higher education than children of the poor. As **Figure 9** shows, those from wealthier families have an enormous advantage. This chart compares student attendance in higher education from families

Figure 7. Adjusted gender parity index for higher education gross enrolment ratios by country or territory, 2000 and 2011



Source: UNESCO Institute for Statistics and Statistical Table B1 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f7

Box 3. Understanding the gender parity index

The gender parity index (GPI) is a measure used to assess gender differences in education indicators. It is defined as the value of a given indicator for women divided by that for men. A GPI value of 1 signifies that there is no difference in the indicators for women and men – they are perfectly equal. UNESCO (2003) has defined a GPI value of between 0.97 and 1.03 (after rounding) as the achievement of gender parity. This allows for some measurement error but does not imply a judgment about the acceptability of any particular level of disparity.

The adjusted gender parity index is derived from the standard GPI. The GPI is adjusted to present disadvantages symmetrically for both genders. When unadjusted GPI is greater than 1, the adjusted GPI is calculated as the ratio of male to female values and the ratio is subtracted from 2. An adjusted GPI of less than 1 indicates that the value of the indicator is higher for men than for women; the opposite is true when the GPI is greater than 1.

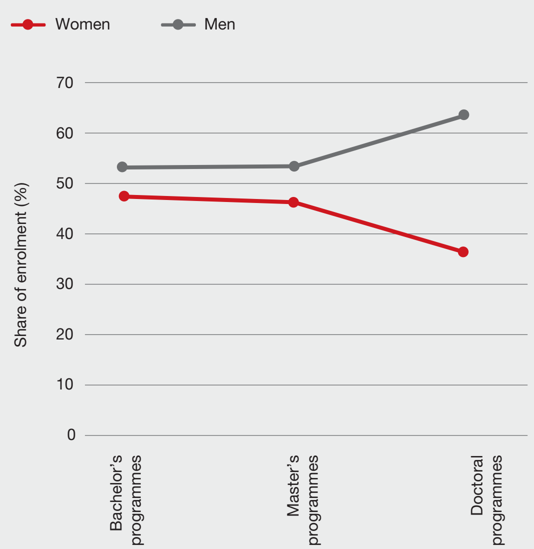
at different wealth levels (households being divided into five wealth quintiles). The differences are stark. In Viet Nam, for instance, 52% of young adults from the richest households have attended higher education, whereas it is only 4% for those from the poorest. These data suggest that a lot of talent is still being wasted as capable students cannot afford higher education. In the countries presented in Figure 9, less than 7% of young adults from households in the lowest quintile (the poorest 20%) have ever attended higher education. In Bangladesh and Cambodia, the proportion is even less than 1%.

A concentration index and related concentration curve were developed to quantify the extent to which higher education opportunities are associated with income inequality *(see **Box 4**).* **Figure 10** illustrates the concentration curves for educational opportunities from primary to higher education across varied wealth quintiles in nine middle- and low-income countries in Asia. In Indonesia and Viet Nam, the bulk of inequality in educational opportunity intensifies after students complete secondary education (as the concentration curve of higher education attendance clearly moves further away from the equity line). By comparison, in Cambodia, for instance, inequality in educational opportunity gets magnified at each stage of schooling from primary to higher education.

Disparity in educational opportunities between the rich and poor expands as educational levels move up. This trend can be seen in **Figure 12** where the concentration index values for different stages of schooling (from primary to higher education) are plotted.

By analysing household survey data, the study found that in middle- and low-income countries in Asia the disparity between higher education opportunities for young people from affluent families compared to those from poor families remains wide.

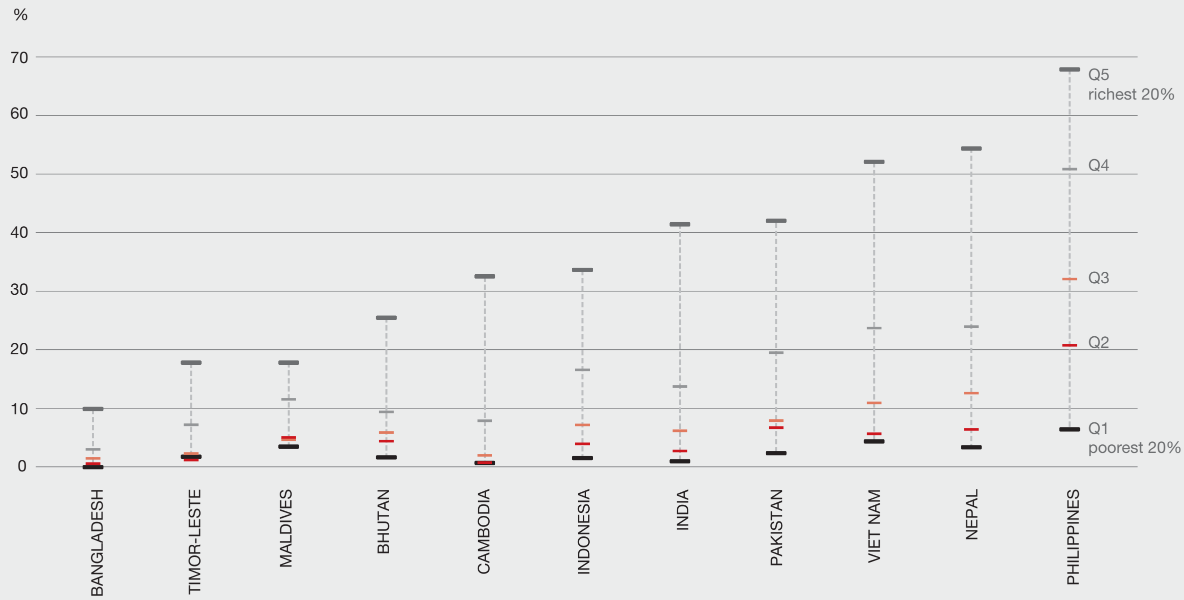
Figure 8. Proportion of female and male enrolment by type of programme in Asian countries, 2011



Notes: Data cover 97% of higher education enrolment in the 26 countries or territories analysed in this report. The percentage is a weighted average.

Source: UNESCO Institute for Statistics, October 2013

Figure 9. Percentage of the population aged 20 to 24 years who have attended higher education by household wealth quintile in selected countries, 2003-2011



Note: In Cambodia, Indonesia, the Philippines and Nepal, the majority (three-quarters to four-fifths) of the population aged 20 to 24 years still lived with their family when the survey was conducted. This implies that the variable of household wealth is an acceptable estimate to investigate the relationship between household wealth and higher education attendance among this age group.

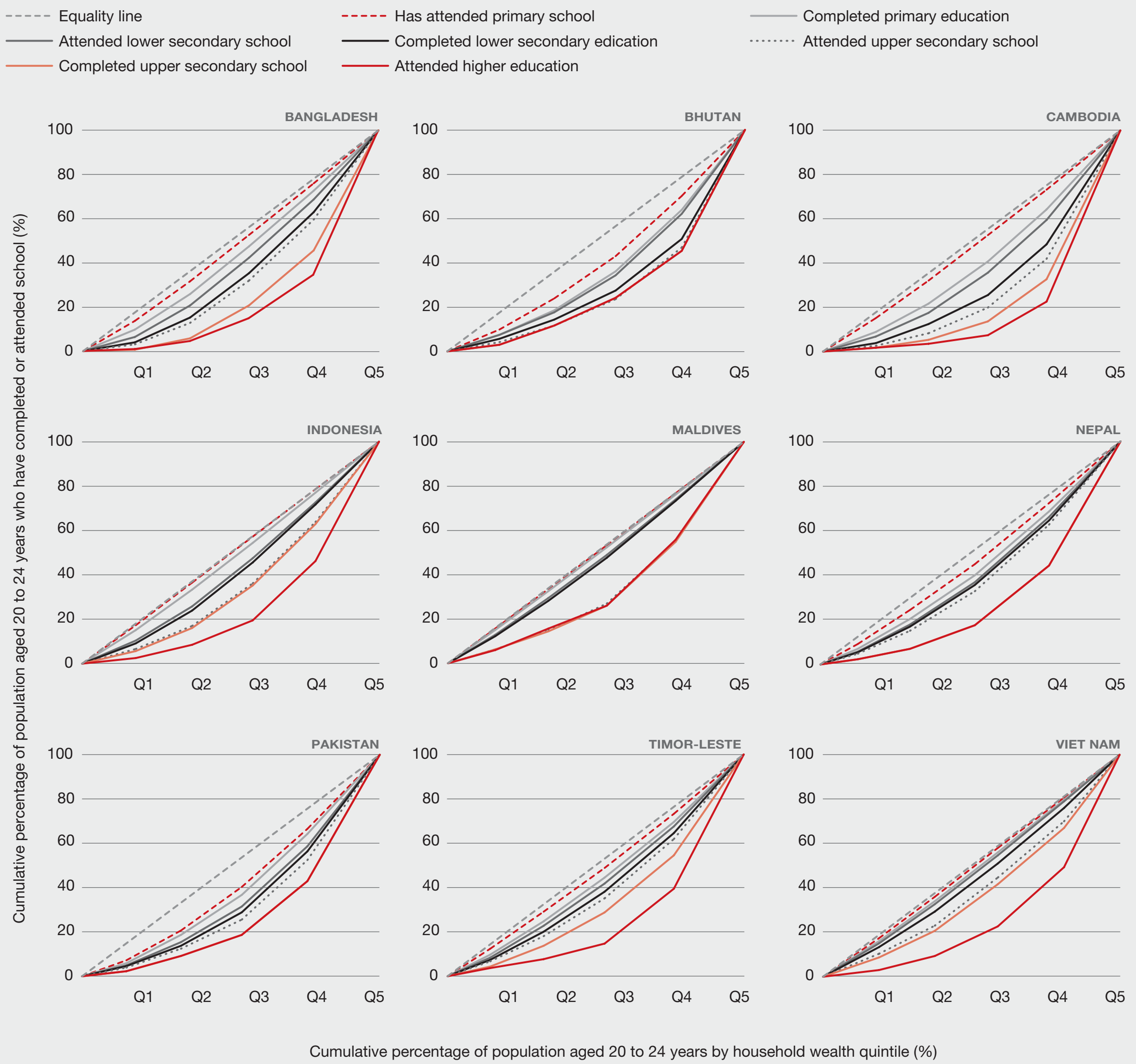
Sources: Authors' calculation based on Bangladesh Demographic and Health survey (DHS) 2011, Bhutan DHS 2010, Cambodia DHS 2010, India DHS 2005-2006, Indonesia DHS 2006, Maldives DHS 2009, Nepal DHS 2006, Pakistan DHS 2007, Philippines DHS 2003, Timor-Leste DHS 2010, and Viet Nam DHS 2011

Due to data limitations, analyses done in the study examined higher education opportunity as a whole and did not separate between undergraduate and graduate programmes. Presumably a similar pattern found in the study would be captured within the educational ladder in the higher education sector, that is, disparities between educational opportunities for the rich and the poor intensify from Bachelor's programmes to doctoral programmes. One may anticipate that after completing a Bachelor's degree, fewer students from poor households advance to graduate-level study.

1.2.2 Expanding up: The growth of graduate enrolment

One consequence of expanding undergraduate enrolment was an accelerated demand for qualified instructional staff. The demand came from two sources. First, the proliferation of higher education institutions created demand for more instructors. At the same time, some existing higher education institutions had grown faster than qualified instructors could be recruited and trained, leading to growing concern about educational quality. For example, in China only about 16% of faculty members in higher education institutions hold doctoral degrees, with another 35% holding only a Master's degree (MOE China, 2011). In Viet Nam, 14% of university instructors hold a doctorate, with another 46% holding a Master's (MOET Viet Nam, 2013). A growing call by international development organizations and national governments for more attention to quality led to a new emphasis on upgrading the competencies of existing teaching staff (ADB, 2011; CHED the Philippines, 2012; MoHE Malaysia, 2006; World Bank, 2009). Hence, the need to prepare college and university instructors to fill new openings and to upgrade those already in the system created a substantial demand for graduate preparation programmes.

Figure 10. Concentration curves for educational opportunity from primary to higher education for population aged 20 to 24 years by household wealth quintile in selected countries, 2003-2011



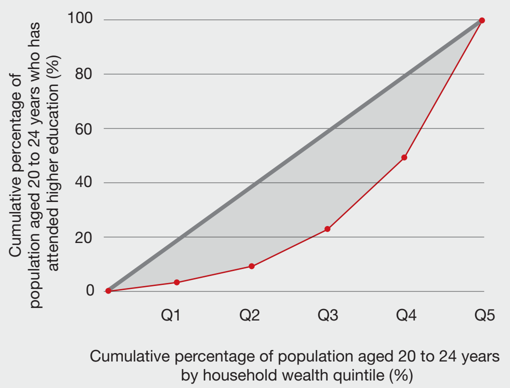
Sources: Authors' calculations based on Bangladesh Demographic and Health survey (DHS) 2011, Bhutan DHS 2010, Cambodia DHS 2010, India DHS 2005-2006, Indonesia DHS 2006, Maldives DHS 2009, Nepal DHS 2006, Pakistan DHS 2007, Philippines DHS 2003, Timor-Leste DHS 2010, and Viet Nam DHS 2011

At the same time, governments expressed new interest in the role of universities as centers of research and innovation that would accelerate national economic development. Since university-based research is generally conducted within graduate programmes and typically utilises graduate students as research assistants, governments recognise that a national investment in graduate education could have a dual payoff. It could help countries meet the demand for qualified instructors at the undergraduate level, while also meeting the national demand for more scientific research. Increasingly countries are adopting dual-track educational policies to address the twin challenges of wider access and the development of research capacity (Kearney, 2008)

Box 4. The concentration curve and concentration index for access to higher education

While the concentration curve and its associated concentration index were initially introduced as measurement tools to reflect inequality in the health sector and later extensively used and documented (Lorenz, 1905; Wagstaff et al., 1991), these two indicators are seldom used in education research. The concentration curve and the concentration index are suitable to measure the extent to which educational opportunities are equally distributed across socio-economic groups (Chakraborty, 2009; d'Hombres, 2010).

Figure 11. Concentration curve for higher education attendance in Viet Nam, 2011



The concentration curve

To show the extent of inequality in educational opportunities across household wealth quintiles, the concentration curve plots the cumulative share of educational opportunities (typically *y*-axis) against the cumulative share of the population ranked by wealth quintile (typically *x*-axis). The 45-degree line is known as the line of equality. A curve below the line of equality indicates that educational opportunities are more concentrated on the richest households. In a hypothetical case where the curve is above the 45-degree line, educational opportunities are more concentrated on the poorest households. Finally, a curve overlapping the 45-degree line suggests that educational opportunities are equally distributed across wealth quintiles.

Table 3. Distribution of the population aged 20 to 24 years by attendance and household wealth in Viet Nam, 2011

Educational attainment or school attendance	Household wealth quintile				
	Q1 (Poorest 20%)	Q2	Q3	Q4	Q5 (Richest 20%)
Completed primary education	16 (16)	18 (34)	22 (56)	24 (80)	20 (100)
Completed secondary education	9 (9)	12 (21)	22 (42)	25 (67)	33 (100)
Has attended higher education	3 (3)	6 (9)	13 (23)	27 (49)	51 (100)

Notes: Data in parentheses are cumulative percentages. **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/t3

The concentration index

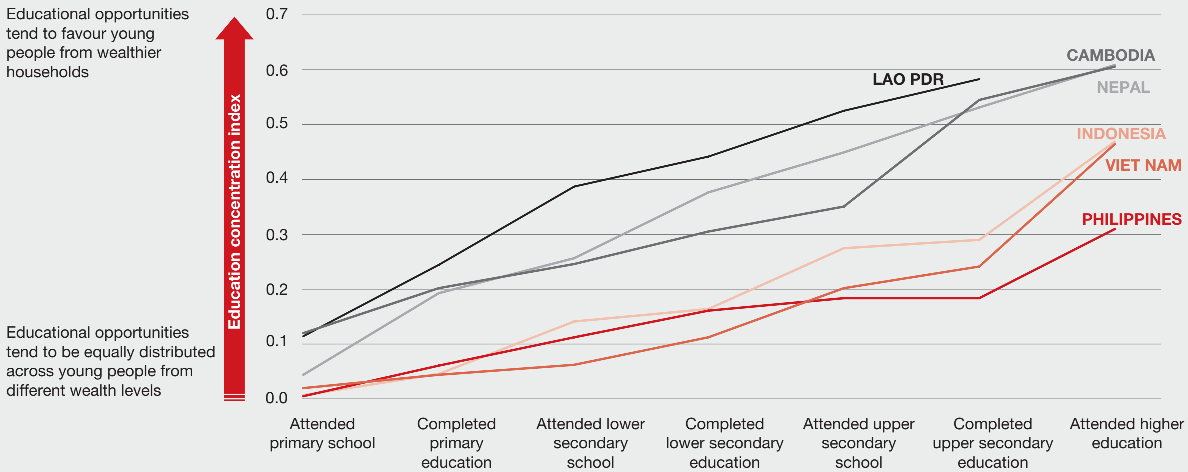
The concentration index can be used to better evaluate the magnitude of inequality. The concentration index is determined by twice the area between the concentration curve and the line of equality. When the concentration curve is above the line of equality, the concentration index yields a minus value; whereas when the curve lies below the line, the index yields a positive value. In the absence of wealth-related inequality, the concentration index is zero. The index is bounded between –1 and 1.

Concentration Index = $1 - 2\int_0^1 L(s)ds$, where L(s) is the concentration curve

An index value close to one implies that educational opportunities tend to favour richer households; whereas an index value close to zero implies that educational opportunities tend to be equally distributed across various income households.

Sources: d'Hombres, 2010; O'Donnell et al., 2008

Figure 12. Concentration index for educational opportunity from primary to higher education for population aged 20 to 24 years in selected countries, 2003-2011



Sources: Authors' calculations based on Bangladesh Demographic and Health survey (DHS) 2011, Bhutan DHS 2010, Cambodia DHS 2010, India DHS 2005-2006, Indonesia DHS 2006, Maldives DHS 2009, Nepal DHS 2006, Pakistan DHS 2007, Philippines DHS 2003, Timor-Leste DHS 2010, and Viet Nam DHS 2011

Currently almost all countries or territories (22 out of 26) across East and South Asia are implementing graduate programmes. However, doctoral-degree programmes which provide advanced research training are currently absent in Bhutan, Lao People's Democratic Republic and the Maldives (UNESCO-UIS, 2013b). This suggests that there is a growing divide between countries able to locally staff the expansion of their higher education systems and those that are relegated to outsourcing instruction to expatriate instructors or alternatively accepting less-qualified instructional staff.

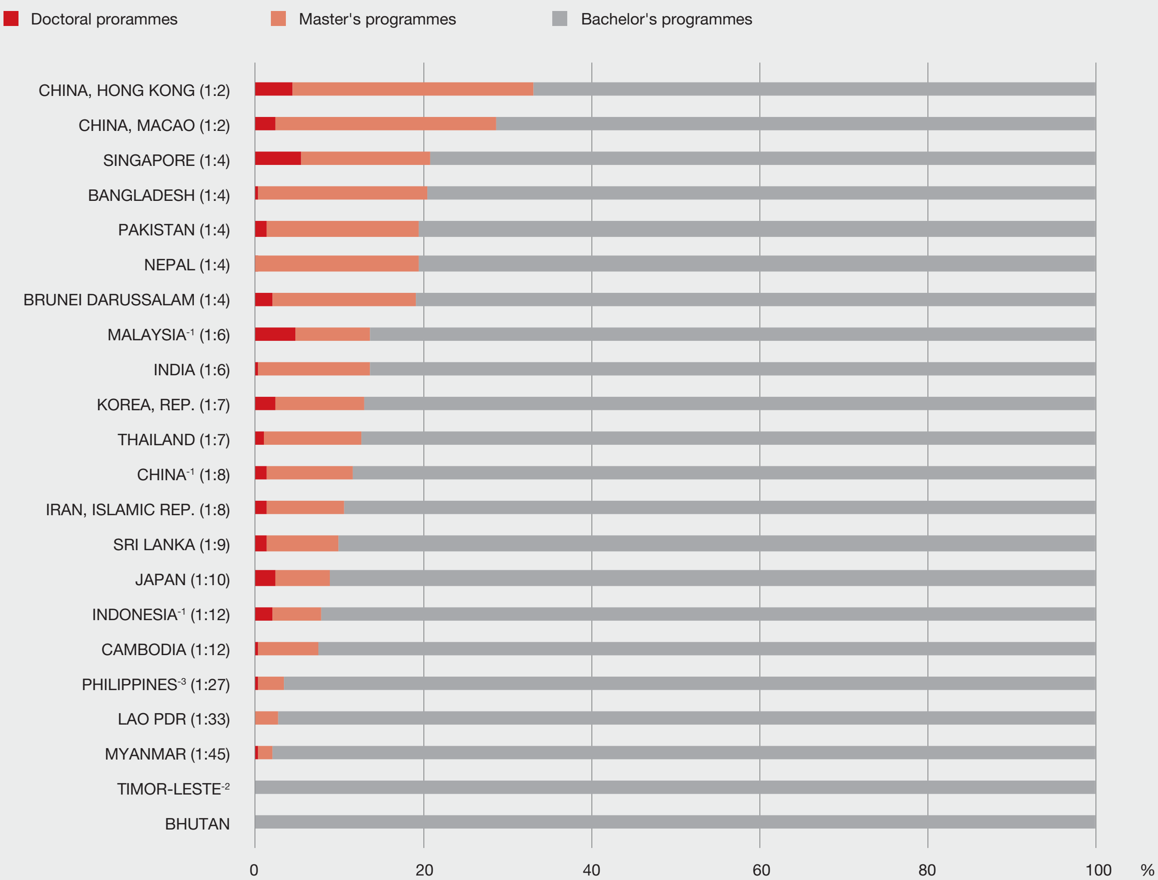
Figure 13 displays the distribution of enrolment by three types of programmes and the ratio of undergraduate enrolment to graduate enrolment in individual countries. Based on the size of graduate enrolment, countries can be roughly grouped into two: one group has modest graduate enrolment, while the other has a relatively large number of graduate students. For instance, in Singapore, the ratio of undergraduate to graduate enrolment is 4:1. The other group of countries has a small (or zero) population of graduate students. In the Philippines, for example, the ratio of undergraduate to graduate enrolment is 27:1.

When taking a country's population into account, as seen in **Figure14**, Thailand leads the region among middle-income countries for having a relatively higher GER for graduate education (5%), followed by Nepal (3%) and Malaysia (3%).

Most graduate education within Asia is provided in public universities, even in countries where private enrolment dominates the majority of higher education enrolment (e.g. Indonesia, Japan and the Philippines) *(see **Table 4**).*

Doctoral education in most countries prepares a new generation of faculty and researchers in academia, as well as a highly-skilled research workforce for other sectors of the economy. **Figure 15** shows the number of Master's and doctoral graduates per 100,000 inhabitants in 2011. Generally, middle-income and low-income countries lag behind industrial countries in the production of doctorates per year. Malaysia and Thailand have a relative

Figure 13. Distribution of higher education enrolment by programme type, 2011 or most recent year available



Notes: Numbers in parentheses are the ratio of enrolments in graduate programmes (Master's and doctoral) to that in Bachelor's programmes.
-3 Data refer to 2008; -2 Data refer to 2009; -1 Data refer to 2010.

Source: UNESCO Institute for Statistics, October 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f13

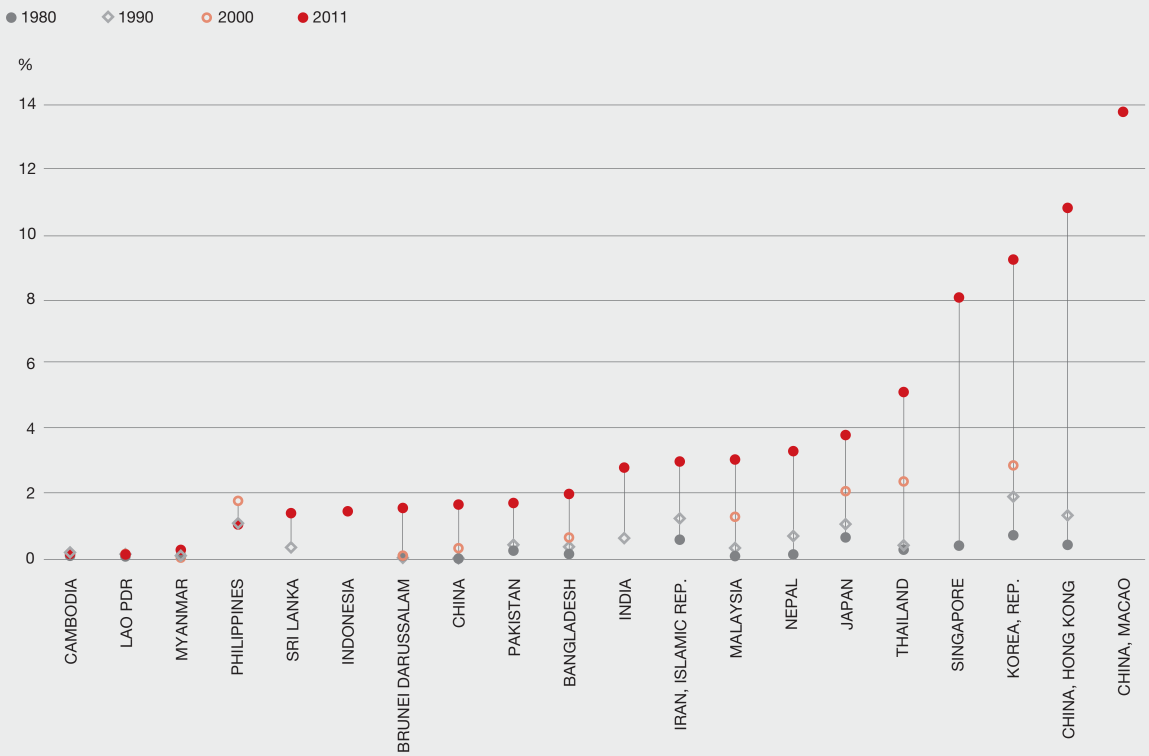
Table 4. Enrolment in Master's and doctoral programmes by type of higher education institutions, 2011 or most recent year available

	Enrolment (in thousands)				
	Public		Private		
Country or territory	Master's	Doctoral	Master's	Doctoral	Public (%)
INDONESIA	155	21	138	10	54
JAPAN	118	56	88	19	62
KOREA, REP.	84	21	186	39	32
MALAYSIA-1	50	18	14	4	79
PHILIPPINES-3	39	5	37	4	52
SRI LANKA+1	28	4	1	–	97
THAILAND	209	20	33	3	86

Notes: 1. – denotes quantity nil.
2. -1 Data refer to 2010; -3 Data refer to 2008; +1 Data refer to 2012.

Source: UNESCO Institute for Statistics, October 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/t4

Figure 14. Gross enrolment ratios for Master's and doctoral programmes by country or territory, 1980-2011



Source: UNESCO Institute for Statistics **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f14

higher proportion of doctoral graduates per 100,000 inhabitants (about five).

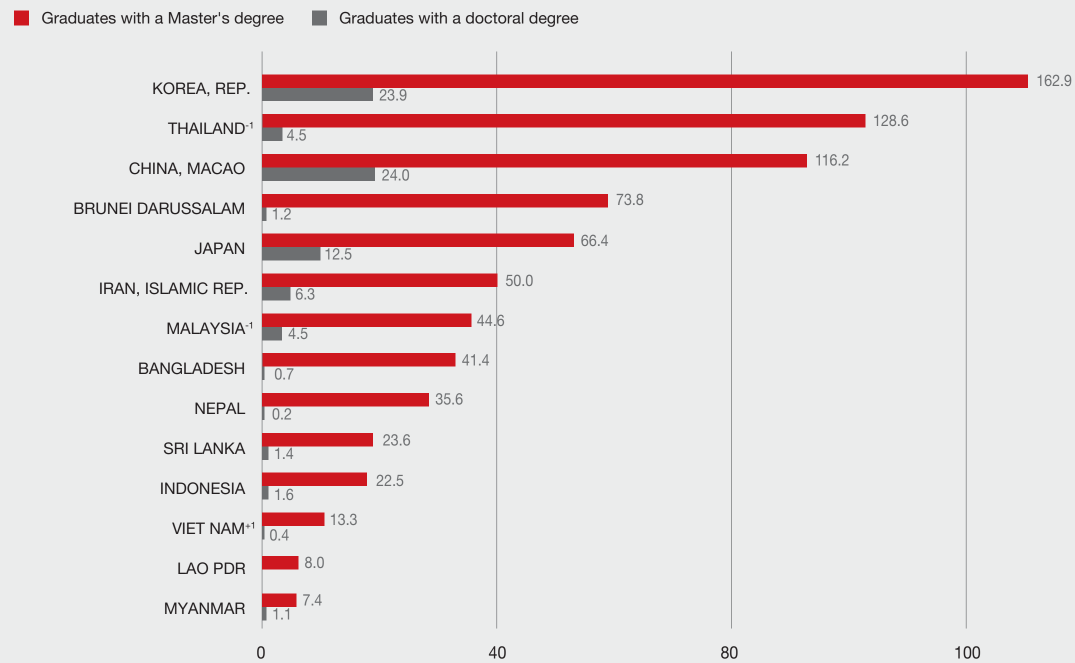
In addition to doctoral graduates who are trained domestically, the UIS estimates that in 2011 there were over 60,000 students from East and South Asia who were pursuing a doctoral degree abroad. For some countries, the share of foreign-trained doctorates is significantly large. In Viet Nam, domestic doctoral enrolment was approximately 4,700 in 2011; during the same year, there were over 3,400 Vietnamese enrolled in doctoral programmes overseas. In Brunei Darussalam and Nepal, foreign-trained doctorates outnumbered those who were domestically trained in 2011.

Graduate-level education in the fields of science, technology, engineering and mathematics

Some middle-income countries of the region have placed greater emphasis on science and technology programmes at the graduate level. This is fueled by a perception that economic growth in industrialised countries is tied to technological advancement, which is possible through advanced education in the fields of science, technology, engineering and mathematics (STEM).

In the 1980s and 1990s when Japan's economy was increasing rapidly, its economic growth drove policymakers and the industry to demand expanded Master's programmes in engineering (Yamamoto, 2000). A couple of decades later, China and Malaysia are also producing a large number

Figure 15. Number of Master's and doctoral graduates per 100,000 inhabitants by country or territory, 2011 or most recent year available



Note: -2 Data refer to 2009; -1 Data refer to 2010.
Source: UNESCO Institute for Statistics and Statistical Table B4 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f15

Table 5. Number of Master's and doctoral graduates and the proportion that graduated from science and technology fields, 2011 or most recent year available

Country or territory	Graduates (in thousands)	% in science and technology
BANGLADESH	64.5	19
BRUNEI DARUSSALAM	0.3	4
CHINA, MACAO	0.8	9
IRAN, ISLAMIC REP.	42.5	38
JAPAN	100.5	41
KOREA, REP.	91.0	21
LAO PDR	0.5	5
MALAYSIA-1	15.7	32
MYANMAR	4.5	57
NEPAL	9.7	10
SRI LANKA	5.2	14
THAILAND-2	78.5	14

Notes: -1 Data refer to 2010; -2 Data refer to 2009.
Source: UNESCO Institute for Statistics, October 2013
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t5

of engineering Master's and doctoral graduates, emphasising the advanced technological skills needed by their economies. Compared to other middle-income countries in the region, the Islamic Republic of Iran and Malaysia have relatively high proportions of science and technology Master's or doctoral graduates (38% and 32% respectively) *(see* ***Table 5****).*

International students at the graduate level

Due to the enhancement of higher education systems in Asian countries, and their aspiration to become educational hubs, the number of international students coming to study in Asia has increased markedly *(see* ***Box 5****).* In 2011, some 492,000 international students were pursuing a higher education degree in East and South Asia, which was double the number in 2005. Japan is the major host country in the region, followed by

Box 5. Definition of international (or mobile) students

International (or mobile) students are defined as students who have crossed a national border and moved to another country with the objective of studying. Two operational definitions are used in the international dataset developed by the UIS, the Organisation for Economic Co-operation and Development (OECD) and Eurostat:

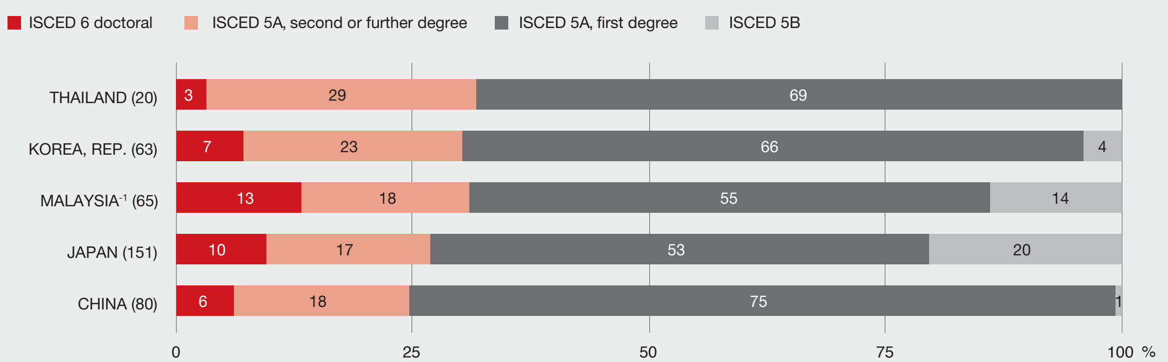
- Students who are not usual residents of their country of study, i.e. those who have recently moved to the destination (host) country from somewhere else.
- Students who received their prior qualifying education in another country, indicating that they have crossed a border.

When data on these two defining characteristics are not available, data on foreign students (who are non-citizens of the country in which they study) are commonly used as a proxy for international (or mobile) students.

Currently, the international dataset does not include students in exchange programmes that usually last less than a school year and who fulfil part of their studies at an educational institution abroad but are credited at their home institution.

Source: UNESCO-UIS/OECD/Eurostat (2013)

Figure 16. Distribution of internationally mobile students by type of programme in selected host countries, 2011



Notes: Numbers in parentheses refer to the number of internationally mobile students (in thousands). -1 Data refer to 2010.
Source: UNESCO Institute for Statistics, October 2013. China's data: Educational Statistical Yearbook of China 2011 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f16

emerging host countries, including China, Malaysia, Singapore and the Republic of Korea (UNESCO-UIS, 2013). *(See Statistical Tables B2 and B3 for a profile of international students.)*

The majority of international students who study in Asian countries are enrolled in undergraduate programmes *(see **Figure 16**)*. International students at the graduate level generally account for one-quarter to one-third of total students from abroad. It is of note that both Japan and Malaysia have a relatively high proportion of international students studying in doctoral programmes in their universities (10% and 13%, respectively).

The expansion of graduate programmes has presumably contributed to the quality of higher education by supplying more academic staff with a Master's or doctoral degree. As illustrated in **Table 6**, in the Philippines and Viet Nam, the qualifications of academic staff have improved over the last decade. In the Philippines, the share of university instructors with a doctorate has increased from 8% in 2002 to 13% in 2012, and the share with a Master's has

Table 6. Percentage of higher education instructors with a Master's or doctoral degree by type of institution, 2012 or most recent year available

Country or territory	All institutions		Public		Private	
	Doctoral	Master's	Doctoral	Master's	Doctoral	Master's
CAMBODIA (2009)	8	52	...	...	...	...
CHINA (2000)	4	20	...	...	...	...
CHINA (2011)	16	35	16	35	4	21
INDONESIA (2007)	7	40	...	...	...	...
MALAYSIA (2010)	20	49	30	54	9	43
PHILIPPINES (2002)	8	26	...	...	...	...
PHILIPPINES (2012)	13	41	...	...	...	...
VIET NAM (2000)	15	22	...	...	...	...
VIET NAM (2012)	14	46	...	...	...	...

Note: ... denotes data missing or not available.

Sources: Educational Statistics Yearbook of China 2000 and 2011; Philippines: Commission on Higher Education; Viet Nam: Ministry of Education and Training; Cambodia and Indonesia: the World Bank (2012)

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t6

increased from 26% in 2002 to 41% over the same period.

Though there is overall improvement in academic qualifications, this is mostly seen in public institutions and very limited in private ones *(see Table 6).* In China, private institutions have a much lower share of academic staff who have a Master's or doctoral degree (25%), compared to 51% in public institutions. In Malaysia, the gap between public and private institutions is even larger; in private institutions, the share of academic staff that has a Master's or doctoral degree is 52% whereas it is 84% in public institutions.

Graduate education and university-based research

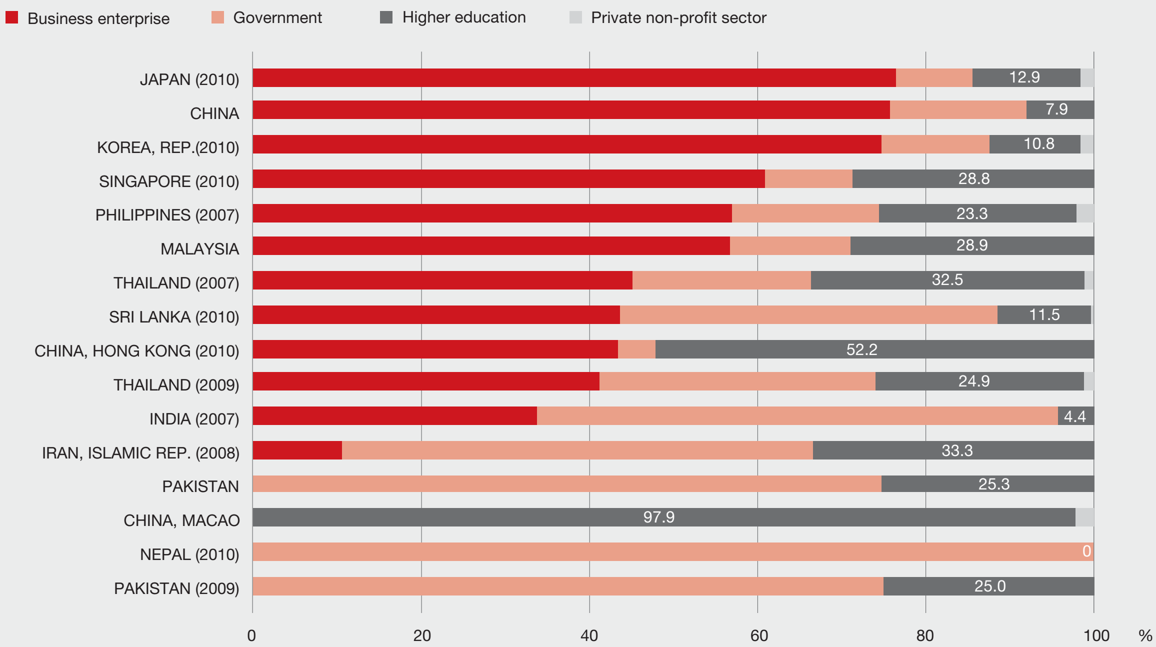
As discussed earlier, graduate education traditionally involves some research training and prepares future higher education faculty and researchers. Generally, academic staff in universities and doctoral students conduct research and produce scientific articles and patents. In most countries in Asia, higher education institutions usually lag behind the private sector in conducting research and development (R&D) activities. In Malaysia, universities performed 29% of total R&D expenditure nationwide, which makes academia the second-largest performer of Malaysia's R&D *(see **Figure 17**),* whereas in Thailand, the higher education sector is the third-largest performer.

Figure 18 illustrates the number of doctoral students in relation to the number of full-time equivalent (FTE) researchers in the higher education sector. As a country's doctoral enrolment increases, so does the number of FTE researchers in the higher education sector.

1.3 SUMMARY

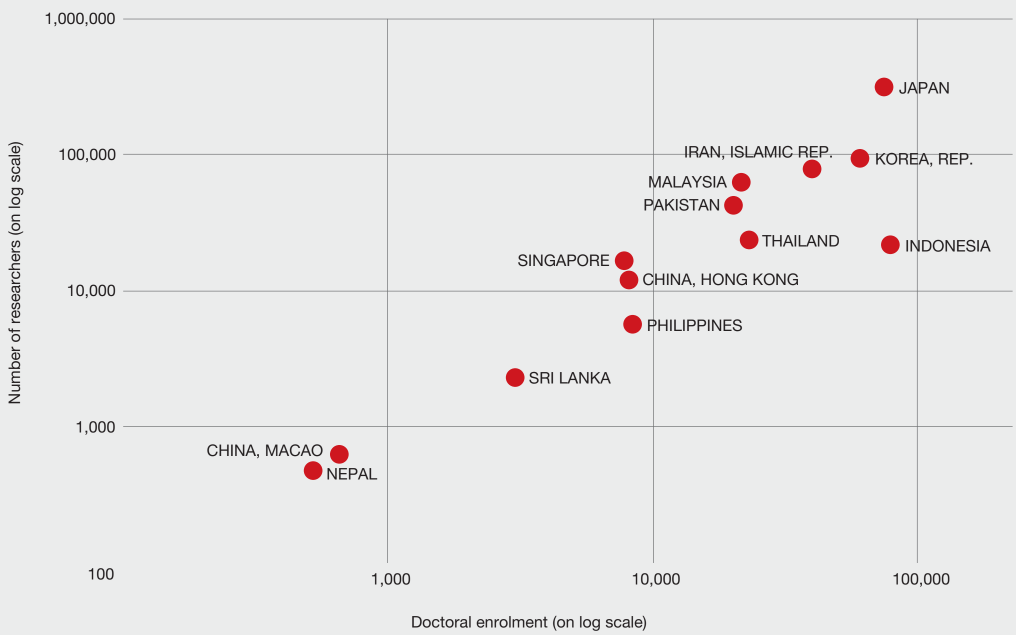
The expansion of higher education across most countries of Asia over the last 20 years is a success story, but with its own set of new challenges. Graduate education was expanded, in large part, to prepare instructional staff to serve the growing undergraduate population but also to further research and innovation in ways that would accelerate national economic development. This expansion placed new demands on government funds, potentially competing with the very sub-sector that it was trying to serve (undergraduate education). The next chapter looks at how governments and higher education institutions negotiated a path through those sometimes complementary, sometimes competing, challenges.

Figure 17. Distribution of gross domestic expenditure on R&D by sector of performance, 2011 or most recent year available



Source: UNESCO Institute for Statistics, July 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f17

Figure 18. Number of researchers in the higher education sector in relation to doctoral enrolments by country or territory, 2011



Source: UNESCO Institute for Statistics, October 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f18

Chapter 2

EXPANDING OUT AND UP: WHAT ARE THE SYSTEM-LEVEL DYNAMICS? CASE STUDY OF MALAYSIA AND THAILAND

David Chapman and Chiao-Ling Chien

While *expanding out* and *expanding up* are both necessary to provide quality higher education to the growing number of students, university personnel engaged in the design and delivery of graduate education face somewhat different demands than their counterparts who focus more exclusively on undergraduate education. While the issues encountered in the expansion of undergraduate education have received considerable attention and are rather well understood, the institutional-level dynamics associated with the expansion of graduate education are less clear. To that end, a two-country case study was undertaken for this report to: i) further elaborate the reasons why selected governments and higher education institutions are expanding their graduate-level programmes; ii) examine how the growth of graduate education affects the professional lives of the faculty and administrators leading those programmes; iii) clarify the extent to which these actors perceive a tension between expanding out and expanding up; and iv) identify institutional-level issues in the continued expansion of graduate education.

This study was conducted as a focused case study of two countries – Malaysia and Thailand – that, among middle-income countries, lead the region in the development of graduate education. Both countries have experienced rapid growth in undergraduate enrolment, both have developed an extensive network of public colleges and universities, both have also embraced the expansion of private higher education as a way to help absorb social demand for higher education, and both have aggressively expanded their graduate programmes. The two countries have highly-respected universities. In these countries, government and education leaders operate from carefully-considered rationale regarding the value and anticipated payoffs from expanding graduate-level education.

At the same time, these two neighboring countries differ in nuanced but important ways in the outcomes they seek, the strategies they use, and the issues they have encountered as they have expanded up. While both countries lead the region in the provision of graduate education, their rationale and primary strategies for doing so diverge. The level of financial and administrative autonomy available to the top universities differs between the countries. Consequently, these two countries offer particularly useful settings in which to investigate the different rationale and approaches that underlie government investment into graduate education.

2.1 NATIONAL STRATEGIES FOR EXPANDING GRADUATE EDUCATION: THE VIEWS FROM TWO COUNTRIES

2.1.1 Graduate education in Malaysia

Since 2000, the higher education system in Malaysia has expanded rapidly. As part of that expansion, enrolment at the graduate level has increased four-fold (from about 21,100 in 2000 to 85,200 in 2010). This reflects the high priority that the government has assigned to enlarging the country's capacity to offer graduate education, as explained in the *National Higher Education Strategic Plan Beyond 2020* (MOHE, 2006). The government wants, among other things, for the country to have its own indigenous research capability and not rely too much on industrial research undertaken by foreign companies. Thus, the government would like to accelerate the production of doctorates. There are about 21,000 PhD holders in Malaysia. The goal is to produce 100,000 PhD holders by 2020 (including locally trained, overseas trained and split-programmes with foreign universities).

To support that priority, the Malaysian government has been generous in providing inputs to graduate education. In 2008, the Ministry of Higher Education (MoHE) designated four universities as research universities, and later added a fifth university to this group, and directed special funds to assist those institutions to expand their graduate-level research and teaching facilities. Between 2008 and 2009, these five research universities received an increase of approximately 71% funding from the government (World Bank, 2011). Additionally, the government has allocated another 500 million ringgit (around US$160 million) to finance graduate students.

Malaysia aims to increase its higher education participation rate from the current 40% to 50% by 2020. **Table 7** shows a comparison of enrolment by type of programmes in public versus private higher education institutions over the past five years. The increase in enrolment in Bachelor's-level programmes or below mainly took place in private higher education institutions (HEIs). For instance, the share of Bachelor's enrolment in private HEIs increased from 36% in 2007 to 45% in 2010. If such a pattern continues, one may expect that private HEIs play an important role in absorbing undergraduate and college students that cannot be served by public HEIs. Then, public HEIs would maintain their optimal size of total enrolment, reduce the intake of undergraduates and allow room to enhance their graduate enrolment.

2.1.2 Graduate education in Thailand

In Thailand, enrolment at the graduate level has increased from about 193,000 in 2007 to 196,000 in 2012, particularly at the doctoral level *(see **Table 8**)*.

Table 7. Enrolment by type of programme and institution in Malaysia, 2007 and 2010

Programme	2007		2010	
	Enrolment (000)	Private (%)	Enrolment (000)	Private (%)
Doctorate	11	9	22	18
Master's	35	13	64	22
Post-graduate diploma	...	...	3	-
Bachelor's	389	36	495	45
Below Bachelor's	296	74	421	72
All types of programmes	...	...	1,004	54

Note: "..." denotes data not available.
Source: Malaysia Higher Education Statistics
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t7

Table 8. Enrolment by type of programme and institution in Thailand, 2007 and 2012

Programme	2007		2012	
	Enrolment (000)	Private (%)	Enrolment (000)	Private (%)
Doctorate	16	8	21	9
Higher graduate diploma	1	0	1	0
Master's	177	11	174	12
Graduate diploma	17	7	5	20
Bachelor's	1,684	16	1,751	13
Below Bachelor's	58	1	24	0
All types of programmes	1,952	15	1,976	13

Source: Thailand Office of the Higher Education Commission (OHEC), Ministry of Education, 2013
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t8

One reason for this focus on graduate education is that the birth rate in Thailand is declining so the size of undergraduate enrolment may not grow much in the future. Consequently, both the government and universities share a common belief that more focus should be placed on the development of graduate education and enhancement of graduate enrolment.

The Thai government has recently categorised its existing higher education institutions into four types: i) research and postgraduate universities; ii) specialised (e.g. science and technology) and comprehensive universities; iii) four-year universities and liberal arts colleges; and iv) community colleges. Universities in each group are encouraged to excel in accordance with their missions and receive government funding in line with these missions (OHEC, 2010; Rungfamai, 2011). Above all, research and postgraduate universities focus on offering postgraduate degree programmes (especially doctorate) and producing researchers.

In 2009, the Office of the Higher Education Commission (under the Ministry of Education) initiated the National Research Universities Project with an additional budget of Baht 12 billion (about US$370 million) for the period of 2010 to 2012. Currently, nine universities are selected for this project. The project was initiated based on the government's belief that Thailand's competitiveness in research is a significant indicator of the production and quality of human resources (Rungfamai, 2011). These universities are expected to produce research work that can be transferred and generate income for communities and industries. Additionally, they are expected to achieve high world university rankings and help Thailand to become the education hub of the Association of Southeast Asian Nations (ASEAN) (OHEC, 2009).

2.2 METHODOLOGY

During May 2013, a total of 51 interviews were conducted with administrators (N=27) and faculty members (N=6) at four public research universities in Malaysia and three in Thailand. The statistical profiles of those research universities can be found in **Table 9**. Additionally, interviews or focus group discussions were conducted with 15 central government officials responsible for higher education in both countries. Interviews were conducted with three officials in two international organizations working in the area of higher education *(see*

Table 10. Number of interviewees by function

Function	Malaysia	Thailand
University administrators	17	10
University faculty members	3	3
Government officers	3	12
International organizations	0	3

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t10

Table 10*)*. The semi-structured interviews were about 45 minutes in length and elicited information in nine areas as detailed in **Box 6**. Interviewers kept cotemporaneous notes and interviews were recorded. Thematic analysis was used to identify main findings.

The next section summarises the main findings from the interviews. All universities in this study have expanded their graduate enrolment and, concomitantly, reduced their undergraduate enrolment. The goal in these research universities is to eventually move to a 1:1 ratio of undergraduate to graduate students. The reasons for that shift are explored later in this chapter.

2.3 FINDINGS

2.3.1 Motivation for increasing graduate education

In both Malaysia and Thailand, government and education officials see the development of graduate education as contributing to national economic development although in somewhat different ways.

Table 9. Enrolment in research universities included in this study

Country or territory	University	Undergraduate (000)	Graduate (000)	Ratio of undergraduate to graduate
MALAYSIA	Universiti Kebangsaan Malaysia (2011)	15	10	1.5 : 1
	University of Malaya (2013)	13	11	1.2 : 1
	Universiti Putra Malaysia (2013)	14	10	1.4 : 1
	Universiti Sains Malaysia (2011)	19	9	2.0 : 1
THAILAND	Chulalongkorn University (2013)	25	13	1.9 : 1
	Mahidol University (2010)	18	8	2.1 : 1
	Suranaree University of Technology (2011)	10	2	6.1 : 1

Note: Numbers in parentheses refer to the school year.
Sources: Universities' websites and Malaysia Higher Education Statistics (2011)
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t9

Box 6. Areas of inquiry during the interviews

1. What are the government's expected outcomes for investing in graduate education?
2. In your view, what are regarded as the main trade-offs between the expansion of undergraduate and graduate education? To what extent is the expansion of graduate education seen as a priority in your country/university?
3. What are the sources of instructional staff for graduate programs?
4. What are the manners of evaluating graduate school faculty for promotion? How does your university hold individual faculty accountable?
5. In your view, how much emphasis is placed on research (as opposed to teaching)?
6. What are the main sources of funding to support university-based research? How does the commercialisation of university-based research work?
7. What is the link between your university and the private sector?
8. How is graduate education financed at this institution/country?
9. What type of employment do most of your graduate students pursue after graduation?

In Malaysia, government and university interviewees saw a fairly direct line between the expansion of graduate education and national economic development. Multiple interviewees cited the Korean model as one which Malaysia seeks to emulate. The model emphasises substantial investment in education as a means of building an educated workforce in the expectation that evidence of an educated workforce, in turn, will attract international investment. This international investment would, then, fuel the economic development of the nation.

To achieve these goals, the higher education system not only has to be good, but it has to be widely seen to be good by the international community. The benefits of upgrading the higher education system will only be achieved as prospective students choose to study in Malaysia, as business and industry locates in Malaysia, and as international investors see the country as offering a high-quality setting for their investment. To this end, it is important to the government that Malaysian higher education be widely respected and internationally ranked. To this end, the universities' interest in gaining international recognition and prestige is more than cosmetic; there are national economic benefits to be gained.

The dominant view among interviewees was that this international attention and respect would be achieved by raising Malaysian universities in international university rankings. Since publication rates are a key ingredient in all international ranking systems, pushing faculty to increase their publications in top-tier international journals was viewed as the most direct way of gaining the desired international attention.

Preparing instructional staff to teach in the wider circle of Malaysian colleges and universities across the country was a valued outcome of expanding graduate education but evolved into being more of a by-product than a central goal of the expansion. It was cited in policy documents as a rationale, but raising the quality of instruction across the wider higher education system, by itself, was not going to draw the kind of visibility that would attract international attention. Nonetheless, the demand for more and better-qualified instructors across other Malaysian higher education institutions ensured that virtually all Master's and doctoral graduates would find employment. PhD production did not depend on private sector demand from business or industry in order for graduates to find employment.

In Thailand, government and education officials also see higher education as an important ingredient in economic development of the country but in a somewhat different way. Local relevance was valued over rankings by many interviewees. Interviewees gave more importance to the relevance of graduate education and university-based research for Thai society. They expressed considerable ambivalence about the value of publication in top-tier international journals, since most are published in English. This meant that these research findings would be largely inaccessible to Thai society, most of whom do not understand English. There was a strong view that it was important for the universities to 'give back' to Thai society for the financial support received by universities and that publishing in English would not necessarily achieve this.

In summary, in both countries the leading research universities are actively expanding their graduate enrolment and for similar reasons. First, expanding graduate education is viewed as a strategy for increasing the publication rate of graduate degree-offering universities. This, in turn, is viewed as a strategy for raising the international ranking of the university. Second, while receiving the benefit of graduate students' research, these programmes are preparing graduates to fill teaching posts at other higher education institutions across the country, thereby raising the instructional quality of their national higher education system more broadly. Malaysia has a third purpose not shared by the universities in Thailand. Expanding the availability of graduate education offers a way to attract international students who are seen as a source of income for the university and the country.

2.3.2 International university rankings

For investment in graduate education to yield the desired payoffs (e.g. prestige, international investment, appeal to international students and faculty talent), top universities need to be regarded as excellent. The most widely-recognised metric of such excellence is international university rankings. Consequently, university personnel in both Malaysia and Thailand are quite concerned about their university's placement in international rankings. High rankings are viewed as a way to earn international respect, justify government investment in their institution, and recruit students and faculty. But there are differences between the countries.

One Malaysian interviewee summed up this thinking in an analogy: The performance of a nation's football team in an international competition tends to be the basis on which observers judge the football prowess of the entire country. If the national team does poorly, the presumption is that football skills across the entire country are weak. If the national team does well, the presumption is that there is wider football strength in the country. The image of the whole country is based on the perception of a few. If Malaysia wants to be seen internationally as a top academic destination, the top universities need high rankings to establish that image.

Not all ranking systems are created equal; they differ in the factors that are included in the formula and the relative weight assigned to common factors. The rank a university receives depends, in part, on which ranking system is being used. Consequently, which ranking system a university uses as its main benchmark often tends to drive internal university incentive systems. Both Malaysian and Thai universities tend to favor the QS system, developed by a group in the United Kingdom. A fuller discussion of alternative ranking systems is presented in Chapter 4.

In Thailand, university personnel took a somewhat more benign view. They also sought high international rankings for their universities, believed that higher rankings would earn international respect, and saw high rankings as a factor in attracting top students. However, as discussed earlier, there was a widespread sense among interviewees that the 'cost' of raising their rankings could get in the way of other ends that they valued. Rankings are important, but relevance of universities to Thai society is also important to these faculty members, and those agendas sometimes conflict.

Over the last five years, Thai universities have dropped in their standing on these international rankings. Such a drop can occur for several reasons. A university may drop on productivity indicators that are included in the rankings or a university might maintain its productivity level but still drop, in relative terms, if additional, more productive universities were included in subsequent years. Regardless of the reason, a drop in rankings is not well received.

2.3.3 Publications as the route to high rankings

Scholarly publications in top-tier international journals are a key ingredient in international university rankings. As might be expected, then, publishing in top-tier international journals is a central feature of the key performance indicators (KPIs) for faculty in both countries. Moreover, graduate students are seen as important contributors to publications, both as they assist in conducting faculty members' research and publish as part of their graduate programme requirements. In both countries, Master's and PhD students in selective universities are required to publish their research in journals as a condition of graduation.

In the research universities in Malaysia, the pressure to publish in top-tier journals is intense. Expectations are explicit and, for the most part, uniformly applied across departments and fields of study. Junior faculty members are expected to publish at least one article a year in an Institute for Scientific Information (ISI) journal; senior faculty members are expected to publish at least two articles a year in such journals.

In the view of some interviewees, mostly administrators, publication is portrayed almost as a social responsibility. From this perspective, a faculty member's research is not complete until it is published. Faculty members generally hold a somewhat different view. Those in STEM fields (i.e. science, technology, engineering and mathematics) assign considerable value to ISI journal publication, many having been inculcated in that tradition during their own graduate school experience. Those in humanities, arts and, to a considerable degree, social sciences tend to feel this pressure for the ISI publication was misplaced. Their fields, some argue, value other types of evidence of their scholarly success, such as books or performances. Consequently, there is considerable resistance from some groups of faculty concerning how that productivity is measured for purposes of salary and career advancement.

The top research universities in Thailand also place a high emphasis on publications in top-tier journals but with more nuance. However, Thai university administrators report considerable resistance among some faculty to the importance assigned to publications. Some interviewees observed that, if they publish in top-tier journals in English, the results will be largely inaccessible to the wider Thai society. Second, a frequent observation is that, though most Thai faculty are proficient in English, some are not fully comfortable writing in English at the level required for publication in top-tier journals.

In some respects, the autonomous nature of top Thai research universities gives administrators more ability to insist that faculty publish. Job security of faculty members who gave up their civil service standing and became university employees depends more on their annual performance reviews than the job security of faculty who are still civil service employees. At the same time, that autonomy allows university administrators to take a more flexible view regarding publication expectations of faculty than their counterparts in Malaysia. This flexibility is exhibited in interviewee reports of how publication expectations are applied differently across colleges and academic departments. Not everyone is treated identically. This flexibility has benefits. As one interviewee pointed out, those faculty most likely to resist the "publish and do so in English" pressure tend to be older and more senior faculty. The university could not easily lose that level of expertise and seniority without negative repercussions. And they need those individuals for institutional leadership.

2.3.4 Encouraging faculty to publish

The challenge facing university officials in both countries is to create an incentive and accountability system capable of harnessing and aligning the energy of faculty members behind national and institutional goals. In both countries, this is accomplished through a system of KPIs. Indeed, the government and universities in both countries employ KPIs as the backbone of their accountability systems and, in both countries, the KPI system is a source of considerable controversy, with strong supporters and strong critics. Supporters argue that raising rankings, publishing and commercialising research are a way to pay back the country for its investment in higher education. Critics feel that the metrics employed in the KPIs are too rigid and often fail to acknowledge the value of professional work that is not publishable in an ISI journal.

2.3.5 Key performance indicators (KPIs)

While government funds for the expansion of graduate education are generous, those funds come with relatively stringent layers of accountability, largely captured in the fairly elaborate KPI system. Universities must report to the Ministry of Higher Education on a series of KPIs which they must meet to continue to receive government funding. These KPIs emphasise the overall number of publications produced, number of patents filed, amount of teaching and amount of outside research funds received. Within the university, academic departments and research units have KPIs that largely mirror the university's, with an emphasis on publication rates and external funds received. Individual faculty members each have KPIs that, again, largely mirror those of the university and their faculty. As described by interviewees at one of the universities, faculty members are expected to teach four courses per year, publish one to two articles in top-tier journals annually (depending on rank, with senior faculty expected to publish more), secure external funding, and be involved in some form of community outreach. Faculty members are expected to be adequate in all areas and to excel in at least one.

University administrators argue the merits of having a set of consistent objectives and verifiable indicators that could be applied across a variety of disciplines. In their view, fairness dictates that everyone is subject to the same expectations regarding teaching load, publication output, external fund raising and community outreach. They view KPIs as a fair and transparent system. Everyone understands what is expected of them. On the other hand, the KPI system is not as popular among faculty members. Many of them believe KPIs are being applied in a rather inflexible manner. Not surprisingly, this 'one size fits all' approach is a point of considerable criticism and debate within the faculty. But views differ. The system appears to have relatively more support among faculty members in STEM areas (science, technology, engineering and mathematics). Faculty members in the arts, humanities and, to a considerable extent, social sciences see it as inappropriate and unfair. Interviewees observed that university administrators have difficulty in knowing how to evaluate a book or art show relative to a publication in an ISI journal, typically to the detriment of those not in the hard sciences. While some of the Malaysian universities are experimenting with introducing more flexibility, these efforts are at an embryonic stage. One point of wide agreement, however, is that virtually all interviewees believed the KPI system puts great pressure on faculty, especially young faculty, and many faculty members regard the system as unfair.

The effectiveness of the KPI system is, in part, limited by larger structural issues. Salaries are fixed by government and are standard across all faculty of similar rank. This means that there are few financial incentives for stellar performance. Furthermore, since most instructional staff are tenured (e.g. have strong employment security), failure to meet KPIs does not put their jobs at risk. They may lose out on promotions and annual raises, but their jobs are secure. To offset this limitation, all of the universities have implemented bonus systems in which faculty members are paid extra for each publication, the amount based on the impact factor of the journal, in addition to bringing in grants and contracts. These amounts are designed to be motivating; in some universities, an assistant professor could earn US$2,000 (or more) for publishing in a top-tier journal.

Thailand employs a more flexible KPI system than seen in Malaysia. The status of the Thai universities in this study as 'autonomous universities' gives them a degree of insulation from central government expectations that is not enjoyed in Malaysia. Generally, these universities are encouraged to conduct self-evaluation in accordance with the KPIs set by the Thai Office of the Public Sector Development Commission and are required to formulate short- and long-term development plans toward their targeted goals with approved KPIs (OHEC Thailand, 2013).

2.3.6 Expanding international enrolment

Both Malaysia and Thailand recruit international students for their graduate programmes but in different ways and for somewhat different reasons. As mentioned earlier, universities in both countries view graduate education as a strategy for increasing their research output. To that end, research publications are a graduation requirement for both Master's and doctoral students. In Malaysia, graduate education is also seen as an income-producing activity. In Thailand, this is not the case and most international graduate students are fully funded by the institutions they attend.

The financial value of international graduate students in Malaysia relates to government control over domestic tuition rates at both undergraduate and graduate levels. Tuition rates for undergraduate students in Malaysian public universities are set by the government and constant across public universities. However, since universities can control the tuition rates they charge to international students, they are a more lucrative market (than domestic students). The MoHE actively seeks to further increase the number of international students studying in Malaysian colleges and universities, largely as a source of national income. The colleges and universities see an advantage in this because they are not constrained by government rules capping the tuition that can be charged to domestic students. Consequently, Malaysia seeks to become a higher education hub at both the undergraduate and graduate levels. Already over 63,500 international students are enrolled in Malaysian colleges and universities, which account for 6% of total higher education students *(see **Figure 19**)*. The Malaysian government has targeted international enrolment at 10% of total higher education enrolment by 2020 (MoHE Malaysia, 2006).

At the graduate level, universities can set their own tuition levels, allowing institutions greater flexibility to utilise tuition as a way to meet university costs. One implication is that, even though the unit cost of graduate education in Malaysia is presumably higher than undergraduate, graduate education offers a more lucrative strategy for universities under pressure to generate more of their own income. Consequently, shifting the balance from undergraduate to graduate enrolment offers economic advantage to universities. As an economic move, then, all four of the research universities involved in this study are in the process of reducing their undergraduate enrolment while increasing their graduate enrolment, with a goal of eventually achieving an undergraduate-to-graduate enrolment ratio of 1:1. With respect to international students, all of these research universities enrol a disproportionate share of international students at the graduate level.

The reasons for international students to select Malaysia vary, but five factors are particularly prominent:

i) Cultural comfort: Malaysia provides a friendly environment for Muslim students. Muslim students can study in a country in which Muslim values and practices are understood, widely-shared and respected;

ii) Cost: Relative to the cost of higher education in traditional destination countries (the United States, the United Kingdom and Australia), the costs of undergraduate and graduate degree programmes in Malaysia are a bargain;

iii) Value for money: Not only are costs relatively low, but the quality of Malaysian higher education is seen to be good, yielding a growing perception that higher education in Malaysia represents value for money;

iv) Language of instruction: Most instruction is offered in English, which is viewed as offering better access to international employment opportunities; and

v) Quality of life: Malaysia offers a good quality of life; it is widely regarded as a comfortable place to live and study.

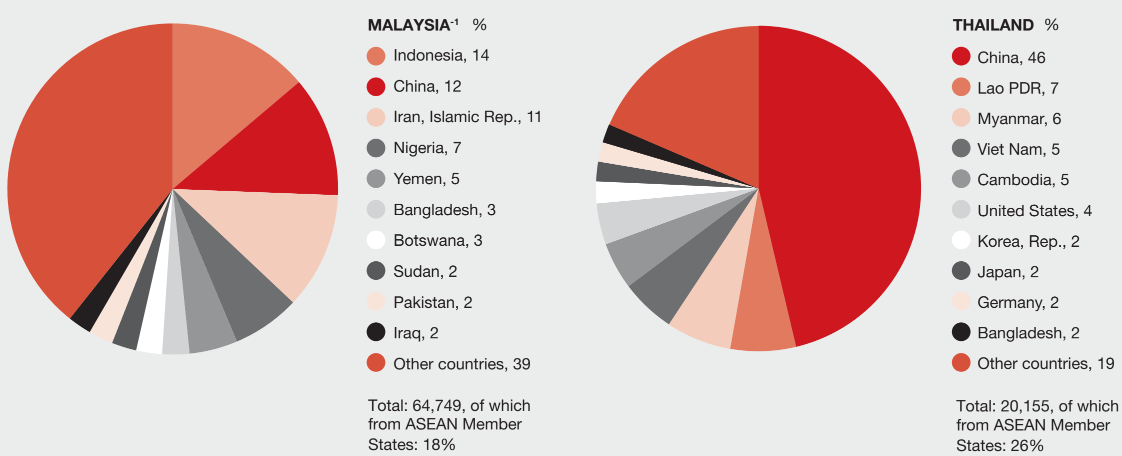
Figure 19 displays the major sources of international students in Malaysia. About one-fifth of its international students come from the ASEAN community. Additionally, Malaysia hosts a disproportionally-large share of students from Muslim cultural backgrounds.

In Thailand, there is some ambivalence about recruiting international students. On the one hand, some interviewees indicated that Thailand aspires to become an educational hub for the ASEAN community. Currently, about one-fifth of its international students originate from ASEAN countries *(see Figure 19).* On the other hand, at Chulalongkorn University and Mahidol University, international student enrolment is only around 5% or less of the student body. Several reasons are offered for the lower international recruitment: most undergraduate classes are taught in Thai and few international students have the language ability to take those courses; many Thai faculty members are not particularly comfortable working in English and reluctant to develop and offer English language courses; and the campuses, more generally, are not set up to host international students. As one interviewee observed, there is only one Halal restaurant on the Mahidol Salaya campus and a Muslim student would find it difficult to have so few dining options.

2.3.7 Commercialisation of research: Fact or wishful thinking?

In both countries, government personnel are generally quite enthusiastic about the idea of universities commercialising their research as a means of generating more of their own income both now and in the future. Commercialisation at these universities has taken two main directions. Much of the attention is on the generation of income

Figure 19. Main sources of international students in Malaysia and Thailand, 2011



Note: -1 Data refer to 2010.
Source: UNESCO Institute for Statistics, October 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f19

from licensing of patents or direct development of inventions. To this end, all universities seek to commercialise those technologies and inventions that have market value, and all the universities have offices specifically charged with assisting faculty to move their inventions and ideas into commercial use. Nearly all the universities could offer examples of technologies they had successfully commercialised. But in all cases, they reported that the financial gain from commercialisation was modest. The other approach to commercialisation was selling the consulting services of faculty members.

The Malaysian Ministry of Education puts a lot of emphasis on commercialisation of research as a source of operating income. There are discussions underway in Malaysia about the extent to which commercialisation should be an explicit expectation within faculty KPIs.

Even if that idea is not adopted (and there are good reasons to think it will not be), the MoHE sees commercialisation as a means by which the universities will be able to generate more of their own income as government funds are reduced, a process that is already underway. Private sector employers sometimes utilise university faculty on a consultancy basis, but there are only a few examples of companies seeking large-scale contracts with universities. In neither country did university faculty nor administrators see research or consulting contracts with private sector enterprises to be meaningful sources of operating funds.

Department heads and faculty members point to a second route of commercialisation which many of them find more promising: selling faculty expertise through consulting services. Several departments have set up small consulting businesses in which they sell the consultant services of their faculty members. Typically, a portion (often 75%) is retained by the faculty member, with the balance going to the department or university.

In Thailand, there is also considerable interest among universities in commercialisation of research. Most interviewees thought that commercialisation was a way that universities could give back to society through the application of technical knowledge. At the same time, they are very cautious about any effort to build commercialisation into expectations related to faculty promotion. There is concern among faculty that government officials hold unrealistic expectations of the return on investment through commercialisation. One professor recounted the commercialisation of research within his department: Faculty filed for 40 patents, 12 were accepted and only 1 was commercialised and it did not generate much revenue. Chula administrators observed that the university earns about US$10 million a year from licenses and royalties, but that represents the yield of 25 years of research and technology and is a minor income source, given the overall budget of the university.

2.3.8 Linkages with the private sector

While a central purpose of government in supporting graduate education is to create an attractive environment for international investment, university personnel in both countries indicated that there is relatively little direct linkage between the private sector and universities. In both countries, interviewees suggested that private sector employers are reluctant to hire PhD graduates viewing them as too expensive and most business and industry do not need that level of expertise in management positions. Few local enterprises engage in research at a level that would require a substantial cadre of PhD-level employees. Companies that do engage in a high level of research tend to be multi-national corporations that draw their research teams internationally. Most doctorate holders go into academic positions, and some more into government positions.

2.3.9 Employment of graduates

In Malaysia, employment of graduates of Master's and PhD programmes has not been a problem to this point, with around 93% of doctoral graduates and another 79% of Master's graduates finding employment within six months of graduation (MoHE

Malaysia, 2013). For example, interviewees at the University of Malaya report 97% employability of their graduates within six months of graduation, though this is not true at all universities. In 2012, over one-half of doctoral graduates (52%) and some Master's graduates (14%) in Malaysia were employed as instructors in colleges and universities *(see **Table 11**).* A PhD does not necessarily help in getting jobs in industry. Most PhD graduates who are local find employment in academia. The foreign-trained PhD graduates tend to already have jobs in their home countries and are on leave from their employer to do their graduate study. Those who are not are still able to quickly find employment back in their own countries. Thailand is similar to Malaysia in that a high proportion of doctoral graduates work in the academia. An earlier survey found that 70% of Thai doctoral students already had jobs in the public sector, which included 40% in public higher education institutions and 30% in other divisions in the public sector (Chittmittrapap and Luksaneeyanawin, 2007).

2.3.10 Industrial PhDs

One effort to strengthen the relationship of universities with private sector businesses and industry in Malaysia is the advent of the industrial PhD. These programmes are designed around specific employer needs and much of the course work can be done on the employment site. These degree programmes tend to require less time to complete: an industrial PhD can be completed in three to five years, less time than a typical campus-based PhD. Students' dissertations are focused on solving a problem being faced by the particular industry in which they are working. These programmes are seen as a way of increasing the relevance of graduate education to the needs of business and industry. While these programmes can be undertaken with any business or industry, they are viewed as being particularly appropriate for engineering.

As an incentive to get these programmes started, the Malaysian MoHE pays the tuition. To date, one such programme is underway at the University of Malaya and other universities as well.

Table 11. Distribution of graduates' employment by occupation in 2012

Major group of occupation	Doctorate	Master's
Higher education instructors	52	14
Professionals, other than higher education instructors	43	66
Managers	4	12
Other	1	8

Source: Ministry of High Education Malaysia, 2013

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t11

2.3.11 Sources of faculty for graduate programmes

Research universities are staffed primarily by Malaysian scholars who have done their graduate coursework abroad, typically in a Western university. With the expansion of PhD programmes in Malaysia, there is an increase in scholars educated in the country, but this is still a relatively new phenomenon. Debate continues about the relative advantage of faculty members from these different backgrounds. Some believe that faculty trained abroad brings a worldview, work ethic and abilities in critical thinking and research that are necessary to build an academically-vibrant environment. They see a risk of narrowing creative thinking in hiring too many Malaysian-trained PhDs. Others observe that foreign study is expensive and, with the rise of local PhD programmes, hiring faculty with foreign training is less necessary than in the past. As money gets tight, there will be greater pressure on hiring locally-trained personnel. To counter this concern, some universities (i.e. the University of Malaya) tend not to hire their own graduates. Nonetheless, universities differ on this point.

2.3.12 Cost and financing of graduate education

The costs of graduate study are generally minimal for Malaysian students at both the Master's and PhD levels. Graduate study is highly subsidised by government, except for MBA programmes. Similarly, in Thailand graduate students are also heavily subsidised. As one senior Thai university administrator pointed out, graduate students can be viewed as a bargain. They are expected to teach undergraduates and to conduct research, and do so at a lower cost than regular faculty. He did not see cost as a factor constraining the expansion of graduate education, at least not at present.

Malaysian government expenditure on higher education is twice the level of Thailand *(see Figure 4).* However, Thai universities have a broader resource base and more administrative autonomy than their counterparts in Malaysia. They receive only limited financial support from the Thai government, and the universities in this study generate a considerable amount of their own funding through auxiliary enterprises. For example, Mahidol University in Thailand operates seven hospitals. Chulalongkorn University owns considerable real estate in downtown Bangkok which it rents. Both universities bid on and receive contracts from government agencies, and both sell research and consulting services to private sector enterprises.

2.4 CONCLUSIONS

In both Malaysia and Thailand, the initial rationale for expanding graduate education was to provide qualified instructional staff to serve expanding undergraduate enrolment. In both countries, this rationale was eclipsed, to a large extent, by the view that graduate education would help fuel national economic development. This shift carried a number of consequences for the management of higher education institutions and for the daily work life of faculty members. In both countries, top research universities receive generous financial support from government. In both countries, top universities have been shifting the composition of their student body to increase the proportion of graduate students relative to undergraduates. In both countries, universities have utilised a KPI system as a means of clarifying productivity expectations of academic departments and of individual faculty members. In both countries, interviewees reported that the pressure on faculty to do more research has been, and continues to be, intense. The focus on economic development triggered an intensified emphasis on universities placing high in international rankings which, in turn, led to pressure for more research. This pressure led some faculty members to focus more of their time and energy on research, sometimes at the expense of their teaching. In short, 'expanding up' has changed organizational dynamics and the nature of faculty work in important ways.

The importance assigned to university rankings illustrated by this study highlights the need for a more careful examination of how rankings are calculated and the extent to which they are sensitive to excellence within specific programme areas within the university. At the same time, the presumed link between university-based research and national economic development illustrated by this study highlights the need for a careful look at the evidence about this relationship. These issues are addressed in subsequent chapters of this report.

Chapter 3

THE CASE FOR GRADUATE EDUCATION: DOES UNIVERSITY-BASED RESEARCH REALLY LEAD TO NATIONAL ECONOMIC DEVELOPMENT?

Martin Schaaper

This chapter examines the role of research in national economic development, with a specific focus on university-based research in low- and middle-income countries. This discussion is complemented by an in-depth look at the available data on research and experimental development (R&D) for Asian countries.

3.1 THE CONTRIBUTION OF RESEARCH TO NATIONAL DEVELOPMENT

Technology and technological advances are key components of innovation and economic growth in high-income economies. Technology has been the real force behind rising standards of living, a role that has grown over the last century given the global trend toward knowledge-based economies. The most dynamic economic sectors in the global marketplace are those that are technology-intensive, and they depend on the capacity to generate, adapt and utilise knowledge as the foundation of productivity growth. This is equally true for the services sector as it is for manufacturing (Trajtenberg, 1990; Romer, 1990; Lichtenberg, 1992; Grossman and Helpman, 1994; Navarro et al., 2010).

Since the Second World War, investment in R&D has been regarded as one of the key strategies to secure technological potential and, therefore, innovation and economic growth. The evidence is plentiful, in particular for high-income countries. Many cross-country studies demonstrate a virtuous circle in which R&D spending, innovation, productivity and per capita income mutually reinforce each other and lead countries to long-term sustained growth rates. For example, growth-accounting studies have estimated that technology accounts for more than one-half of economic growth (i.e. gross domestic product, GDP) in all member countries of the Organisation for Economic Co-operation and Development (OECD) except Canada. Other studies found the rate of return from R&D to be about four times that from physical capital (Jones and Williams, 1998, 2000; Hall and Jones, 1999; Rouvinen, 2002; Crespi and Zuniga, 2012; Boskin and Lau, 2000).

In another example, the U.S. Bureau of Economic Analysis' first satellite R&D account estimated the contribution of R&D to economic growth to be 6.5% over the 1995-2002 period, up from the longer-term 40-year average of 4.5% (by comparison, the 40-year average contribution of buildings and factories is only 2%). Of note is that this estimate is only for the impact of R&D investment on the industry in which the R&D is conducted. Analyses of industry-level impacts of R&D indicated that about one-half of output growth and three-quarters of productivity growth are attributable to R&D investment (Tassey, 2009; Okubo et al., 2006; Griliches, 1995).

A central characteristic of R&D is that its payoffs are not limited to the original investors, which are the private benefits of research, but also accrue to competitors, other firms, suppliers and customers with the so-called spillover effects. As knowledge gradually leaks out, private benefits decline and spillover effects increase. Consequently, private and spillover returns follow different timelines. Private effects generally taper off after a while. There is a time lag before spillover effects take effect, but

Box 7. Measuring the impact of research

Measuring the impact of research is difficult for many reasons. One problem is that not all impacts are direct and some can be negative or result from the identification of problems that require a non-research response. A second problem is that the time between the performance of research and when its benefits become apparent can be significant, unpredictable and vary for different kinds of research. Thirdly, research does not exist in isolation but draws on the work of other researchers or on complementary progress in other areas of research or technology. Fourthly, the impact that research has will often depend on the imagination, creativity and identified needs or problems of people outside the research system. Furthermore, converting research outputs to innovations requires significant investment and the bringing together of many complementary skills. This means that the cost of research is often a very small proportion of the cost of the investment necessary to produce the impact. Much R&D is directed toward social goals, the output of which is difficult to measure (national defence, environmental quality, energy independence, space exploration, health care). Furthermore, measurement of the output in R&D-based industries (based on inaccurate price indexes) does not allow for quality improvements due to R&D (Griliches, 1995).

While the focus of impact measurement tends to be on the beneficial effects of research, it is not unknown for research to create unintended or unwanted impacts that need to be balanced against any obvious benefits. Moreover, in many cases the benefits that flow from research can take the form of preventing harm or reducing damage, rather than of making things better.

In conclusion, while it is obvious that investment in research has impact and that many of these impacts make life better, it is much more difficult to demonstrate the contribution made by individual research projects or to quantify the contribution that research has made, especially given all the other inputs necessary to achieve successful innovation.

Source: The Group of Eight (2011)

these social returns are considerably more long-lived than private effects. A large number of studies estimate the social return from R&D exceeding the private return by 50% to 100% (Griliches, 1995; Sveikauskas, 2007; Mohnen 1996; Griffith et al., 2006; Griffith et al., 2004; Mairesse and Mohnen, 2010; Mairesse et al., 2005; OECD, 2009; Crespi and Zuniga, 2012).

3.1.1 The role of universities

Universities are a crucial factor for knowledge production and dissemination in high-income economies, speeding up the processes of innovation and technical progress. They play a central role, not only as producers of basic research, but also by creating human capital in the form of higher-skilled labour (Lundvall, 1992; Etzkowitz and Leydesdorff, 2000; Gibbons et al., 1994; Schiller and Liefner, 2007; Anselin et al., 1997).

It is important to remember that significant advances in knowledge are usually the result of basic research, not applied research; the social gains expected from basic research are obvious. However, many elements of university and government research have very low returns and overwhelmingly contribute to economic growth only indirectly, although these indirect effects can be important and often take the form of knowledge spillovers to the private sector. Essentially, as recognised since the work of Adam Smith, basic research efforts are likely to generate substantial external economies. Private-profit opportunities alone are not likely to draw as large a quantity of resources into basic research as is socially desirable. Of course, some government and university research has been highly successful. All the most important technologies that have driven growth trace their funding back to government, such as aviation technologies, space technologies, semiconductors, the Internet, nuclear power and nanotechnology. However, these government successes have been influential mainly through their impact outside the public sector (Nelson, 1959; Anselin et al., 1997; Sveikauskas, 2007; Mazzucato, 2013).

Although it is hard to quantify how the results of university research spill over to industry, the contribution is likely to be considerable. In a study of selected firms in information processing, electrical equipment, chemicals, instruments, drugs, metals and oil industries, Mansfield (1991) found that about one-tenth of the new products and processes commercialised from 1975 to 1985 could not have been developed (without substantial delay) if not for recent academic research undertaken within the last 15 years. The average time lag between the conclusion of the relevant academic research and the first commercial introduction of the innovations based on this research was about 7 years (and tended to be longer for large firms than for small ones). Griliches (1995) found that the rate of return on basic science is about three times that of applied R&D which, in turn, is about double the rate of return on physical capital.

More recent studies have found that public research led to considerable gains in economic productivity in OECD countries. The resulting benefit significantly outweighed the costs of the research. The gains in productivity were even greater in countries where research was concentrated in universities as opposed to government laboratories. This may reflect the focus of research in these laboratories which address public missions that do not impact directly on productivity (defence, health and environment), whereas universities provide industry with the basic knowledge required for technological innovation (Guellec and Van Pottelsberghe de la Potterie, 2001). In a spectacular example, it is estimated that between 1988 and 2010, U.S. federal investment in genomic research generated an economic impact of $796 billion, while spending on the Human Genome Project between 1990 and 2003 amounted to $3.8 billion only. This figure equates to a return on investment of 141:1. The widespread benefits continue to grow over time (Tripp and Grueber, 2011).

While there is a growing tendency to focus on the impact of university research, we should not forget that the rationale for academic research extends far beyond narrowly-defined economic benefits. Knowledge concerning the universe is important for its own sake, and the education of students involved in academic research projects is socially important as well (Mansfield, 1991).

3.1.2 Research in low- and middle-income countries

While in high-income countries the contribution from R&D to national development is well established, the evidence from low- and middle-income countries is less clear. In order for low- and middle-income countries to reach per capita income levels similar to those of the richest economies, they need to expand their access and capacity to use technology. This process of 'catching up' generally occurs through imitation and technology acquisition rather than independent R&D and innovation. However, technology transfer poses substantial problems of adaptation and absorption that are related to investments in technological capability. A successful transfer requires a complex array of skills, knowledge and organisational structures to operate a technology efficiently and accomplish any process of technological change. This dynamic effort implies a process of learning. Each firm has to exert considerable absorptive efforts to learn the tacit elements of technology and gain adequate mastery (Bell and Pavitt, 1993; Katz, 1986; Crespi and Zuniga, 2012; Archibugi and Pietrobelli, 2003).

Another factor explaining the mixed results of R&D in low- and middle-income countries is linked to their distance from the technology frontier. In general, the firms closest to the cutting edge of technological development tend to reap the greatest benefits from R&D. Their proximity to competitors serves as a constant stimulus for innovation rather than imitation as a source of productivity growth. As firms in low- and middle-income countries move closer to the technological frontier, they will invest more in R&D. In contrast, firms that remain at the periphery tend to assess their prospects and judge that the return to investment in R&D is insufficient. In short, these firms lack the incentives to invest in innovation. As a result, in many low- and middle-income countries, innovations by firms consist basically of incremental changes with little or no impact on international markets and are mostly based on imitation and technology transfer, e.g. acquisition of machinery and equipment and disembodied technology purchasing. Their innovations are predominantly focused on new production lines for exports (Acemoglu et al., 2006; Anlló and Suárez, 2009; Navarro et al., 2010; Goedhuys et al., 2008).

In addition, R&D is hampered in many low- and middle-income countries by underdevelopment of financial markets or inappropriate government policies. R&D activities are costly and require a critical mass before being able to generate technological progress and yield economic results. The issue is especially sensitive for low- and middle-income countries, which traditionally have lacked clear-cut scientific and technological strategies, in addition to firms which are capable of generating technological linkages with other locations. Also, technology transfer often occurs when multinational companies operating in low-income and emerging countries import machinery. If these companies invest in R&D, they are more likely to do so in the home country of the mother company (Griffith et al., 2004; Sveikauskas, 2007; Cantwell and Iammarino, 2003; Bilbao-Osorio and Rodríguez-Pose, 2004; Acemoglu et al., 2006). Countries such as Malaysia and Thailand may be caught in a middle-income trap. The Republic of Korea managed to break through this trap, moving to the technology frontier and making the transition to a research-intensive country.

One of the consequences is that in the absence of a sufficient level of R&D, the absorptive capacity needed to take full advantage of technology transfer is often lacking, as well as the capacity to design new pathways to production and new markets. For example, Malaysia, supported by the benefit of oil and gas revenues, created an investor-friendly, low-wage climate allowing it to become the most intensive exporter of high-tech goods in the world without much domestic R&D and with weak higher education institutes. The results of innovation surveys in Latin America reveal a combination of low R&D effort and high investment in technology embedded in machinery. This is not the case for some of the Asian countries in this study, which coupled high shares of firms acquiring machinery, equipment and software with high shares of firms engaged in intramural R&D.[4] Even though acquiring technology by buying equipment and sophisticated machines can be an important step in catching up and advancing toward the technological frontier, the impact of embedded technology at the firm level can be very limited if internal capabilities in R&D are absent or if the means of production are owned by multinational companies, rather than being financed by domestic capital. Such an absence, notably the weakness of the human capital dedicated to innovation, can lead to a technological gain to the economy as a whole that is not sustainable, even after intensive periods of modernisation of the manufacturing base in a given country (Hanson, 2007; Navarro et al., 2010).

As a result, the evidence with regard to the ability of firms in low- and middle-income economies to transform R&D into innovation is much more mixed than in the case of firms in industrialised countries. Satisfactory results showing a positive association between R&D, innovation and productivity have been found for newly-industrialised economies, such as the Republic of Korea (Lee and Kang, 2007), Malaysia (Hegde and Shapira, 2007), Taiwan of China (Yan Aw et al., 2011), and China (Jefferson et al., 2006), which began investing in R&D and human capital a few decades ago. There is evidence that higher levels of investment in innovation (notably in R&D) lead to a higher propensity to introduce technological innovation in firms from Argentina (Arza and Lopez, 2010; Chudnovsky et al., 2006), Brazil (Correa et al., 2005; Raffo et al., 2008), and Bulgaria (Stoevsky, 2005). On the other hand, results from Chile (Alvarez et al., 2010; Benavente, 2006) and Mexico (Perez et al., 2005) do not support this finding (Crespi and Zuniga, 2012). Focusing on a panel of 27 transition and 20 Western European countries between 1990 and 2006, Krammer (2008) found that domestic efforts and investment in R&D had a

4 China, Hong Kong Special Administrative Region of China, India, Indonesia, Japan, Malaysia and Thailand.

deeper effect for the Western European countries than the Eastern ones, since the latter had inherited at the beginning of the 1990s an outdated R&D stock, specialised in mature, heavy industries with little potential for innovation and productivity growth.

To take full advantage of R&D being carried out in a country, framework conditions are important. The most important condition is that a large stock of human capital helps countries accelerate technological catch-up. The connection between human capital and innovation in low- and middle-income countries, and its corresponding impact on productivity, stems mainly from the contribution of skilled workers dedicated to adapting existing technologies: that is, from their contribution to moving closer to the technological frontier rather than expanding it. Statistics regarding the availability of human capital for innovation in Latin America, for example, confirm the report by firms of an overall deficit of qualified technical and professional personnel with relevant skills for innovation activities (Nelson and Phelps, 1966; Navarro et al., 2010; López Boo, 2009).

The results of a study on R&D in peripheral regions and non-peripheral regions of the European Union (EU) show a strong relationship between the initial level of wealth, the level of skills available in a region, the relative importance of high-technological sectors, and their capacity to produce a large number of patent applications. A possible explanation for this fact is that these regions are well endowed with an appropriate learning capacity, which allows them to better transform their R&D investment into innovative outcomes and to absorb and use foreign technology (Bilbao-Osorio and Rodríguez-Pose, 2004; Verspagen, 1997).

The negative effect of having a large poorly-educated population is a key factor which explains poor innovative performance. There are positive externalities from higher educational attainment in the form of both a higher rate of innovation and more rapid technology transfer. R&D is unprofitable for low levels of human capital and becomes profitable only when human capital reaches a threshold level. The presence of skilled labour is a more decisive mechanism for the transmission of tacit knowledge than either university research or industry research. Improving human capital by formal education and continuous R&D activities increases the absorptive capacity of firms, thereby facilitating technology adoption and mastery. It offers possibilities to generate improvements and follow-up innovations. The level of development of financial markets, supportive innovation policies, regulatory and administrative burdens, but also more subtle habits and practices and trust among the local business community, are factors that affect the learning process as well. Furthermore, there is evidence that countries where the ease of doing business and the quality of tertiary education systems are relatively high tend to benefit more from their own R&D efforts, as well as from international R&D spillovers and human capital formation. Strong patent protection is also associated with higher levels of total factor productivity[5], higher returns to domestic R&D, and larger international R&D spillovers. There is even evidence that countries whose legal systems are based on French, and to a lesser extent Scandinavian law, benefit less from their own and foreign R&D capital than countries whose legal origins are based on English or German law (Bilbao-Osorio and Rodríguez-Pose, 2004; Mytelka, 2000; Goedhuys et al., 2008; Griffith et al., 2004; Sorensen, 1999; Audretsch and Feldman, 1996; Coe et al., 2008).

3.1.3 The role of universities in low- and middle-income countries

The most important role of universities in the learning systems of low- and middle-income countries is not to generate new knowledge but to raise the skills of the population, i.e. to build up human capital, and to help absorb ideas from developed countries (Mathews, 2001; Viotti, 2002; Schiller and Liefner, 2007).

5 Total factor productivity (TFP), also called multi-factor productivity, is a variable which accounts for effects in total output not caused by traditionally-measured inputs of labour and capital. If all inputs are accounted for, then total factor productivity (TFP) can be taken as a measure of an economy's long-term technological change or technological dynamism.

Universities in low- and middle-income countries find themselves in a different position from their peer institutions in industrialised countries. They tend to be under-funded and unable to purchase and apply the latest research equipment. Their faculty and staff tend to be less qualified on average. In Thailand, for example, Thamrongthanyawong (2005) estimated that the number of Thai PhD graduates is insufficient to replace the professors who are retiring over the next five years. Furthermore, salaries at Thai universities are so low that professors prefer to teach more hours rather than carry out research in order to earn extra income (Weesakul et al., 2004). As a result, universities in low- and middle-income countries are usually far below the academic standards set by universities in industrialised countries. Consequently, they put more emphasis on undergraduate teaching, which is a very important function in many low- and middle-income countries that strive to improve the skills of their populations. Graduate education and research do not belong to the core activities of many universities in low- and middle-income countries. Thus, universities themselves have to continuously improve their teaching and research capabilities in order to be able to meet the future needs of their societies (World Bank, 2000; Altbach, 1998; Schiller and Liefner, 2007).

While traditionally universities would carry out basic research, some universities in Asia are strongly encouraging faculty to engage in research that can be commercialised as a means of generating income for the institution itself. Case studies in Malaysia and Thailand revealed that university officials clearly challenged the efficacy of that notion. While all major universities have an office aimed at helping faculty commercialise their research, very little of it can actually be commercialised, and that which is commercialised generally does not yield large financial payoffs.

During the same interviews in Malaysia and Thailand, these officials also argued that having universities that placed in the top tier of university rankings would send a message to the world that the country had a strong education system. This, in turn, would attract international investment into the country. Whether this will really happen, remains to be seen. In fact, the way to raise a university's standing in international rankings is to generate a lot of research, playing into the formula used by international university ranking systems. Hence, the value of university-based research is symbolic. The payoff is not so much in the particular research finding, but in how the generation of ample research could shape international rankings (although the rankings depend on more than papers alone).

The development of the research system in the Republic of Korea

The case of the Republic of Korea is very interesting and has been the subject of considerable study. **Table 12** provides some indicators about the remarkable growth of this country. Over a period of 45 years, GDP per capita increased 12 times over (expressed in constant 2005 PPP$). Total R&D expenditure has risen dramatically from 166 million in 1965 (in constant 2005 PPP$) to PPP$55 billion in 2011. This equated to an increase from 0.26% of GDP in 1965 to 4.04% in 2011, one of the highest in the world. While the government was the dominant source of R&D expenditure before 1980, since then the private sector took over as the main performer, registering 76.5% of total R&D expenditure and 66.8% of the total number of researchers in 2011.

What are the reasons for this impressive expansion of Korean research? The development of their R&D system can be divided into three phases. In the 1960s, the Republic of Korea was one of the poorest countries following the Korean War. Given these conditions, the country embarked on the promotion of both export- and import-substitution industries such as textiles, garments, furniture and assembly of electronic goods, like radios and television sets. As those labour-intensive industries expanded, decisionmakers decided to establish selected heavy industries and chemical industries to provide materials and components for these enterprises. The Korea Institute of Science and Technology (KIST)

Table 12. GDP per capita and selected R&D indicators for the Republic of Korea, 1965-2011

	1965	1970	1975	1980	1985	1990	1995	2000	2005	2011
GDP per capita (in constant 2005 PPP$)	2,230	3,291	4,284	5,544	7,547	11,383	15,761	18,730	22,783	27,554
R&D expenditure (in millions of constant 2005 PPP$)	166	399	621	1,540	4,532	8,756	16,823	20,213	30,618	55,402
R&D expenditure as a % of GDP	0.26	0.38	0.41	0.73	1.47	1.79	2.37	2.30	2.79	4.04
Total researchers (in headcounts)	2,135	5,628	10,275	18,434	41,473	70,503	128,315	159,973	234,702	375,176
Researchers (in headcounts) per 1 million population	75	176	291	484	1,016	1,645	2,846	3,403	4,876	7,537
Share of researchers in the business sector	5.2	20.6	25.8	27.9	45.8	54.9	53.5	59.0	65.7	66.8

Sources: Ministry of Science and Technology as cited in Kim (2000), UNESCO Institute for Statistics database, November 2013, and World Bank, World Development Indicators database, November 2013.
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t12

was established in 1966 for technology assimilation and development of industrialisation. In the 1970s, the country expanded into strategic industries, such as shipbuilding, machinery, industrial chemicals, electronics and automobiles. Specialised government research institutes (GRIs) were created as technology windows for diversified technological needs. The industrialisation in the early phase was a process of learning how to absorb and improve upon imported foreign technologies for industrial development. Technological learning, as opposed to indigenous technology development, was at the core of the development strategy in the early stage (Chung, 2010; Lee, 2011; Pillay, 2010).

In the second phase, during the 1980s and 1990s, the socio-economic R&D demands focused on critical and essential technologies to overcome protectionism and secure competitive advantages in the international market. In the 1980s, efforts were undertaken to ensure a market-conducive environment by deregulating various sectors and liberalising trade. R&D in the private sector started picking up in response to these demands. More company research institutes began to emerge to create technology-intensive industries, and in-house R&D emphasised technology indigenisation for the creation of new information technology industries. It was during this phase that higher education was expanded and the government launched national R&D projects and the Industrial Technology Development Programme. Large companies internalised imported technologies, and the joint efforts of GRIs and universities were able to provide complex technologies needed for industry. This way, the 1990s saw an increase in the country's industrial value chain (Ibid).

In the third phase, after the financial crisis of the late 1990s, emphasis was placed on fundamental technologies to lead the global technology market for continuous growth in the knowledge economy and public technologies (such as technologies for environmental protection) in order to meet various social demands. Government R&D programmes adjusted the focus towards frontier programmes for the 21st century and next-generation growth engine technologies. The role of universities in basic research became more important and industry-academic linkages were encouraged. The private sector realised the necessity to develop technologies needed for future knowledge-intensive industries and directed the work of their research institutes towards this. It also began working with GRIs and universities in strategic partnerships to develop a domestic technology base (Ibid).

Various factors are behind the rapid growth of R&D and innovation. Investment in education has played a significant role. To achieve sustained productivity growth by consistently increasing the value-added of output, a highly-educated labour force was necessary. Education gives rise to a person's initial tacit knowledge, which is an essential building block in technological learning. A continued expansion of R&D capabilities in industry drew on the skilled labour force that had resulted from the government's expansion of the higher education system. A second important factor has been the outward-looking, export-driven development strategy of the government, which drove domestic industries out to the international market, putting them under fierce competition. In order to survive the competition, they have had to keep up with technological changes by investing heavily in R&D. Thirdly, the government's industrial policy that favoured large firms gave birth to a unique business organization in Korea, *"chaebol"*, which are typically global multinationals owning numerous international enterprises. *Chaebols* enjoy greater financial affluence owing to the economies of both scale and scope of their business operations. They have deeper pockets and are able to engage in risky and expensive R&D projects that are even unthinkable for small- and medium-sized firms (Ibid).

In summary, two major lessons can be drawn from the Korean experience. First, human resources are the key to science and technology development and thus to economic growth. Second, nothing can better motivate private businesses to invest in technology development than market competition. There are still challenges though. The country still lags far behind advanced industrial countries in terms of the cumulative R&D stock which is the real determinant of a nation's knowledge power. The challenge therefore is how to overcome the disadvantage of being a late starter. Second, the weakness in basic sciences poses a fundamental problem. Korean R&D efforts have been devoted overly to industrial technology development, while scientific research has been more or less neglected, resulting in weak university research capability. For the Republic of Korea to sustain the past development into the future, it has to further strengthen basic scientific research capability at universities and improve framework conditions for innovation, the core of which is the competitive market (Ibid).

3.2 WHAT DO THE DATA TELL US?

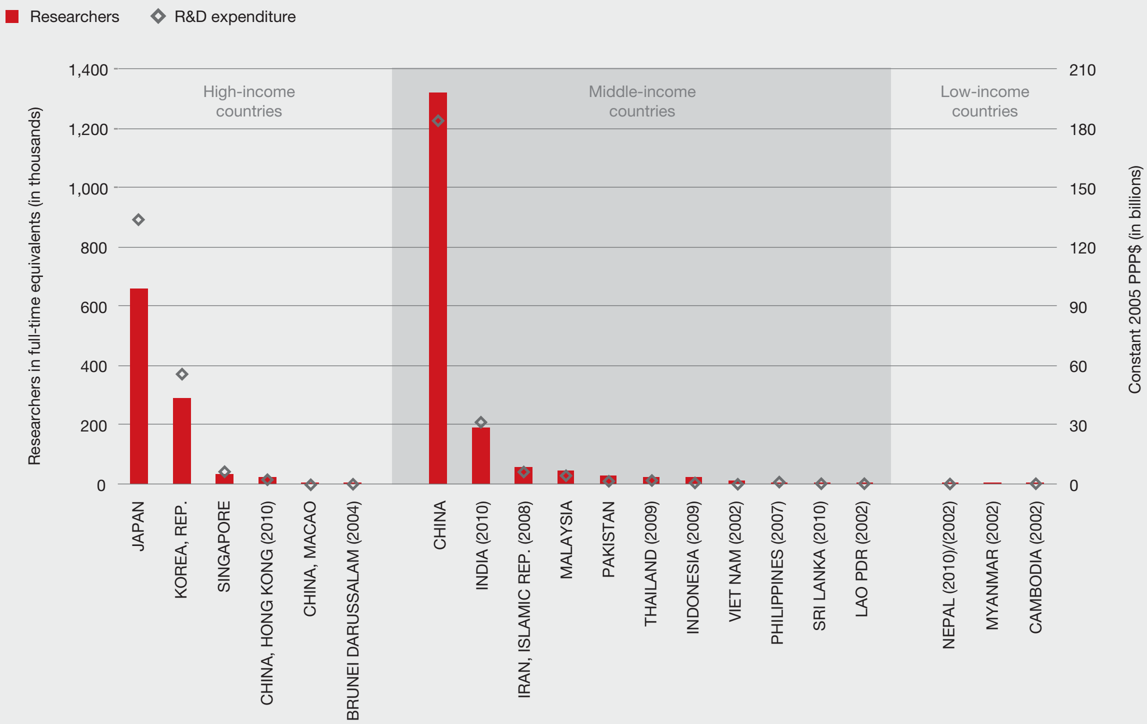
The second part of this chapter explores country-level data on R&D personnel and expenditure to assess the state of play of the countries covered by this study. These data are collected by countries and compiled by the UIS through its biennial survey *(see **Box 8**).* The methodology applied by countries follows the conventions of the OECD Frascati Manual, which lays down the guidelines for the measurement of R&D. The Frascati Manual defines

Box 8. Collecting R&D data from countries: Coverage and quality

Of the 26 countries or territories that are covered in this study, R&D personnel and expenditure data are available for 19 countries. Overall, the data gathered from high-income countries are complete. The data gathered from middle-income countries generally are more complete than from low-income countries. There are no data at all for Afghanistan, Bangladesh, Bhutan, the Democratic People's Republic of Korea, Maldives and Timor-Leste.

Furthermore, although in theory all countries collect data according to Frascati Manual guidelines, in reality there are a number of issues which make the data less comparable than they should be. For example, not all sectors are covered in all countries. In particular, the business sector is often not covered in less-developed countries. For R&D expenditure, sometimes data are based on budgets rather than on actual expenditure by performers. In some cases, estimates are obtained by compiling information on grants for research projects, an approach that tends to underestimate the actual expenditure as staff costs are often not included.

Figure 20. Total R&D efforts by country or territory, 2011 or most recent year available



Notes: Partial data for Macao Special Administrative Region of China, Indonesia, Brunei Darussalam, Cambodia, Lao People's Democratic Republic, Myanmar and Pakistan. Macao Special Administrative Region of China: Excludes business and goverment sector. Pakistan: Excludes business sector. Nepal: R&D expenditure based on budget data. No data for Afghanistan, Bangladesh, Bhutan, the Democratic People's Republic of Korea, Maldives and Timor-Leste.

Source: UNESCO Institute for Statistics, July 2013 and OECD, Main Science and Technology Indicators database, September 2013

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/f20

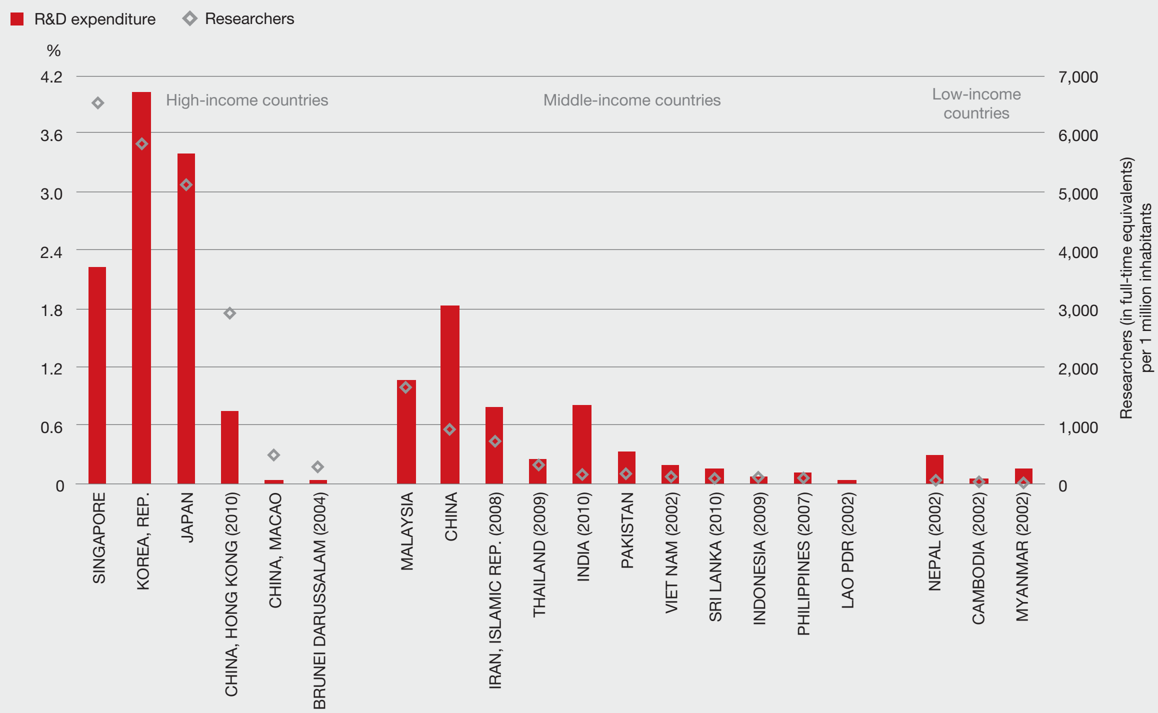
R&D as “creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications” (OECD, 2002, §63).

Figure 20 shows the absolute R&D efforts of the countries in this study. On the left-hand axis, the number of researchers expressed in full-time equivalents is shown, while the right-hand axis shows R&D expenditure, expressed in billions of constant 2005 purchasing power parity (PPP) dollars. The main purpose of this figure is not to clearly identify differences between the countries, but to highlight the sheer absolute volume of research carried out in China, Japan and the Republic of Korea. Together, these three countries accounted for 90% of all R&D expenditure and 87% of all researchers in 2011 in the Asian countries covered by this report.

However, the size of a country’s population and economy is of course an important determinant in its absolute R&D efforts. It makes little sense to compare the absolute number of researchers in China with the number of researchers in, say, Cambodia. Therefore, **Figure 21** shows the same data, but normalised for the size of the economy and population.

The data paint a different picture. When we look at the flagship R&D indicator, R&D expenditure as a percentage of GDP (often referred to as ‘R&D intensity’), the countries that stand out are the Republic of Korea (4.0%) and Japan (3.4%), followed by Singapore (2.2%) and China (1.8%). The Republic of Korea and Japan are third and fifth globally. Behind the four abovementioned countries, Malaysia is the only country to have reached the often-used benchmark of 1%. India and Hong Kong Special

Figure 21. R&D expenditure as a percentage of GDP and researchers per 1 million inhabitants, 2011 or most recent year available



Notes: Partial data for Macao Special Administrative Region of China, Indonesia, Brunei, Cambodia, Lao People's Democratic Republic, Myanmar and Pakistan. Macao Special Administrative Region of China: Excluding business and government sector; Pakistan excluding business sector Nepal: R&D expenditure based on budget data No data for Afghanistan, Bangladesh, Bhutan, Democratic People's Republic of Korea, Maldives and Timor-Leste

Source: UNESCO Institute for Statistics, July 2013 and OECD, Main Science and Technology Indicators database, September 2013

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/f21

Administrative Region of China are clustered together around the 0.75% mark, while the other countries are far behind. Of note is that in terms of researcher density (the number of researchers per population of 1 million), Singapore has the highest number of researchers per population of 1 million in the region, placing it fourth globally.

There is a clear relation between the level of development of a country and the amount of resources devoted to R&D. Correlation is not causation, but nevertheless, many countries seem to think that by increasing R&D expenditure, development will follow automatically. At least, that is a conclusion that could be drawn from targets many countries set for the level of R&D they should carry out. Low- and middle-income countries often use 1% as a yardstick for their R&D intensity, such as Malaysia (by 2015) and Thailand (by 2016), while some countries set more ambitious targets, such as India (2% by 2007), the Philippines (2% by 2020), China (2.5% by 2020), Singapore (3% by 2010) and the Republic of Korea (5% by 2012) (OECD, 2013; UNESCO, 2010; A*STAR, 2011; Linton, 2008).

Table 13 shows the development of R&D intensity over the last 10 years, which serves as a basis for assessing whether countries are on track to reach their targets.

Significant growth can be observed in Hong Kong Special Administrative Region of China, Japan (although it declines again after 2008), the Republic of Korea, China and Malaysia. If China's growth continues at its current speed, the 2.5% target will be met by 2020. The other countries, though, seem to have set targets which are not realistic. Singapore seemed on track to reach its target, until R&D

Table 13. R&D expenditure as a percentage of GDP, 2001-2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
BRUNEI DARUSSALAM	…	0.02	0.02	0.04	…	…	…	…	…	…	…
CAMBODIA	…	0.05	…	…	…	…	…	…	…	…	…
CHINA	0.95	1.07	1.13	1.23	1.32	1.39	1.40	1.47	1.70	1.76	1.84
CHINA, HONG KONG	0.54	0.58	0.68	0.72	0.77	0.79	0.75	0.72	0.77	0.75	…
CHINA, MACAO	0.07	0.07	0.06	0.06	0.09	0.08	0.06	0.10	0.06	0.05	0.04
INDIA	0.73	0.71	0.71	0.74	0.81	0.80	0.79	0.84	0.82	0.80	0.81
INDONESIA	0.05	…	…	…	…	…	…	…	0.08	…	…
IRAN, ISLAMIC REP.	0.55	0.55	0.67	0.59	0.73	0.67	…	0.79	…	…	…
JAPAN	3.07	3.12	3.14	3.13	3.31	3.41	3.46	3.47	3.36	3.26	3.39
KOREA, REP.	2.47	2.40	2.49	2.68	2.79	3.01	3.21	3.36	3.56	3.74	4.03
LAO PDR	…	0.04	…	…	…	…	…	…	…	…	…
MALAYSIA	…	0.65	…	0.60	…	0.61	…	0.79	1.01	1.07	1.07
MYANMAR	0.07	0.16	…	…	…	…	…	…	…	…	…
NEPAL	…	…	…	…	…	…	…	0.05	0.26	0.30	…
PAKISTAN	0.17	0.22	…	…	0.44	…	0.67	…	0.46	…	0.33
PHILIPPINES	…	0.14	0.13	…	0.11	…	0.11	…	…	…	…
SINGAPORE	2.06	2.10	2.05	2.13	2.19	2.16	2.37	2.84	2.43	2.09	2.23
SRI LANKA	…	…	…	0.18	…	0.17	…	0.11	…	0.16	…
THAILAND	0.26	0.24	0.26	0.26	0.23	0.25	0.21	…	0.25	…	…
VIET NAM	…	0.19	…	…	…	…	…	…	…	…	…

Notes: Break in series for Macao Special Administrative Region of China 2010, Japan 2008, Republic of Korea 2007, China 2000 (underestimated before 2000), Indonesia 2009, Malaysia 2008, Sri Lanka 2000 and 2004, and Brunei Darussalam 2004. Partial data for Macao Special Administrative Region of China (excluding business and government sector), Indonesia, Brunei Darussalam, Cambodia, Lao People's Democratic Republic, Myanmar and Pakistan (excluding business sector). Figures for Nepal are based on budget data.

Sources: UNESCO Institute for Statistics database, July 2013 and OECD, Main Science and Technology Indicators database, September 2013

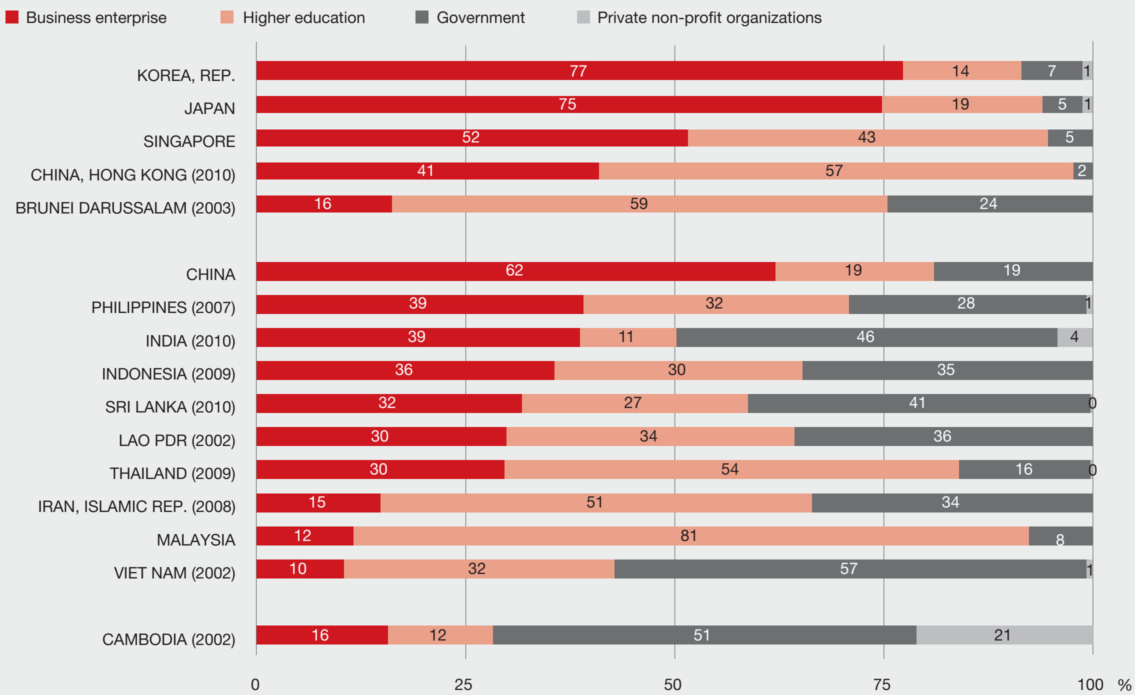
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t13

started to decline after 2008. However, the number of researchers per 1 million inhabitants continued to increase and was 50% higher in 2010 than it was in 2001, which is inconsistent with decreasing R&D expenditure, so it is not clear if the observed change is a real phenomenon or the result of a change in the data collection methodology. The Republic of Korea has increased its R&D expenditure considerably, but the 5% mark is just too high. India did not manage to increase its R&D intensity at all. The Philippines and Thailand will also find it hard to reach their targets, based on trends over the last 10 years.

R&D performers, in particular firms, will not increase their R&D expenditure simply because governments have set a target. If they do not expect a benefit from R&D, they will not increase their investments. If governments are serious about reaching these targets, they will need to foster an enabling environment by improving the framework conditions that were set out in the first part of this chapter. They have various policy instruments at their disposal to do so. One commonly-used instrument is through tax subsidies on R&D. Although empirical studies have frequently estimated positive and quite sizable effects of government support to business, when the government increases R&D spending through subsidies or direct provision, a significant fraction of the increased spending goes directly into higher wages, an increase in the price rather than the quantity of inventive activity. This empirical finding holds not only in the short term but also in the longer term.

As an alternative measure to promote R&D, an increase in public expenditure targeted to educate scientists and engineers neither affected the income distribution nor concentration in the economy but

Figure 22. Share of researchers (in full-time equivalent) by sector of performance, 2011 or most recent year available



Notes: Partial data for Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic and Myanmar. Macao Special Administrative Region of China and Pakistan are excluded because their data do not include the business sector.

Source: UNESCO Institute for Statistics, July 2013 and OECD, Main Science and Technology Indicators database, September 2013.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/f22

unambiguously raised productivity growth (Goolsbee, 1998; Grossmann, 2004). This is an argument for expanding up in line with, for example, the Korean experience. Other areas in which governments could intervene are the reduction of regulatory and administrative burdens and strengthening intellectual property rights systems, as highlighted earlier. Although there are many pitfalls, and many countries fail, there are countries that have successfully embarked on a path towards a knowledge-based society, raising their R&D investment levels considerably, and thus raising living standards of their citizens in the process. In Asia, these countries include China, Singapore and the Republic of Korea.

Generally, the more-developed countries have a higher R&D intensity, with the largest share of R&D performed by industry. These correlations are to some extent present in the Asia region as well, as shown in **Figure 22**. The four countries that invested most in R&D in relative terms are also the countries that had the highest share of researchers employed in industry.[6] In the case of the Republic of Korea and Japan, as many as three-quarters of all researchers were employed by the business sector. Malaysia had the highest share of researchers working in the university sector.[7]

Malaysia and the Philippines both have comparatively high rates of business investment in R&D.[8] However, this is largely because of the presence of large foreign firms operating in these countries. There is evidence that similar developments are underway in Thailand. The challenges for the science, technology and innovation systems of these countries will be to leverage knowledge and technology from this

6 For the breakdown by sector of performance, the data for researchers are of higher quality than expenditure data, which is why these data are shown.

7 Expenditure data, however, show the complete reverse picture, which points to a data quality issue.

8 Expenditure data, however, show the complete reverse picture, which points to a data quality issue.

Box 9. Types of R&D activity

The Frascati Manual defines basic research as experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units (OECD, 2002, §64).

foreign investment for their domestic economies. One possible explanation for the low private sector R&D expenditure in South Asia is the fact that these countries encouraged research in public institutions, on the assumption that local industry would use this knowledge. There have been no incentives for university–industry collaboration or for the promotion of contract research by industry, even though the promotion of R&D in private enterprises is vital for innovation and consequently for economic development (UNESCO, 2010).

As discussed in the first part of this chapter, R&D can be classified into basic research and applied research. The Frascati Manual also defines a third category, experimental development *(see **Box 9**).* The Frascati Manual also distinguishes four main actors that carry out R&D activities on the national territory: the business sector, government sector, higher education sector and the private non-profit sector. In general, basic research is mostly done by universities, while firms typically engage in applied research and experimental development. Government research institutes are usually more involved in basic and applied research than in experimental development.

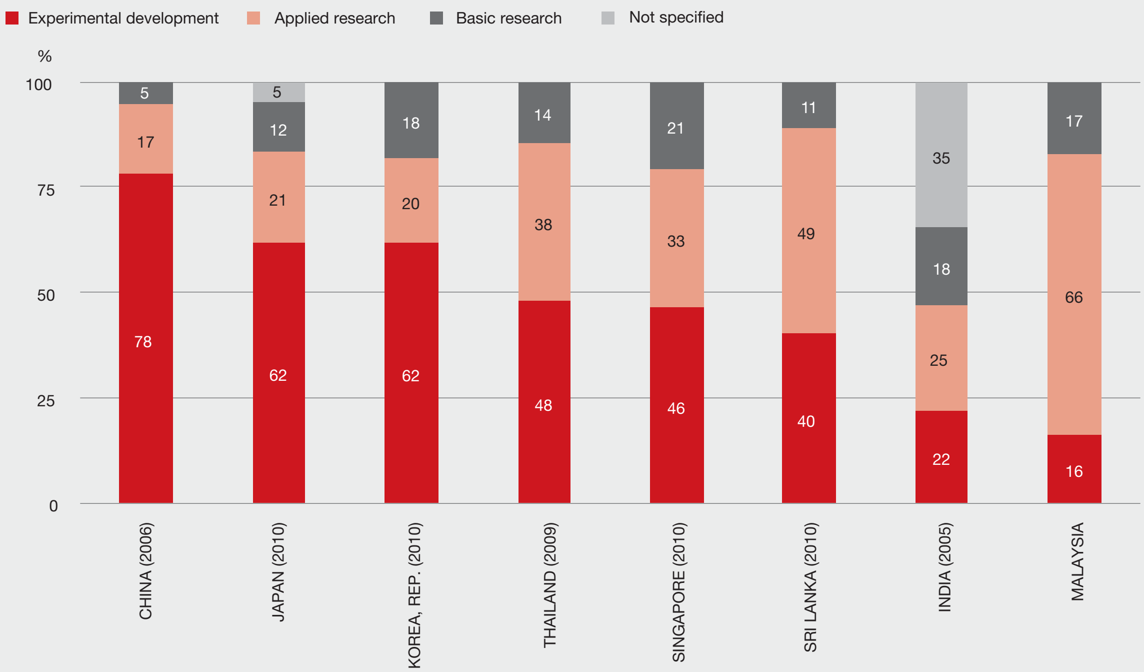
Figure 23 shows the distribution of R&D expenditure by type of activity. The UIS collects these data only at the aggregate level and not broken down by sector of performance. Therefore, the level of basic research carried out by universities cannot be assessed. What this figure shows is that the proportion of basic research carried out in China is particularly low, which is raising debate within the country. Experimental development is generally done by firms, and indeed, the countries with the highest contributions of the business sector in their R&D activities are also the countries with the highest shares of experimental development.

Figure 24 displays the share of female researchers in the higher education sector and compares this with the overall share. Myanmar is an extreme case. There are only data for one year, 2002, so it is hard to tell if the data are accurate or if there are methodological issues. In most countries, the percentage of female researchers is greater in the higher education sector than in the other sectors. In the Philippines, the share of female researchers is slightly above gender parity (when the female share accounts for 45% to 55% of the total). In Thailand, Malaysia and Viet Nam, gender parity has been reached. In most of the other countries though, the shares are below the global average of 30%.

These results point to a path that governments can take to increase their research intensity. By making it more attractive for women to enter a research career, untapped potential can be used to increase the number of researchers.

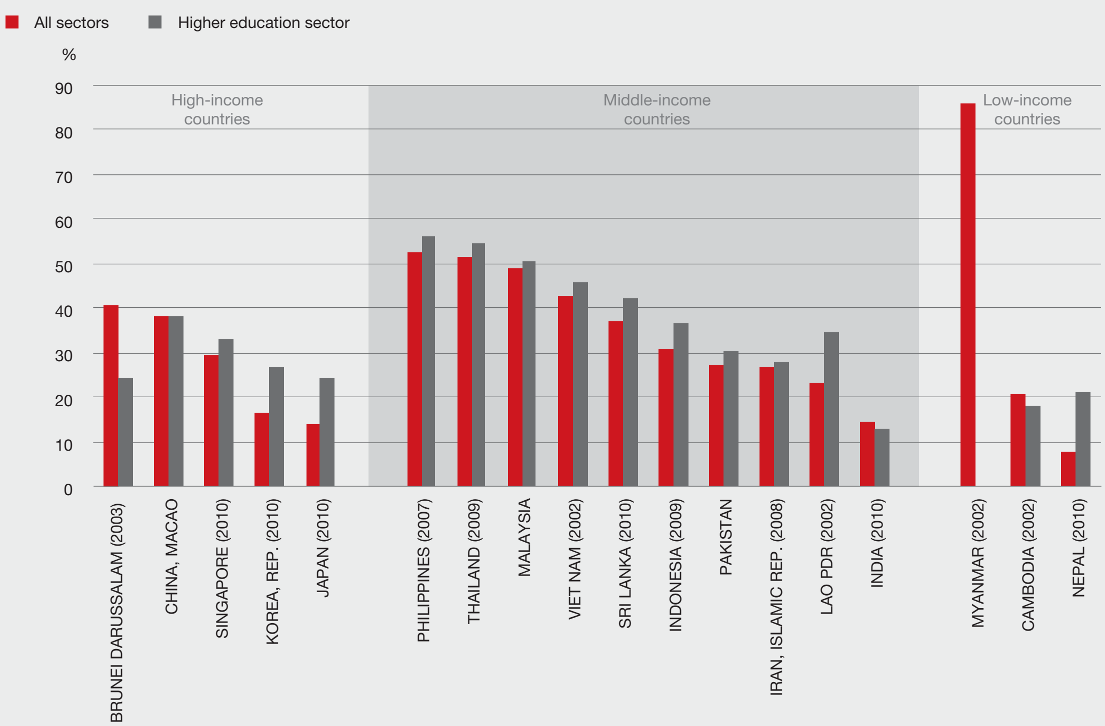
Figure 25 displays the distribution of researchers by field of science. The figure highlights the high shares of engineering in the Republic of Korea, Singapore and Japan (although for Singapore the result is biased, because social sciences and humanities are not covered in the data), while Malaysia has the highest share in natural sciences.

Figure 23. Distribution of R&D expenditure by type of activity in selected countries, 2011 or most recent year available



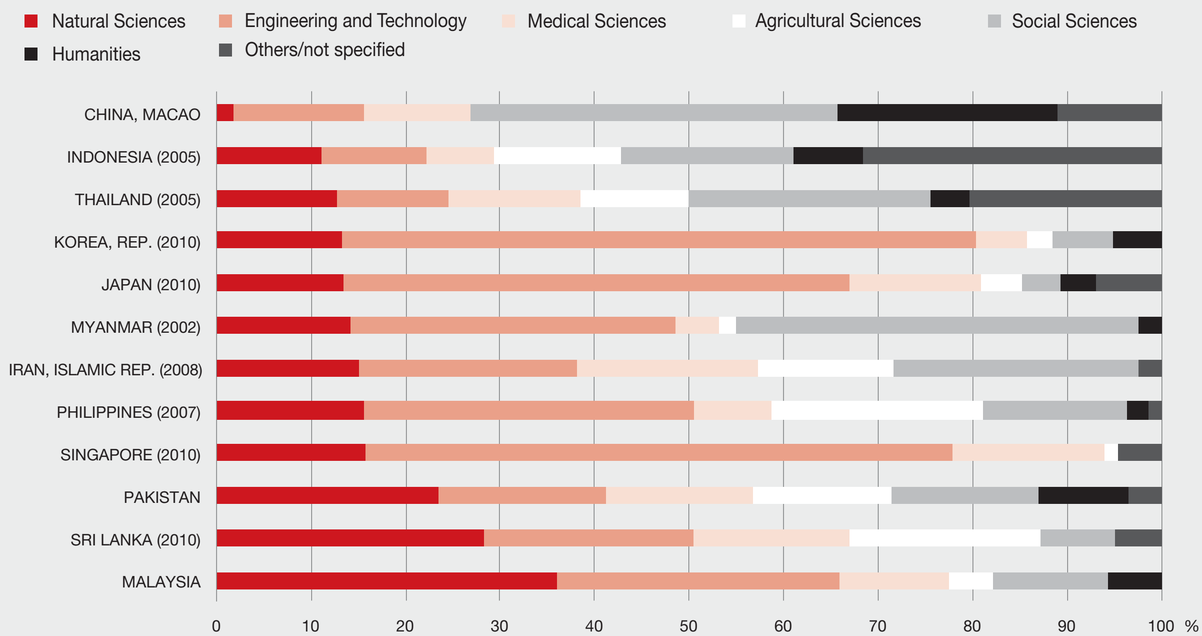
Source: UNESCO Institute for Statistics, July 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f23

Figure 24. Female researchers (in headcounts) as a percentage of all researchers by sector, 2011 or most recent year available



Note: Data for India are in full-time equivalents.
Source: UNESCO Institute for Statistics, July 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f24

Figure 25. Distribution of researchers in the higher education sector by field of science, 2011 or most recent year available



Notes: Sri Lanka: The Social Sciences field includes Humanities. Singapore: Social Sciences and Humanities are excluded.
Source: UNESCO Institute for Statistics, July 2013 **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f25

3.3 SUMMARY AND CONCLUSIONS

The previous discussion leads to two conclusions on the role of universities in low- and middle-income countries and the directions they can take in order to help their economies grow. As the overall level of human capital in many low- and middle-income countries is insufficient to absorb foreign technology in the operations of firms, one path is to focus on raising the overall skills of the population. Part of this expansion should be in graduate education, as the impact of embedded technology can be very limited if capabilities in R&D are absent. But higher education institutions should also be expanding undergraduate and technical education, in order to raise the overall level of human capital in society. If one considers the emerging Asian countries to be in a learning phase, the most important role of universities in learning systems is not to generate new knowledge but to raise the skills of the population. Applied research, engineering, design and technology are critical in this phase.

The other direction universities can take is to increase the amount of research carried out internally. This will not only increase the overall level of research carried out in the country, which is beneficial for technology absorption, but will also increase the quality of education, raising in turn the level of human capital in the country. It will normally also raise the profile of the university, making it a more attractive place to study. If universities decide to carry out more research, a related question is whether they focus more on basic or applied research. Although from the literature it is quite clear that basic research is essential and pays off significantly, this pay-off is not always clear from the beginning and can take a long time to occur. As a result, more and more universities are foregoing basic research in favour of applied research, often encouraged by the government.

These different directions need not be mutually exclusive. Expanding undergraduate education, graduate education and internal R&D are all important and all have their place in a university expansion strategy. The question is what the trade-off is between these various strategies. They all carry costs and have different impacts. These impacts are influenced by many framework conditions, such as the overall level of educational attainment in the country, the level of development of financial markets, university-industry links, supportive innovation policies, regulatory and administrative burdens, and the strength of the intellectual property rights systems. These are all elements governments and individual universities need to take into account when deciding on the right mix for their activities.

For example, in almost all the countries of the South Asian sub-region, incentives for public sector laboratories to work with industry are either ineffective or missing altogether. The service structures of scientists and engineers need to be changed to motivate them either to seek careers in industry or be actively involved in solving problems of industry. Increasing the mobility of scientists via appropriate incentive measures is the best route for knowledge transfer from university to industry (UNESCO, 2010).

Countries collect data on the financial and human inputs into R&D, and submit these data to UNESCO. Although these data paint a picture on the total national effort devoted to R&D, its orientation and trends, these data, by themselves, are not sufficient to assess the impacts of R&D, so they only serve as illustration. The data show a clear relation between the relative amount of resources devoted to R&D and the income level of a country. Generally speaking, the more developed a country, the more it invests in research. More-developed countries also tend to invest more in business R&D and engineering research than lesser-developed countries. Correlation is not causation, so these results should be regarded with caution. For example, it does not tell us if more research leads to higher income levels, or if higher income levels allow for more research to be carried out. That would require an econometric analysis using the microdata, possibly linking the data to other sources. Still, once the business sector starts to make significant investments in research, this will have a clear positive impact on productivity and hence economic growth in a country. The Republic of Korea remains one of the best cases in point. The picture that emerges from that country is of modest R&D spending in the early days of reverse engineering and manufacture under licence, with ramping up as the need arose to access new markets.

Chapter 4

UNIVERSITY RESEARCH PRODUCTIVITY ACROSS ASIA

As the case studies of Malaysia and Thailand illustrated, the mechanism through which higher education systems seek to achieve international respect is by having their top universities earn high positions in international university ranking systems. A key ingredient in high rankings is a university's publication rate. Consequently, faculty members – particularly those teaching in graduate programmes – are under pressure to publish in top-tier international journals. The importance Asian governments and top-tier universities assign to research and publication warrants a closer look at how university quality is measured, how research productivity is distributed across countries and institutions, and the extent to which cross-border collaboration in research, as evidenced by international co-authorship, helps shape rankings.

Part 1 provides a brief overview of international university ranking systems, how the major ranking systems differ, and the implications of universities choosing to benchmark against one system versus another. However, university ranking systems typically treat the university as the basic unit of analysis. A rank is assigned to the overall institution. Yet, often there are pockets of excellence, even in those universities that may not earn the highest overall institutional rankings. These pockets of excellence can still have meaningful implications for institutional reputations and national economic development. Part 2 examines patterns of research excellence below the level of the university by focusing on broad and niche subject areas. One way to increase both research capacity and output is through collaboration. To that end, Part 3 examines patterns of international collaboration in research.

PART 1. INTERNATIONAL UNIVERSITY RANKINGS: HOW DO THEY COMPARE?

Chiao-Ling Chien

Annual world university ranking exercises have taken on larger-than-life prominence among top universities, in addition to those aspiring to be on the list. While university rankings continue to be controversial, they are nonetheless reshaping the strategic planning of university administration, national higher education reforms, and the conditions of employment of many faculty members. The following discussion compares three of the most commonly-used ranking systems, examines how universities respond to university rankings, and explores some of the pros and cons of such ranking systems in terms of how they affect the development of higher education.

4.1.1 How are universities ranked?

The three ranking systems that are the most widely used include the Academic Ranking of World Universities (ARWU), the QS World University Ranking (QS-WUR) and the Times Higher Education World University Ranking (THE-WUR). The indicators and weights used in the three rankings can be seen in **Appendix III**. While these three ranking systems utilise many of the same indicators, there are meaningful differences.

All three ranking systems are indicator-based. Rankings are based on explicit criteria and clearly-defined indicators of those criteria; indicators are assigned a weight to reflect the differential importance of criteria in the final ranking. All three systems use bibliometric analysis as a measure of research output and quality (where a proxy for quality is measured by the frequency with which a publication is cited by other authors). All three ranking systems evaluate the standing of only a relatively small number of universities, typically about 3% of higher education institutions worldwide (Marope and Wells, 2013). Additionally, these rankings have scale distortion whereby large universities are more likely to be ranked highly just by virtue of their sizes.

Despites their commonalities, these ranking systems differ in important respects, such as the indicators they employ. The ARWU system prides itself on relying only on hard data, while both QS and THE include scores based on reputational surveys (e.g. a survey to assess employers' satisfaction with graduates of particular universities and a survey of faculty members' assessment of the academic reputation of particular universities). The use of such surveys is criticised by ARWU, scholars and university administrators as potentially unreliable, as results may vary over time due to sampling errors or the process of selecting respondents (Liu, 2013; Redden, 2013).

The three ranking systems also differ in the relative importance they assign to different criteria, for example, teaching versus research. Furthermore, these systems draw on different data sources to assess research performance of universities. ARWU and THE use bibliometric data from the Web of Science, operated by Thomson Reuters, while QS utilises the Scopus system, operated by Elsevier. Scopus and the Web of Science databases differ in several ways. For instance, they differ in content data coverage and citation indexing tools, which yield different results in a citation search (Jacso, 2005). Furthermore, the choices within ranking systems,

Table 14. Number of universities in top world university rankings, 2012

Country or territory	ARWU Top 100	ARWU Top 500	QS-WUR Top 500	THE-WUR Top 400
CHINA	–	28	19	9
CHINA, HONG KONG	–	5	6	6
INDIA	–	1	7	3
INDONESIA	–	–	3	–
JAPAN	4	21	20	13
KOREA, REP.	–	10	13	6
MALAYSIA	–	1	6	–
PAKISTAN	–	–	1	–
PHILIPPINES	–	–	2	–
SINGAPORE	–	2	2	2
THAILAND	–	–	2	1

Note: – denotes zero.

Sources: Academic Ranking of World Universities (ARWU), QS World Universities Rankings (QS-WUR) and Times Higher Education World University Rankings (THE-WUR)

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t14

the databases and data retrieval methods affect the ranking order of universities (Markpin et al., 2013). One consequence of these differences is that a country's number of universities ranked among the top differ across rankings. As illustrated in **Table 14**, more Asian countries (and universities) appeared in the 2012 QS Top 500 than in the ARWU Top 500. Indonesia, the Philippines and Thailand are more prominent in the QS than in the other rankings.

Given these differences, as might be expected, countries tend to favour the ranking system that puts them in the most advantageous position. For example, there has been a tendency for national governments to benchmark using QS rather than ARWU, in part because QS includes the reputational survey component.

These ranking systems change over time to respond to methodological criticisms and capture new market opportunities. For example, QS revised its methodology in 2007. To expand into new markets, both QS and THE have developed regional rankings which allow more universities to be included in their ranking exercises. Placing in the top 200 universities in Asia is more feasible than securing a position in the top 200 worldwide. These regional rankings also provide an opportunity to tweak the ranking formulae to accommodate for regional differences. For example, the QS Asia Ranking modified its indicators to be more suitable to Asian universities.

4.1.2 The position of Asian universities in world university rankings over time

The position of universities in the ranking order can shift over time, sometimes for reasons other than a change in research outputs or the instructor-student ratio. This can occur when new universities joining the ranking system enter at a higher place than universities already in the system, pushing them down. Scott (2013) observes that some universities in less-industrialised countries are rapidly improving and producing more scientific publications, which yield higher scores in university comparisons. A university's relative placement depends on the performance of other universities; when emerging institutions move up in their ranking, they squeeze out other universities originally placed above them. This, in turn, can lead to shifts in how countries fare. As **Table 15** shows, the number of universities in China in the ARWU Top 500 increased from 8 to 28 from 2004 to 2012, while the number in Japan declined from 36 to 21.

4.1.3 Government and university responses to rankings

Rankings are influencing both government and institution-level priorities. According to a 2006 international survey to higher education leaders, many universities have embedded rankings in their strategic planning processes at all levels of the organization, from departments, faculty, colleagues to senior executives (Hazelkorn, 2008). This is well illustrated in the case studies of Malaysia and Thailand: government funding for top-tier universities is sometimes contingent on universities attaining and maintaining a place in the top rankings. This has led universities to shift priorities toward those activities that are most directly tied to raising rankings, such as research publications in top international journals, sometimes at the expense of other institutional priorities. All of the universities included in the Malaysia and Thailand case studies were shifting their undergraduate to graduate enrolment ratios to increase the number of graduate students. In some cases, the stated reason was because graduate students are expected to publish as a condition of graduation and, in so doing, improve the research productivity statistics of the institution.

Table 15. Number of universities in Top 500 Academic Ranking of World Universities, 2004, 2008 and 2012

Country or territory	2004	2008	2012
CHINA	8	18	28
CHINA, HONG KONG	5	5	5
INDIA	3	2	1
JAPAN	36	33	21
KOREA, REP.	8	8	10
MALAYSIA	–	–	1
SINGAPORE	2	2	2

Note: – denotes zero.
Source: Academic Ranking of World Universities
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t15

At the same time, research productivity was included as an explicit item in the departmental and individual key performance indicators (KPIs). A campus-wide KPI exercise stressing research productivity was put into place in the University of Malaya. Administrators encouraged the faculty of engineering to prioritise research activities, for example, by improving transparency in information-sharing and increasing the importance of research in promotions and contract renewals. The faculty conducted Institute for Scientific Information (ISI) publication analysis monthly (e.g. growth rate and proportion of top-tier journal papers) and tracked grants received; these results were displayed on LCD monitors around the faculty. Additionally, the dean communicated the faculty's research to the university's industrial partners. Faculty members displayed notable resentment and resistance to this approach. However, it was successful in raising research productivity. **Table 16** provides an illustration of the relative importance of different dimensions within overall rankings and the types of actions universities sometimes take to increase their position on these dimensions.

Governments care about the international rankings of their universities. When the Higher Education Commission in Thailand launched the National Research University Project (2010-2012), one of its selection criteria in awarding funds was that the applying universities be ranked in the Top 500 of the THE or QS Ranking (OHEC, 2010). Similarly, the government of the Philippines, in its Roadmap for Public Higher Education Reform (2011-2016), was explicit in its desire to have three public universities ranked in the Top 500 worldwide rankings by 2016 (CHED, 2012). China, India, Japan, Malaysia, Singapore, the Republic of Korea and Viet Nam have all launched initiatives to create world class universities. China's 985 Project and 211 international university ranking systems have strong proponents and equally strong critics.

4.1.4 Conclusions

Advocates argue that overall university ranking systems have made universities more transparent, accountable and open to official and public scrutiny (e.g. Marope and Wells, 2013). They provide an easy means of reviewing and comparing institutions. They hasten higher education reform. One dimension which all three ranking systems measure is research performance. This focus is important because such attention can enhance performance, improve accountability and provide an objective means of optimising resource allocation (Hazelkorn, 2009a). In countries that allocate large-scale public funding to university research, ranking systems are particularly important as an indicator of the return on investment.

On the other side of the equation, critics argue that the focus on publishing in top-tier international journals favors the hard sciences (e.g. physics, life and medical sciences), whereas social sciences and humanities (for which book publications are more pertinent) are not weighted as high as journal articles. Moreover, some suggest that the heavy reliance on

Table 16. Illustration of institutional actions to promote high rankings

Dimension	Actions
Organization/ management	▪ Modify institution's strategic planning ▪ Establish centres of excellence ▪ Set up international colleges ▪ Explicate performance agreements and key performance indicators ▪ Regularly broadcast evaluation results
Research	▪ Increase outputs, quality and citations ▪ Reward faculty for publications in top-tier journals ▪ Require doctoral students to publish before graduation
Student	▪ Modify the ratio of undergraduates to graduates ▪ Proactively recruit international students ▪ Increase exchange or study abroad activities
Faculty	▪ Recruit high-achieving scholars ▪ Create new contract types for employees ▪ Identify weak performers ▪ Recruit international academic staff
External relations	▪ Flag ranking results to the public (e.g. university's website or newspaper)

Sources: Author's interview in the case study of Malaysia and Thailand; Hazelkorn (2009a)

citations as a measure of research quality is subject to a halo effect (Hazelkorn, 2009a). Secondly, since most top-tier journals are in English, it works against researchers who did not study or do not work in an English-speaking country. Third, critics point to the relative neglect of teaching quality in ranking systems. Ranking systems do not necessarily measure what many educators regard as the most important output of higher education. Fourth, critics observe that the intense competition to publish may push university researchers toward more applied research and away from basic research, which they see as having long-term negative consequences for national economic development. Finally, critics are concerned that the emphasis on top-tier universities has led many governments to concentrate resources on a small number of elite universities rather than seeking a more balanced development of the higher education system (Hazelkorn, 2013). However, advocate or critic, governments and university leaders are not indifferent to ranking results (Salmi, 2011).

PART 2. LOOKING FOR RESEARCH EXCELLENCE IN THE RIGHT PLACES

Saeed Ul Hassan, Inn Beng Lee and Peter Haddawy

The proliferation of college and university ranking systems conducted by magazines, newspapers, governments and academics has fueled considerable debate about the usefulness and accuracy of rankings in general. Many of these rankings operate at the institutional level, possibly masking variations in programme quality within universities. To provide a better measure of quality below the aggregate institutional level, the United Nations University International Institute of Software Technology (UNU-IIST), the Center for Measuring University Performance and its independent International Advisory Board have established the Global Research Benchmarking System (GRBS), intended to provide objective data and analyses to benchmark research performance in 15 broad disciplinary subject areas and 251 niche subject areas. This system supports universities to better understand their research profiles, identify niche areas in which they can excel, make more rational decisions on strategy and resource allocation, and publicise programme strengths.

The basic message to be conveyed by using GRBS is that pockets of excellence can be found across a wide range of universities, not just in those that place near the top in world rankings. Indeed, a recent policy brief released by the Innovation for Growth Expert Group of the European Commission shows that Asian universities have achieved research performance in areas of science and technology that rivals or exceeds that of European universities, particularly at the level of world class performance (Bonaccorsi et al., 2013). If governments are consolidating funding to support top-tier, international universities, they may be missing the subtler, but still substantial, contributions to high-quality research being made by a wider set of higher education institutions. If governments are funding higher education in the belief that good research will fuel national economic development, they need to broaden their gaze to acknowledge these achievements. More importantly, governments may benefit by targeting their research support to a swath of universities that may not yet have earned a position in the top overall rankings but which are doing particularly good work in important niche areas. To the extent that research does promote economic development, targeted support for universities that have more narrowly-defined programmes of demonstrated excellence in areas of strategic importance may be equally or more fruitful than focusing on only those institutions that achieve overall top rankings. At the level of higher education institutions, identification of these pockets of excellence may give less-prestigious universities information they can use to leverage wider status and programme strength.

This section explores issues related to the production of research and scholarly publications. Analyses are presented to measure research performance of Asian universities in broad, as well as narrowly-focused, subject areas. Further analyses then examine rates of growth in research performance and within-region research collaboration.

4.2.1 Rating research performance of universities by subject

This study aims to identify the current status, trends and examples of research excellence of Asian universities. The examination of institutional performance within niche subject areas identifies universities that may not excel in overall rankings yet have top research performance in more narrowly-focused subject areas. Specifically, this study addresses three main questions: i) Within each broad subject and niche subject area, which universities exhibit the strongest performance?; ii) Which universities have demonstrated the fastest rate of increase in their publication rates?; iii) Which universities are leaders in within-region scientific collaboration? To answer these questions, GRBS is used to examine the research performance of Asian universities across the 15 broad subject areas listed in **Table 17** and 251

Table 17. Broad fields of study and list of countries considered in this analysis

Subject area[a]	Country or territory[b]
Agricultural and Biological Sciences	AFGHANISTAN
Biochemistry, Genetics and Molecular Biology	BANGLADESH
Chemistry	BHUTAN
Computer Science	BRUNEI DARUSSALAM
Earth and Planetary Sciences	CAMBODIA
Economics and Business Sciences	CHINA [190]
Engineering	CHINA, HONG KONG [7]
Environmental Sciences	CHINA, MACAO
Health Professions and Nursing	INDIA [44]
Materials Sciences	INDONESIA
Mathematics	JAPAN [108]
Medicine	KOREA, DPR
Multidisciplinary	KOREA, REP. [42]
Other Life and Health Sciences	LAO PDR
Physics and Astronomy	MALAYSIA [8]
	MALDIVES
	MYANMAR
	NEPAL
	PAKISTAN
	PHILIPPINES
	SINGAPORE [3]
	SRI LANKA
	TAIWAN OF CHINA [35]
	THAILAND [9]
	TIMOR-LESTE
	VIET NAM

Notes: [a]All Science Journal Classification (ASJC), which maps source titles in a structured hierarchy of disciplines and sub-disciplines, allows research activity to be categorised according to the field of research (UNU-IIST, 2013).

[b]Initially, 26 countries or territories were analysed and eventually 9 (as shaded) were selected for final analyses. Numbers in brackets present the number of universities analysed.

niche subject areas (from Aerospace through Zoology) (UNU-IIST, 2013).

4.2.2 Data source and methodology

This study uses data from the 2012 release of GRBS, which is based on Scopus publication and citation data for the four-year period covering 2008 to 2011. GRBS covers over 1,300 universities in North America, Europe and Asia-Pacific. For each region, universities are selected for inclusion by identifying those with the highest publication output in each broad and niche subject area. When a university is selected based on its output in any area, it is included in the analyses of all areas in which it meets the statistical threshold of publication output.

Universities from the Asia region were selected as follows: first, in each of the 251 niche subject areas, the 50 universities with the highest publication outputs were identified for inclusion. Among these 50 universities, and for statistical reasons only, those with 50 or more publications in the four-year period were included in the subsequent analyses. The cutoff of 50 publications was necessary because some indicators lose meaning if the volume is too low. Second, to ensure inclusion of universities with significant publication output, but lacking particular niche strength, an additional selection process was carried out. The 200 universities with the highest number of publications in each of the 15 broad subject areas were identified for inclusion. Again, a cutoff of 50 publications was applied. If a university was identified to meet the selection criteria in any subject area, it was analysed across all subject areas in which it met the statistical cutoff criterion.

The results of this two-part identification process were then combined to derive the final set of universities. In total, 446 universities from 9 of the initial 26 Asian countries or territories were selected for the analysis *(see Table 17)*. If a country was not included in the study, it was because no university from the country had sufficient publication output in the four-year period to meet the selection criteria.

BIBLIOMETRIC INDICATORS

This study uses a set of bibliometric indicators to evaluate research performance of universities in broad and narrow subject areas. To provide a comprehensive comparison of research performance, seven indicators (presented in **Table 18**) were chosen to reflect the volume, quality, output and scholarly impact of research activity. Volume indicators include total publications, total citations and H-index which measures both publications and citations.

The measures of scholarly quality used in this analysis include the percentage of publications which

Table 18. Indicators used in the bibliometric analysis

Dimension		Indicator	Description
Volume	Output	Total publications	Total number of publications within a four-year period.
	Impact	Total citations	Total number of citations within a four-year period to papers published in the same period.
	Output and impact	Four-year H-index	A university having a four-year H-index of X means that at least X of its publications (during a four-year period) have no less than X citations (within the same period). A four-year H-index is computed for a particular subject area. The H-index used in this report adopts the same formula proposed by Hirsch (2005) for individual researchers.
Quality	Output	Percentage of publications in top 10% of the source normalized impact per paper (SNIP)*	Percentage of total publications in source titles that are within the top 10% of that subject area, based on the SNIP value (Moed, 2010) of the last year with a specified period. For the period covering 2008-2011, the SNIP values for 2011 are used.
		Percentage of publications in top 25% SNIP	Percentage of total publications in source titles that are within the top 25% of that subject area, based on the SNIP value of the last year within a specified period.
	Impact	Percentage of citations from top 10% SNIP	Percentage of total citations received from publications in source titles that are within the top 10% of that subject area, based on the SNIP value for the last year within a specified period.
		Percentage of citations from top 25% SNIP	Percentage of total citations received from publications in source titles that are within the top 25% of that subject area, based on the SNIP value for the last year within a specified period.

Note: *SNIP accounts for differences in topicality between subject fields. It is a ratio of a source title's citation impact and the degree of topicality of its subject field. The SNIP numerator gives a source title's raw impact per paper (RIP), which is similar to the journal impact factor. The denominator is the citation potential in a source title's field, a measure of the citation characteristics of the field, determined by how often and how rapidly authors cite other works and how well the field is covered in the database (in this case, Scopus).

Figure 26. Interpretation of band values and research performance

Band	1	2	3	4	5	6	7	8	9	10
Performance	World class	Excellent		Above average		Below average				

appear in the top 10% and 25% of source titles within each field and the percentage of citations from those source titles. Note that the top 10% and top 25% indicators are correlated since a paper or citation in the top 10% is also in the top 25%. Also of note is that, since percentages are being used rather than absolute numbers, the quality measures are independent of volume of publications and citations. The score for each indicator is normalised by dividing by the maximum score for that indicator over the entire global data set. An overall score is computed by adding the sums of the normalised indicators with the composite score normalised to range from 1 to 100. These scores are then used to assign universities to bands, with each band corresponding to a score range of 10 (e.g. Band 1 = 90-100; Band 10 = 0-10). In order to be rated highly, universities need to perform consistently well across all seven indicators. Note that the band values were computed globally by considering more than 1,300 universities from North America, Europe and Asia.

In any of the broad or niche subject areas, universities achieving Band 1 are considered to be “world class” in those areas; those achieving Bands 2 and 3 are deemed to have “excellent” research performance; those achieving Bands 4 and 5 are deemed to have “above average” research performance; and those scoring in Band 6 or beyond are deemed to perform "below average" as compared to the 1,300 universities globally included in GRBS *(see **Figure 26**).*

PUBLICATION GROWTH RATE AND IN-REGION COLLABORATION INDICATORS

In addition to the aforementioned composite university rating indicators, the publication growth rate identifies universities with the highest publication growth rate over the four-year period, and the in-region collaboration shows which universities play an active role in regional research development in Asia. The indicators are calculated as follows:

- Publication growth rate (PGR): Publication growth rate is computed using the arithmetic mean return (AMR) which is the sum of annual publication changes (compared with the previous year) divided by number of years.
- In-region collaboration (IRC): It is the number of publications produced by a university in collaboration with other universities in Asian countries studied in this report. The percentage of in-region collaboration (% IRC) is the ratio of IRC to the total number of publications produced by a university.

4.2.3 Results and discussion

4.2.3.1 Broad subject areas

Table 19 and **Figure 27** provide an overview of the research performance of the selected Asian universities. Table 19 presents the number of universities in each country by research performance category. A university is counted if it has achieved that performance category in at least one broad subject area. Seven countries or territories have universities that place in the 'world class' or 'excellent' research performance categories in at least one broad subject area, and of which Japan, the Republic of Korea and Singapore have achieved world class research performance in one broad subject area.

Table 19. Number of universities by research performance in broad subject areas, 2008-2011

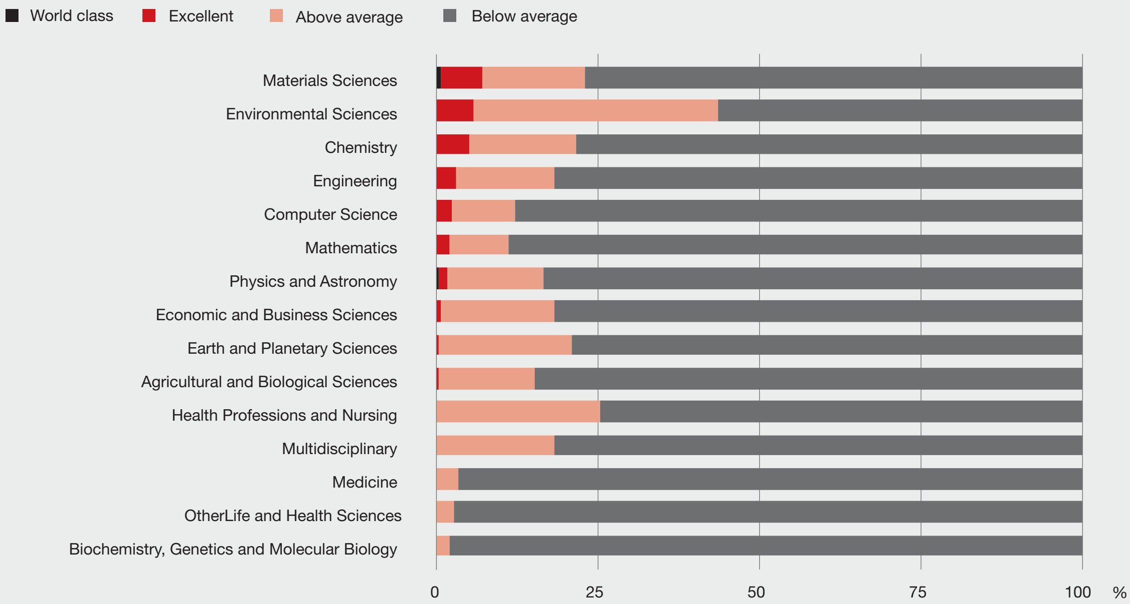
Country or territory	World class	Excellent	Above average	Below average
CHINA	–	11	65	190
CHINA, HONG KONG	–	4	6	7
INDIA	–	–	8	44
JAPAN	1	5	30	108
KOREA, REP.	1	4	24	42
MALAYSIA	–	1	3	8
SINGAPORE	1	2	3	3
TAIWAN OF CHINA	–	4	29	35
THAILAND	–	–	6	9
TOTAL	**3**	**31**	**174**	**446**

Note: – denotes zero.
Source: Global Research Benchmarking System (GRBS)
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t19

Figure 27 summarises the distribution of research performance of the selected Asian universities across the 15 broad subject areas. More detailed information on research performance of universities rated as 'above average' or higher in each of the 15 subject areas is reported in **Appendix IV**. The central message from the data provided in this appendix is that top-quality, world class research is being conducted within specific subject areas at universities that may not yet have achieved a high place in the overall world rankings of universities.

World class research performance at the broad subject levels is relatively rare in Asia. One university in Japan has achieved world class research performance in Physics and Astronomy, and two others in the Republic of Korea and Singapore have achieved world class performance in Materials Sciences. Arguably, the three broad subject areas of greatest strength in Asia (considered as 'excellent') are Chemistry, Environmental Sciences and Materials Sciences. Overall, most research conducted in broad subject areas in Asian universities is in the 'below average' performance bands (Bands 6 to 10).

Figure 27. Distribution of universities by research performance in broad subject areas, 2008-2011



Note: See list of nine selected countries and their universities in Table 17.
Sources: Global Research Benchmarking System (GRBS) **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f27

4.2.3.2 Niche subject areas

At niche subject level, a total of 438 Asian universities were identified in 251 niche subject areas based on their publication output following the methodology previously described. Analyses are presented at two levels: i) by country, examining the percentage of contribution and distribution by performance band; and ii) by the range of research-active areas of universities. The range of research-active areas is measured by the number of niche areas in which a university is active, defined as having publication output above the cutoff threshold of 50 publications in the four-year period. This can be considered a measure of the comprehensiveness of a university's research activity.

To facilitate the comparison of universities of varying ranges of research-active areas, universities are grouped into three range categories. **Table 20** shows that in terms of comprehensiveness of research areas of its universities, China dominates with 13 wide-range universities (active in at least 100 niche areas), 22 medium-range universities, and 155 narrow-range universities. Detailed information about individual universities that have achieved world class research performance in niche areas can be seen in **Appendix V.**

Table 20. Number of universities by range of research-active areas, 2008-2011

	Range			TOTAL
	Wide	Medium	Narrow	
CHINA	13	22	155	**190**
CHINA, HONG KONG	2	3	2	**7**
INDIA	0	3	41	**44**
JAPAN	7	10	85	**102**
KOREA, REP.	4	11	27	**42**
MALAYSIA	0	3	4	**7**
SINGAPORE	1	1	1	**3**
TAIWAN OF CHINA	2	7	25	**34**
THAILAND	0	2	7	**9**
TOTAL	**29**	**62**	**347**	**438**

Notes: "Wide": when a university's range of research areas exceeds the threshold in at least 100 niche areas. "Medium": exceeding the threshold in 50-99 areas. "Narrow": less than 50 areas.
Source: Global Research Benchmarking System (GRBS)
DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/t20

Table 21 presents the number of universities with niche subject areas ranked with world class performance in select Asian countries. It also gives the distribution of niche subject areas by performance category. The percentage of fields in each performance category represents the total share of fields for which the universities analysed in that country have achieved that level of performance. As shown in the first column, China, Hong Kong Special Administrative Region of China and Singapore have the largest number of niche subject areas with world class performance. Over the subject areas in which its universities are research active, Singapore has the highest percentage of niche subject areas with world class performance (17.3%) and with excellent performance (29.4%). It is followed by Hong Kong Special Administrative Region of China.

Table 22 shows the 40 Asian universities with world class performance in at least one niche subject area, ordered by the range of research-active areas, as measured by the number of niche subject areas in which they exceed the publication threshold. Among the 18 wide-range, research-active universities, the National University of Singapore leads in having world class performance in 21 niche areas, followed by Tsinghua University (China), the University of Science and Technology (Korea) and Zhejiang University (China).

Among the 12 medium-range, research-active universities, Nanyang University of Technology (Singapore) leads with world class performance in 16 areas, followed by Hong Kong Polytechnic University (11), City University of Hong Kong (7) and Universiti Sains Malaysia (6). It is noteworthy that Universiti Sains Malaysia is the only university from Malaysia with world class performance at any subject level.

Among the 10 narrow-range universities, Feng Chia University (Taiwan of China) leads the group with world class performance in three subject areas. The Indian Institute of Technology is the only university from India with world class performance at any subject level.

It is noteworthy that world class performance in Asia is strongly correlated with the range of research-active areas. The four top-performing universities are all wide-range universities. In addition, the top-performing wide-range universities all outperform the top medium-range universities, which outperform the top small-range universities.

The most research comprehensive universities include the University of Tokyo (159 areas), Seoul National University (158 areas), National Taiwan University (155 areas), Kyoto University (151 areas), Shanghai Jiaotong University (147 areas) and

Table 21. Distribution of universities by research performance in niche areas, 2008-2011

Country or territory	World class (number)	Distribution (%)			
		World class	Excellent	Above average	Below average
CHINA	53	0.9	7.3	22.8	69
CHINA, HONG KONG	22	4.6	16.7	53.9	24.8
INDIA	1	0.1	4.4	21.2	74.3
JAPAN	16	0.5	3.5	27.6	68.4
KOREA, REP.	14	0.7	8	29.7	61.6
MALAYSIA	6	2.6	0.9	11.7	84.8
SINGAPORE	37	17.3	29.4	42.5	10.7
TAIWAN OF CHINA	10	0.8	11.6	41.4	46.1
THAILAND	0	0	4.5	23.8	71.7
TOTAL	**159**	**1.1**	**7.2**	27.4	**64.2**

Source: *Global Research Benchmarking System (GRBS)* **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/t21

Table 22. Asian universities with world class research performance in at least one niche subject area, 2008–2011

Range	University	Country or territory	World class	Excellent	Above average	Below average	TOTAL
Wide	National University of Singapore	Singapore	21	31	67	12	**131**
	Tsinghua University	China	12	43	29	24	**108**
	University of Science and Technology, Korea	Korea, Rep.	11	22	32	35	**100**
	Zhejiang University	China	10	25	43	67	**145**
	Southeast University	China	7	28	34	38	**107**
	University of Tokyo	Japan	6	29	94	30	**159**
	Kyoto University	Japan	6	20	87	38	**151**
	Graduate University of Chinese Academy of Sciences	China	4	16	32	52	**104**
	Seoul National University	Korea, Rep.	2	39	75	42	**158**
	National Taiwan University	Taiwan of China	2	38	80	35	**155**
	Shanghai Jiaotong University	China	2	35	44	66	**147**
	Shandong University	China	2	10	33	66	**111**
	Tohoku University	Japan	1	18	55	59	**133**
	Yonsei University	Korea, Rep.	1	13	64	43	**121**
	Huazhong University of Science and Technology	China	1	5	39	66	**111**
	National Cheng Kung University	Taiwan of China	1	30	43	36	**110**
	Nanjing University	China	1	14	33	52	**100**
	Wuhan University	China	1	11	30	58	**100**
Medium	Nanyang Technological University	Singapore	16	32	21	10	**79**
	Hong Kong Polytechnic University	China, Hong Kong	11	13	36	16	**76**
	City University of Hong Kong	China, Hong Kong	7	22	28	11	**68**
	Universiti Sains Malaysia	Malaysia	6	2	7	39	**54**
	Hong Kong University of Science and Technology	China, Hong Kong	4	20	32	9	**65**
	Tokyo Institute of Technology	Japan	3	11	37	23	**74**
	University of Science and Technology of China	China	2	18	33	29	**82**
	Harbin Institute of Technology	China	2	24	30	19	**75**
	Jilin University	China	2	10	23	48	**83**
	Tongji University	China	1	10	16	56	**83**
	National Chung Hsing University	Taiwan of China	1	7	31	29	**68**
	Chongqing University	China	1	4	13	46	**64**
Narrow	Feng Chia University	Taiwan of China	3	3	10	11	**27**
	China Medical University Taichung	Taiwan of China	1	3	10	34	**48**
	Indian Institute of Technology, Delhi	India	1	6	18	17	**42**
	China University of Geosciences	China	1	2	17	22	**42**
	National Taiwan University of Science and Technology	Taiwan of China	1	5	18	12	**36**
	China University of Mining Technology	China	1	4	4	20	**29**
	Hohai University	China	1	3	1	22	**27**
	Yuan Ze University	Taiwan of China	1	2	13	8	**24**
	Taiyuan University of Technology	China	1	2	2	16	**21**
	Xidian University	China	1	0	10	18	**29**

Note: Universities are ordered by number of research-active areas and then by number of world class niche subject areas.

Source: *Global Research Benchmarking System (GRBS)* **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/t22

Table 23. Universities with world class research performance in niche subject areas and their positions in selected international university rankings

Range	University	Country or territory	ARWU 2013	THE-WUR 2012-2013	QS-WUR 2012
Wide	National University of Singapore	Singapore	101-150	29	25
	Tsinghua University	China	151-200	52	48
	University of Science and Technology, Korea	Korea, Rep.	NA	NA	NA
	Zhejiang University	China	151-200	301-350	170
	Southeast University	China	401-500	NA	551-600
	University of Tokyo	Japan	20	27	30
	Kyoto University	Japan	26	54	35
	Graduate University of Chinese Academy of Sciences	China	NA	NA	NA
	Seoul National University	Korea, Rep.	101-150	59	37
	National Taiwan University	Taiwan of China	101-150	134	80
	Shanghai Jiaotong University	China	151-200	276-300	125
	Shandong University	China	301-400	NA	601+
	Tohoku University	Japan	101-150	137	75
	Yonsei University	Korea, Rep.	201-300	183	112
	Huazhong University of Science and Technology	China	301-400	NA	451-500
	National Cheng Kung University	Taiwan of China	301-400	301-350	271
	Nanjing University	China	201-300	251-275	168
	Wuhan University	China	401-500	NA	451-500
Medium	Nanyang Technological University	Singapore	201-300	86	47
	Hong Kong Polytechnic University	China, Hong Kong	201-300	251-275	159
	City University of Hong Kong	China, Hong Kong	201-300	182	95
	Universiti Sains Malaysia	Malaysia	NA	NA	326
	Hong Kong University of Science and Technology	China, Hong Kong	201-300	65	33
	Tokyo Institute of Technology	Japan	101-150	128	65
	University of Science and Technology of China	China	201-300	201-225	186
	Harbin Institute of Technology	China	301-400	NA	401-450
	Jilin University	China	301-400	NA	601+
	Tongji University	China	401-500	NA	451-500
	National Chung Hsing University	Taiwan of China	NA	NA	601+
	Chongqing University	China	NA	NA	NA
Narrow	Feng Chia University	Taiwan of China	NA	NA	NA
	China Medical University Taichung	Taiwan of China	NA	NA	NA
	Indian Institute of Technology, Delhi	India	NA	NA	212
	China University of Geosciences	China	NA	NA	NA
	National Taiwan University of Science and Technology	Taiwan of China	NA	351-400	396
	China University of Mining Technology	China	NA	NA	NA
	Hohai University	China	NA	NA	NA
	Yuan Ze University	Taiwan of China	NA	NA	NA
	Taiyuan University of Technology	China	NA	NA	NA
	Xidian University	China	NA	NA	NA

Notes: Universities are ordered by number of research-active areas and then by number of world class niche subject areas. NA denotes not applicable. 600+ denotes that universities are ranked 600th or beyond

Source: Global Research Benchmarking System (GRBS) **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/t23

Table 24. Number of universities with the highest publication growth rate by broad subject area and country or territory, 2008–2011

Broad subject area	CHINA	CHINA, HONG KONG	INDIA	JAPAN	KOREA, REP.	MALAYSIA	SINGAPORE	TAIWAN OF CHINA	THAILAND
Agricultural and Biological Sciences	8	–	–	–	–	4	–	3	–
Biochemistry, Genetics and Molecular Biology	9	–	1	–	–	5	–	–	–
Chemistry	8	–	–	–	–	4	–	3	–
Computer Science	9	–	1	–	1	3	–	–	1
Earth and Planetary Sciences	9	–	2	–	2	1	1	–	–
Economics and Business Sciences	10	–	–	–	–	4	–	1	–
Engineering	9	–	1	–	–	5	–	–	–
Environmental Sciences	8	–	1	–	2	3	–	1	–
Health Professions and Nursing	–	–	–	1	8	2	–	4	–
Materials Sciences	8	–	1	–	–	5	–	1	–
Mathematics	7	–	2	–	1	4	–	–	1
Medicine	7	–	4	1	2	1	–	–	–
Multidisciplinary	4	1	–	1	1	7	–	–	1
Other Life and Health Sciences	12	–	2	–	–	1	–	–	–
Physics and Astronomy	6	–	–	1	3	5	–	–	–
ALL AREAS	114	1	15	4	20	54	1	13	3

Notes: Universities are ordered by number of research-active areas and then by number of world class niche subject areas. – denotes zero.

Source: *The Global Research Benchmarking System (GRBS)* **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/t24

Zheijiang University (145 areas), as shown in the last column of Table 22.

Table 23 shows a comparison of research ratings using the GRBS methodology with the three university ranking systems that are predominant in Asia: ARWU, THE-WUR and QS-WUR. The table compares the niche subject area performance of the 40 universities with world class performance in at least one niche area, showing their rankings within the three systems. The entries in the table are sorted first by number of niche areas with world class performance and equal values by number of niche areas with excellent performance. While there is some correlation between the ranking of niche subject area performance and the three ranking systems, it is not strong. The strongest agreement seems to be with the QS ranking, which may be due to the fact that QS makes use of Elsevier's Scopus database for its bibliometric indicators, while the other two use Thompson Reuter's Web of Science database. The lack of agreement between GRBS and the predominant ranking systems is not surprising given that rather different sets of indicators are used and the ranking systems measure performance at aggregate level. This shows that the GRBS methodology adds an important dimension to the information provided by existing ranking systems.

4.2.3.3 Growth in publications and within-region collaboration

Among the selected Asian universities, the 15 with the highest publication growth rates and in-region collaboration in each of the broad subject areas are reported in **Appendix VI**. **Tables 24** and **25** summarise these results, showing the number of

Table 25. Number of universities with the highest in-region collaboration by broad subject area and country or territory, 2008-2011

Broad subject area	CHINA	CHINA, HONG KONG	INDIA	JAPAN	KOREA, REP.	MALAYSIA	SINGAPORE	TAIWAN OF CHINA	THAILAND
Agricultural and Biological Sciences	2	1	–	5	1	3	–	–	3
Biochemistry, Genetics and Molecular Biology	3	3	–	7	2	–	–	–	–
Chemistry	2	6	–	3	1	2	–	–	1
Computer Science	8	6	–	1	–	–	–	–	–
Earth and Planetary Sciences	4	3	–	6	2	–	–	–	–
Economics and Business Sciences	7	6	–	–	2	–	–	–	–
Engineering	4	5	–	5	1	–	–	–	–
Environmental Sciences	3	6	–	4	1	1	–	–	–
Health Professions and Nursing	6	3	–	2	2	1	–	–	1
Materials Sciences	3	5	–	4	1	2	–	–	–
Mathematics	7	6	–	1	1	–	–	–	–
Medicine	5	3	–	3	2	1	–	–	1
Multidisciplinary	4	1	–	5	–	5	–	–	–
Other Life and Health Sciences	4	3	–	3	2	1	–	–	2
Physics and Astronomy	2	2	–	5	4	2	–	–	–
ALL AREAS	**64**	**59**	**–**	**54**	**22**	**18**	**–**	**–**	**8**

Note: – denotes zero.
Source: The Global Research Benchmarking System (GRBS) **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/t25

universities that have the highest publication growth rates and in-region collaboration in select countries.

Table 24 shows that China dominates, with its universities appearing 114 times in the list of Asian universities with the highest publication growth rates in 15 broad subject areas. This is followed by: Malaysia (54), the Republic of Korea (20), India (15), Taiwan of China (13), Japan (4), Thailand (3), Hong Kong Special Administrative Region of China (1) and Singapore (1). However, the Asian universities with the highest publication growth rates are predominantly those operating at 'below average' research performance. This may reflect the fact that a common strategy among universities in early stages of developing their research programmes is to encourage faculty members to increase the volume of research output, with more mature stages being characterised by a greater emphasis on research quality.

In-region collaboration is an indicator of the extent to which a university contributes to research development in the region. From Table 25 it is evident that universities from China, Hong Kong Special Administrative Region of China and Japan lead in in-regional collaboration.

The six Asian universities with the highest within-region collaboration include the Chinese University of Hong Kong, the University of Hong Kong, Seoul National University, University of Tokyo, Osaka University and Kyoto University. Among these, the universities with the largest number of niche subject areas with world class performance are the University of Tokyo, Kyoto University, and Seoul National University. This suggests that these three universities may be playing an important role in leading research development with other universities in the Asian region. It is also noteworthy that the University of Tokyo has world class performance in the broad area of Physics and Astronomy, an area in which it also has particularly high in-region research collaboration *(see Appendix VI).*

4.2.4 Conclusions

A comparison of world class performance at the broad and niche subject levels illustrates the importance of carrying out niche-level subject analyses in understanding university research excellence. As shown in Table 19, only three universities in Asia achieve world class performance in broad subject areas: the University of Tokyo in Physics and Astronomy, the National University of Singapore in Materials Science, and the University of Science and Technology (in the Republic of Korea) also in Materials Science. In contrast, Table 22 shows that 40 universities achieve world class performance in at least one niche subject area and six achieve world class performance in ten or more areas. At the country level, universities in China achieve world class performance in a total of 53 areas, followed by Singapore (37), Hong Kong Special Administrative Region of China (22), Japan (16) and the Republic of Korea (14) *(see Table 21).* One can clearly see that performance analyses carried out only at the aggregate university level or even at the broad subject level miss significant pockets of research excellence, possibly creating the false impression of a lower level of research performance in Asia than is the case.

PART 3. INTERNATIONAL SCIENTIFIC COLLABORATION

Gali Halevi and Henk F. Moed

Publishing in scientific journals is a primary mechanism through which researchers make their findings known to colleagues in their field, contribute to scientific progress, and draw on the experience of others to inform national development in their own countries. Publishing also plays an important role in networking by creating lines of communication among scholars working in similar areas of inquiry. Such knowledge-sharing and networking can also have payoffs in raising the quality of graduate instruction, as instructors are able to keep abreast of current findings in their field. Finally, publishing in international, peer-reviewed journals is widely seen as a marker in assessing national, institutional and individual research quality. It is common for organizations funding research to use bibliometric information on research publications to monitor the quality of individual researchers, institutions and national research systems as a whole.

A widely-advocated strategy for helping universities improve research quality and output is international collaboration (ADB, 2011, 2012; Chapman et al., 2010; Chapman et al., in press 2013; Chapman and Sakamoto, 2010; Fraunhofer ISI, Idea Consult and SPRU, 2009; Glänzel and Schubert, 2004; Knight and de Wit, 1999). The basic premise is that, as university researchers from different countries work together, they are able to increase their productivity and, often, their creativity.

4.3.1 Tracking publication output and research collaboration

One of the most common ways to track scientific development is through the analysis of scientific publications affiliated with state and regional research institutions. The Association of Southeast Asian Nations (ASEAN) countries today represent the ninth largest economy in the world with a GDP of US$1.8 trillion. Since the initiation of ASEAN Vision 2020, which called for investments to be made in the development of a knowledge economy, attention was given to ways in which such development could be measured and inform science policy in the region (ASEAN, 1997).

Recent studies on science, technology and innovation development in the region indicate that large differences exist among the countries, specifically

Table 26. Main research questions and bibliometric indicators used in this study

Concepts	Main questions	Indicators
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 specialisation	In which subject fields does a country specialise?	Distribution of publication output based on Scopus' subject classification (26 main disciplines)
Distribution of publication output by institutional sector	How important are the various institutional sectors in research?	Distribution of publication output by four institutional sectors: higher education, government, private, and health
Global and regional collaboration	How frequently do Asian countries collaborate with each other and with countries outside the region?	The percentage share of a country's publication output co-authored with researchers abroad
State of scientific development	In what phase of its scientific development is a country?	Based on an experimental model taking into account the trend in a country's annual number of publications and the percentage share of internationally co-authored articles

between East and Southeast Asian countries, in terms of technological capabilities, R&D investments, training and employment, and scientific production (UNESCO, 2010; Degelsegger and Gruber, 2011). Moreover, several studies attempted to measure the value of knowledge creation in the area and the ways in which it translates to economic growth and prosperity. These studies used data on scientific publications and investments to assess the overall knowledge development in the region and inform science policy strategies (Dodgson et al., 2006; Nguyen and Pham, 2011; Rodriguez and Soeparwata, 2012). Findings indicate that scientific investment differs from country to country with foci in different areas.

A European Union Commission Report, which examined the extent of scientific collaboration between the European Union and Southeast Asian countries, indicates that, despite lack of funding, there is a great motivation for scientific collaborations within these countries (Degelsegger and Gruber, 2011). This motivation stems from an interest in knowledge-sharing, access to international publications, interest in building new institutes and reorganizing the higher education sector. The greatest motivation for international collaboration is the training of young researchers.

The study reported in this section examined the publication output of individual countries, the research areas in which they specialise, and trends in regional and global research collaboration in 26 countries or territories across Asia. The research questions and indicators applied in the following analysis are summarised in **Table 26**.

4.3.2 Methodology

This section analyses data on scientific publications extracted from Scopus, a multidisciplinary database covering about 19,400 peer-reviewed journals, 360 book series and 5.3 million conference papers in 2012 (Scopus, 2013). While most of these journals have international author and reader populations, a part is published from scientifically-emerging countries and is still more nationally-oriented.

Data on all publications indexed in the Scopus database were organized by country and sorted into three adjacent time periods: i) 1997-2001; ii) 2002-2007; and iii) 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. Within that, publications were coded to denote the number of co-authorships among authors from countries in the study set and with authors in countries outside the target countries. Publications were further categorised by authors' type of institutional affiliations, e.g. whether they were affiliated with a higher education institution, government, a private sector organization or employed in the health sector.

4.3.3 Results and discussion

Figure 28 indicates that the number of publications generated within a country increases in almost linear fashion with doctoral enrolment. This suggests that doctoral students play a key role in the production of a country's publication output.

Likewise, the number of authors from a country publishing research articles (at least in Scopus) increases with the number of full-time equivalent (FTE) researchers, although the number of authors grows more slowly than the number of FTE researchers *(see* ***Figure 29****).* One possible explanation is that larger countries have comparatively more FTE researchers to support their authors than smaller countries. In other words, publishing authors in larger countries are "richer" than their counterparts in smaller countries. A second explanation might be that the fraction of a country's total research capacity that is publishing articles in Scopus-covered journals declines as the country becomes more research-intensive. This is supported by the observation that 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. 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 increases sub-linearly with the number of FTE researchers.

4.3.3.1 A bibliometric model that describes the state of scientific development

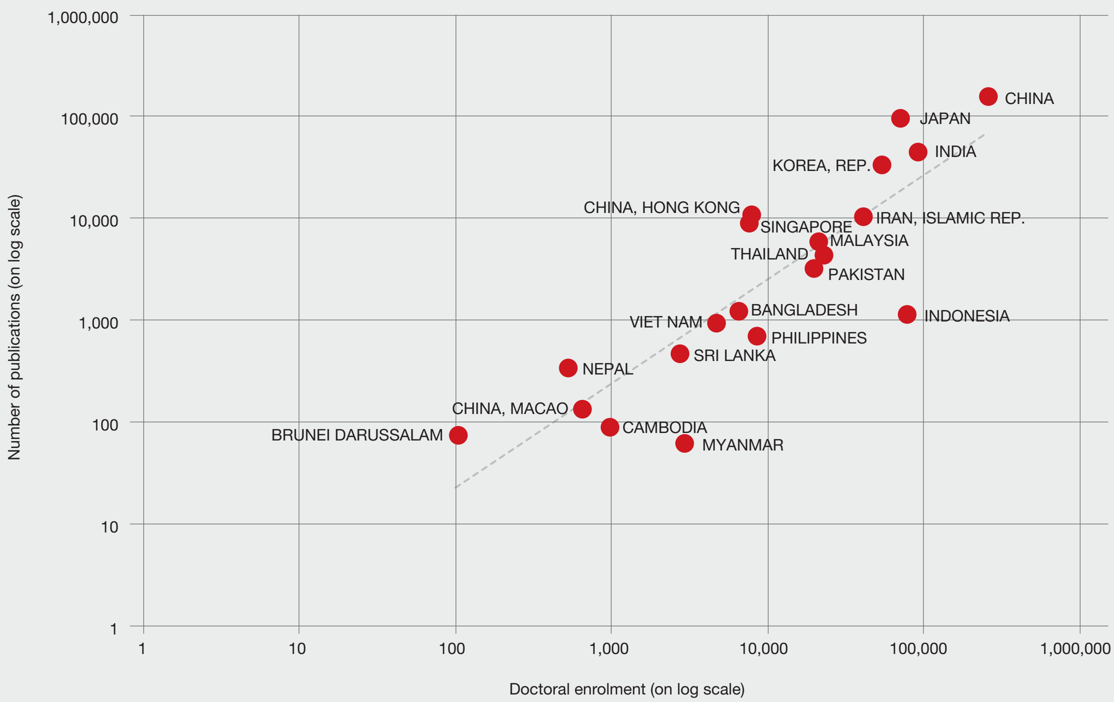
Bibliometric indicators based on publications in international, peer-reviewed journals can be used to characterise a country's scientific development. A simplified and experimental bibliometric model for different phases of development of a national research system distinguishes four phases: i) a pre-development phase; ii) building up; iii) consolidation and expansion; and iv) internationalisation. These phases are discussed below. 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. The share of a country's internationally co-authored articles, however, 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. International research is carried out by a limited number of researchers only. There is no clear policy and structural funding of research. Activities result from initiatives by a limited number of active researchers, who may sometimes 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.

2. ***Building up phase:*** Researchers in the country start establishing projects with foreign research teams, often funded by foreign or international agencies, and focus 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 is low and the internationally co-authored papers may be concentrated in particular years.

3. ***Consolidation and expansion phase:*** The country develops its own scientific

Figure 28. Number of publications indexed in Scopus in relation to doctoral enrolment by country or territory



Notes: The number of publications is measured by the average number of publications from a country indexed in Scopus per year during 1997-2012. Data on doctoral enrolment refer to 2011 or the most recent year available. The dashed line represents the best fit of a power law relationship of the form $P = kD^{\alpha}$, where P denotes publications, and D denotes doctoral enrolment. Plotting this functional relationship on a double logarithmic scale yields a straight line. The exponent α denotes the scaling parameter, which is represented by the slope of the straight line. If α=1, y increases linearly with x. If α>1, y increases superlinearly with x, indicative of a cumulative advantage. If α<1, y increases sublinearly with x, indicative of a cumulative disadvantage. The analytical result shows $P = 0.219D^{1.016}$, with R^2 (a measure of the goodness of fit of the power law relationship) is 0.736.

Sources: Researcher data by the UNESCO Institute for Statistics. Publication data by Scopus.

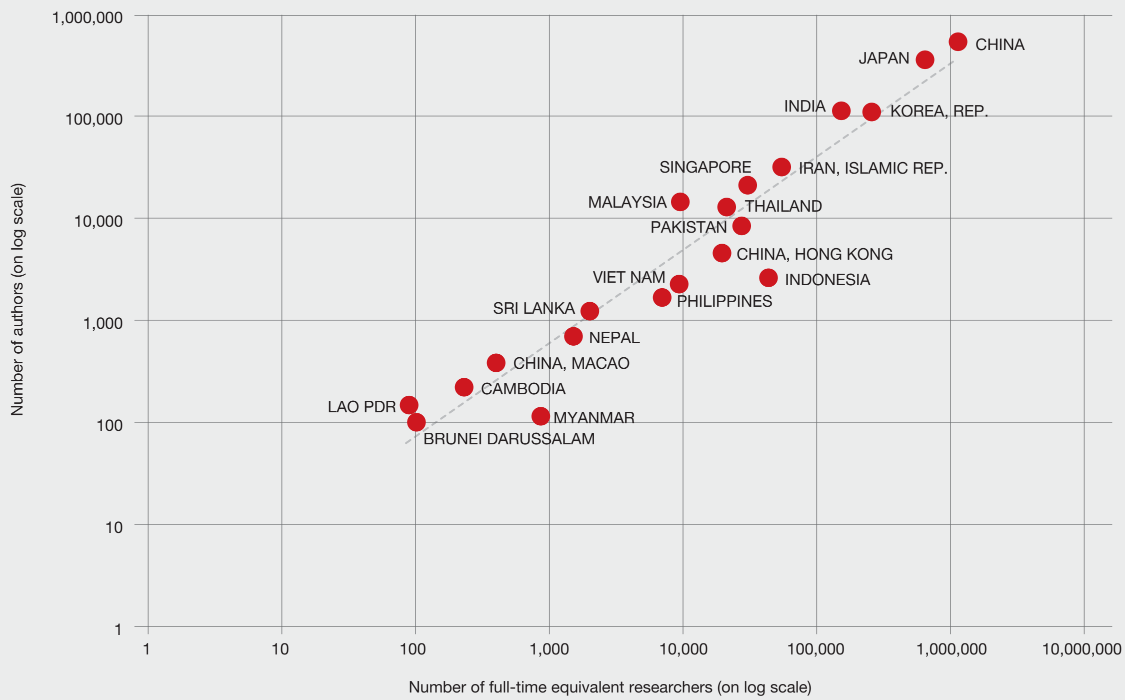
infrastructure. The amount of funds available for research increases. The national research capacity increases. Nationally-oriented journals internationalise and have a larger probability of being indexed in Scopus and other international scientific literature databases. More and more research papers 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. ***Internationalisation phase:*** National research capacity is further expanding, research institutions in the country start functioning as fully fledged partners, and increasingly take the lead in international collaborations. Overall impact increases; the country's researchers influence the global research agenda; the country increasingly becomes a world leader, at least in specific research domains. Both the number of publications and the share of internationally co-authored articles increase.

The trends in the annual values of the two key indicators – the number of published articles and the percentage of internationally co-authored papers – are summarised for each development phase in **Table 27**.

Table 27 reflects the discontinuities that the model assumes that take place in the indicator values over time when moving from one phase into another.

Figure 29. Number of authors of publications indexed in Scopus in relation to number of researchers by country or territory



Notes: Number of authors is measured by the average number of publishing authors from a country indexed in Scopus per year during 1997-2012. Data on FTE researchers refer to 2011 or the most recent year available. The dashed line represents the best fit of a power law relationship of the form $A = kF^{\alpha}$, where A denotes the number of authors, and F denotes the number of FTE researchers. The analytical result shows $A= 1.161F^{0.906}$, with $R^2 = 0.914$. For the meaning of the dashed line and the parameters in the functional relationship see the note of Figure 27.

Sources: Researcher data by the UNESCO Institute for Statistics. Publication data by Scopus.

The model is experimental and needs to be further validated and empirically tested. Its function in this study is not only analytic, in the sense that it provides a framework to roughly categorise countries in terms of scientific development and compare "like with like" rather than directly compare them on the basis of absolute numbers. It also serves to underline that the scientific and economic conditions in which a less-developed country finds itself at a certain moment is not static but can be viewed as a phase in a process that scientifically-developing countries have already started with great success.

From a bibliometric point of view, citation impact indicators should be added. In addition, international scientific collaboration is not only a matter of development; cultural and historical factors play a role as well. The development process that the model seeks to capture takes place during a time span that is much longer than the time period analysed in this study. Rather than following one particular country through all stages, this study tracks a series of countries during the most recent ten-year period and draws hypotheses

Table 27. Schematic overview of trends in bibliometric indicators per development phase

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.

Source: Authors

Table 28. Country classifications based on the trend in the percentage of international co-authored publications between 2003 and 2012

Trend[a]	Country or territory by income level[b]		
	High income	Middle income	Low or lower-middle income
Positive	▪ China, Hong Kong ▪ Japan ▪ Singapore		▪ Cambodia ▪ Nepal ▪ Pakistan
Negative		▪ China ▪ Indonesia ▪ Iran, Islamic Rep. ▪ Malaysia ▪ Philippines ▪ Thailand ▪ Viet Nam	▪ Bangladesh ▪ Myanmar
No significant trend	▪ Brunei Darussalam ▪ Korea, Rep.	▪ India ▪ Sri Lanka ▪ Maldives	▪ Afghanistan ▪ Bhutan ▪ Korea, DPR ▪ Lao PDR

Notes: a) Trends in a country's percentage share of internationally co-authored papers are identified on the basis of a linear regression model with the publication year as an independent variable. A trend is labeled positive (negative) if the linear regression coefficient is significantly positive (negative) at the 95% confidence level.

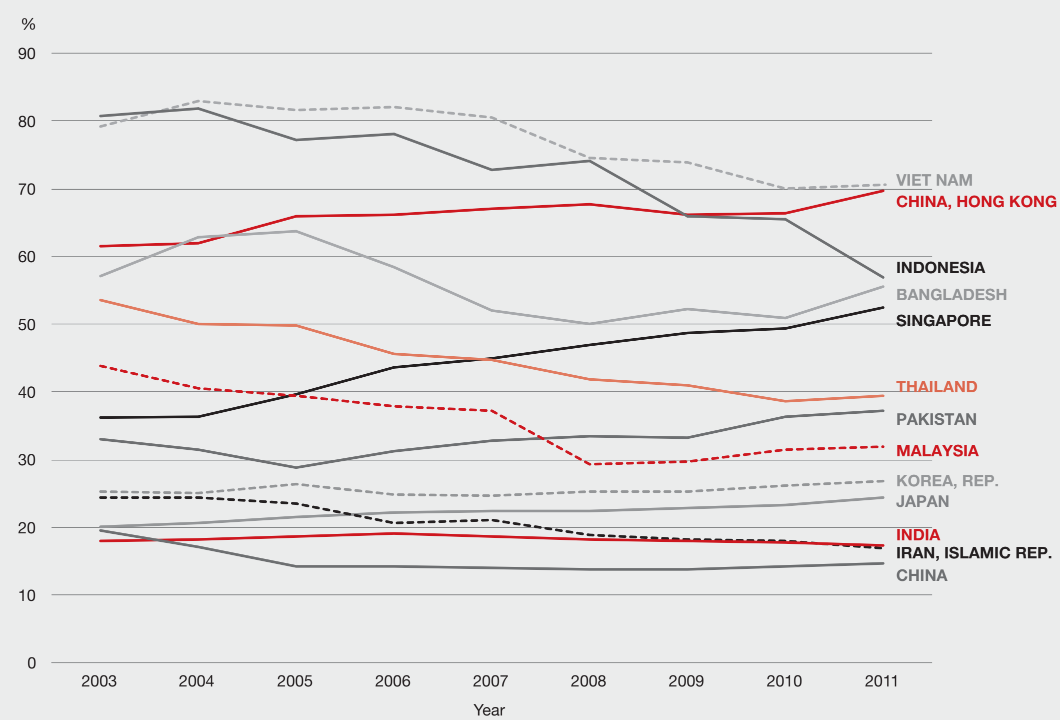
b) Country by income level is based on the World Bank classification 2012.

Source: Scopus

on the current phase of a country's development on the basis of the assertions made in the development model.

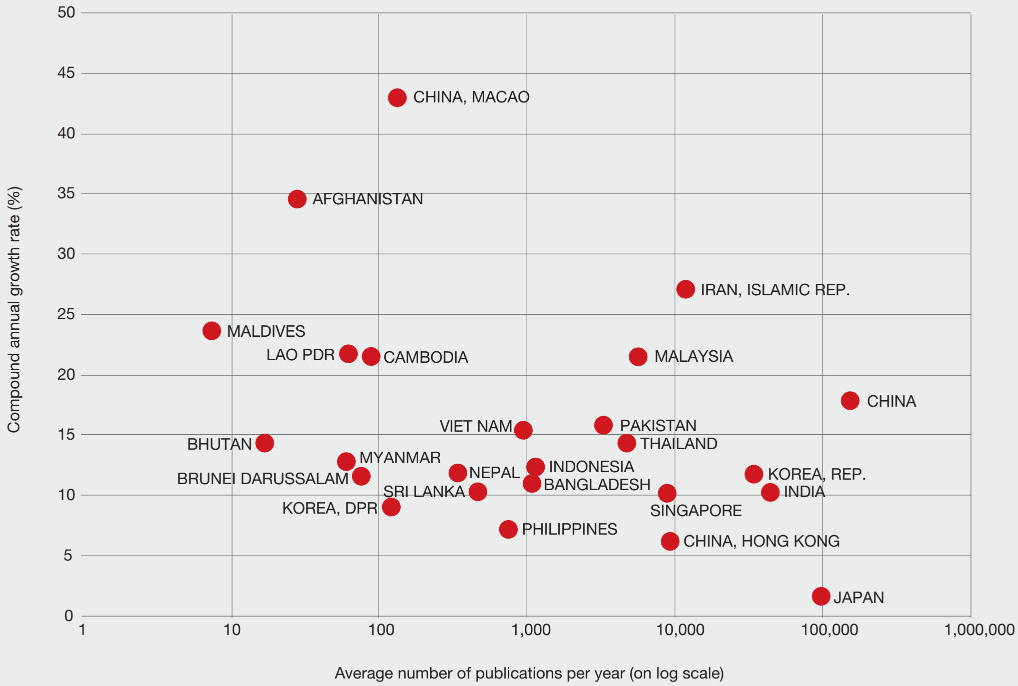
Table 28 compares a classification of countries according to the model based on income. Three out of five high-income countries or territories show a positive trend in international co-authorship. Seven middle-income countries or territories show a significant decline in the percentage of internationally co-authored articles, and none shows a significant positive trend. A decline trend is a sign of the consolidation and expansion phase in scientific development which is apparently dominant in middle-income countries. The fact that low- or lower middle-income countries are spread over the three trend categories is partly due to the low annual publication counts for these countries. The trend in the percentage of internationally co-authored papers for 13 countries is presented in **Figure 30**.

Figure 30. Trends in the percentage of internationally co-authored articles in selected countries or territories, 2003-2011



Source: Scopus **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f33

Figure 31. Number and annual growth rate of publications indexed in Scopus by country or territory, 1997-2012



Note: The compound annual growth rate (CAGR) is defined as $\sqrt[(2012-2007)]{(P2/P1)} - 1$, where P1 and P2 denote the number of publications made from a country in 1997 and 2012 respectively.
Source: Scopus **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f31

4.3.3.2 Publication output

There has been a considerable increase in scientific output across Asian countries over the last decade. **Figure 31** shows the annual growth rate of scientific publications by country. These data show significant differences among countries in their average number of publications per year, by up to 400%. Among countries with more than 1,000 papers per year, the largest output originates from China. However, the Islamic Republic of Iran, Malaysia and Pakistan have a compound annual growth rate above 15%.

4.3.3.2 Disciplinary specialisation

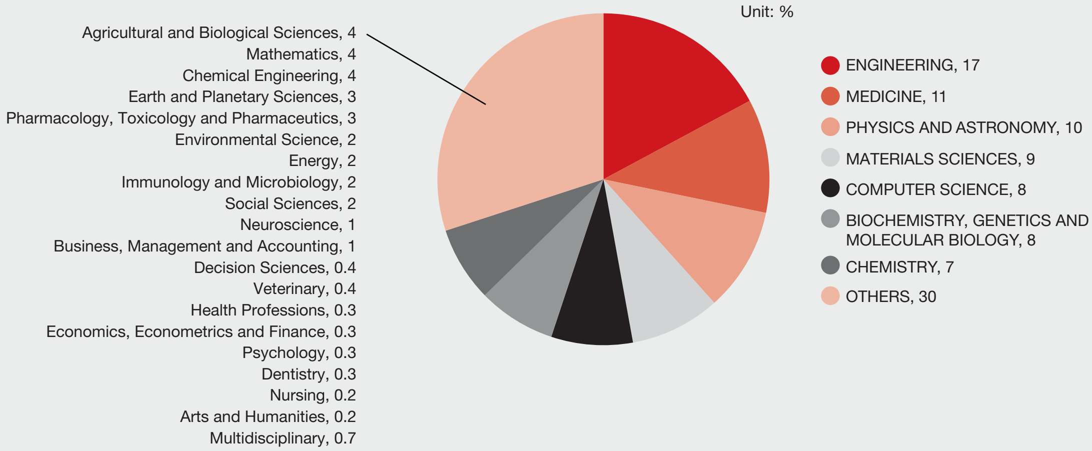
The major disciplinary foci of the region are concentrated around Engineering, Medicine, Physics and Astronomy, Material Sciences, Computer Science, Biotechnology and Chemistry *(see **Figure 32**)*.

The area showing the greatest growth between 1997 and 2012 has been Arts and Humanities, Computer Science, and Nursing, while the least growth has been in Neuroscience, Health Professions and Veterinary *(see **Figure 33**)*.

4.3.3.3 Publication output by institutional sector

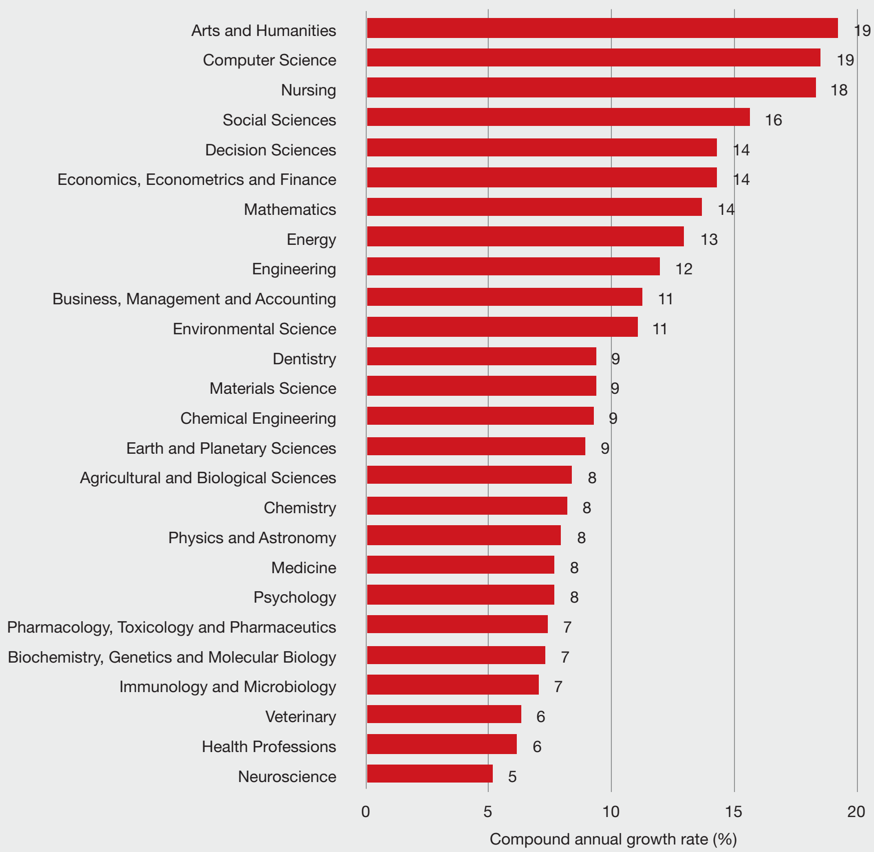
Table 29 illustrates for each country a rough indication of the percentage share of articles produced by researchers working in the higher education sector, as opposed to other sectors of the economy. These data draw on work conducted by the Scimago group, which created the Scimago Institute Rank. In constructing this ranking system, considerable effort has been made to standardise institutional names and assign institutions to sectors (e.g. higher education, government, private sector, health and others). This table shows that large

Figure 32. Distribution of publications by discipline in the Asian countries analysed in the study, 1997-2012



Source: Scopus **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f32

Figure 33. Growth rate of publications by discipline in the Asian countries analysed in the study, 1997-2012



Source: Scopus **DataLink** http://dx.doi.org/10.15220/2014/ed/sd/2/f33 differences exist in the size of the relative contribution of the higher education sector among the countries in the study set. The implication is that care should be taken in drawing conclusions about the state of a country's scientific development merely on the basis of its universities in world rankings. Government-funded research institutes are not included in such rankings. This also justifies the need to use the GRBS that focuses on academic institutions (discussed in Part 2 of Chapter 4) to evaluate nationwide research performance.

Table 29. Proportion of publications produced by the higher education sector in selected countries or territories

%	Country or territory
0-20	Afghanistan; Cambodia; Lao PDR; Korea, DPR
20-40	Bhutan
40-60	Myanmar; Nepal; Viet Nam
60-80	Bangladesh; Brunei Darussalam; Indonesia; India; Sri Lanka; Philippines; Singapore
80-100	China; China, Hong Kong; China, Macao; Japan; Korea, Rep.; Malaysia; Pakistan; Thailand; Timor-Leste

Source: Scimago Institute

4.3.3.4 International collaboration in research

There are tight co-authorship networks within Asia, as seen in **Figure 34**. Within the three clusters of research collaboration, the first cluster includes China, Hong Kong Special Administrative Region of China, Singapore and Macao Special Administrative Region of China which constitute the East Asian region. As can be seen, China also serves as a link between Hong Kong Special Administrative Region of China, Macao Special Administrative Region of China and Singapore to other members of the region, such as Japan, India and Thailand. For the most part, this cluster focuses on the areas of Engineering, Physics and Astronomy, and Computer Science.

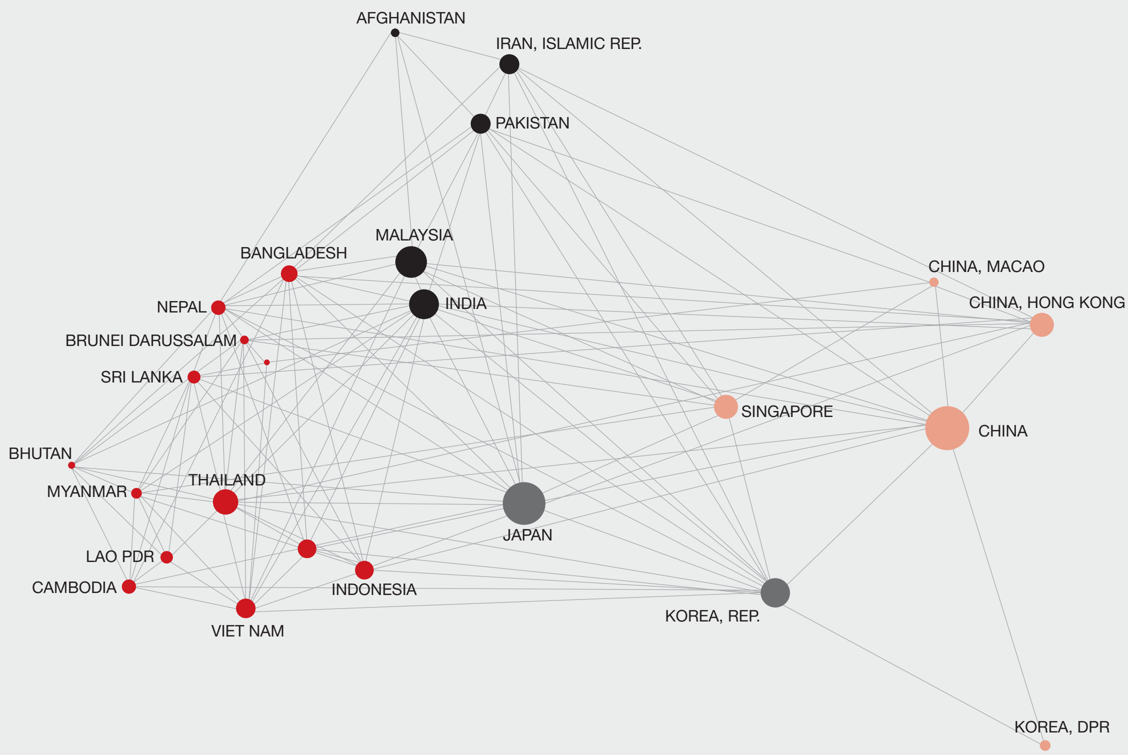
The second cluster, which includes India, Malaysia, Pakistan, the Islamic Republic of Iran and Afghanistan, constitutes the South Asian region and focuses on Medicine, Agriculture, Chemistry and Engineering. The third cluster, which includes Thailand as its centre, closely connects Indonesia, Bangladesh, Sri Lanka, Brunei Darussalam, Nepal, Lao People's Democratic Republic, Cambodia, Viet Nam and Myanmar, which together constitute the Southeast Asian region. This cluster focuses mostly on Agriculture, Medicine and Earth Sciences. Finally, the map shows that the Republic of Korea plays an essential role in bridging the Democratic People's Republic of Korea and other countries.

When tracking the evolution of research collaboration within the Asia region from 1997 onwards, the network maps show how countries have moved into a much tighter and more active collaborative network. In particular, the clusters surrounding India and Thailand have come closer together, in addition to Japan. In the period between 2008 and 2012, the collaborative efforts within the region have tightened even more and reflect the participation of smaller countries in scientific collaboration. Over this period, Bhutan, Cambodia, Nepal and Sri Lanka took a more prominent place in the scientific fabric of the region. As might be expected, countries entering this collaboration align with the cluster's strongest disciplinary foci. Thus, Bhutan can be seen focusing on Agriculture and Medicine, which are the main foci in Thailand. The same is true for Cambodia and Nepal.

Research collaboration between Asian and Western countries

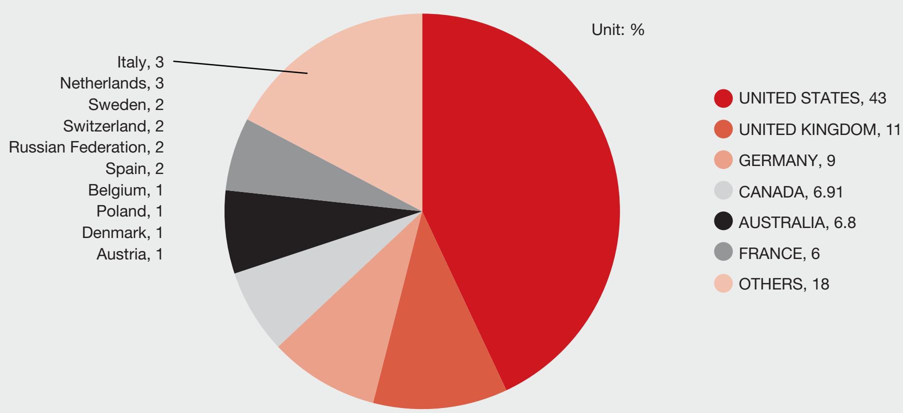
The patterns in co-authorship for the region show a high percentage of collaborative research between the target Asian countries and Australia, Canada, France, Germany, the United Kingdom and the United States as shown in **Figure 35** which is based on the absolute number of co-publications between two countries. This means that there is a tendency that a particular study country will have a larger number of co-publications with a large country than with a small country. A size-normalised strength measure of the relationship between two countries is presented shortly.

Figure 34. Co-authorship networks within Asia, 2008-2012



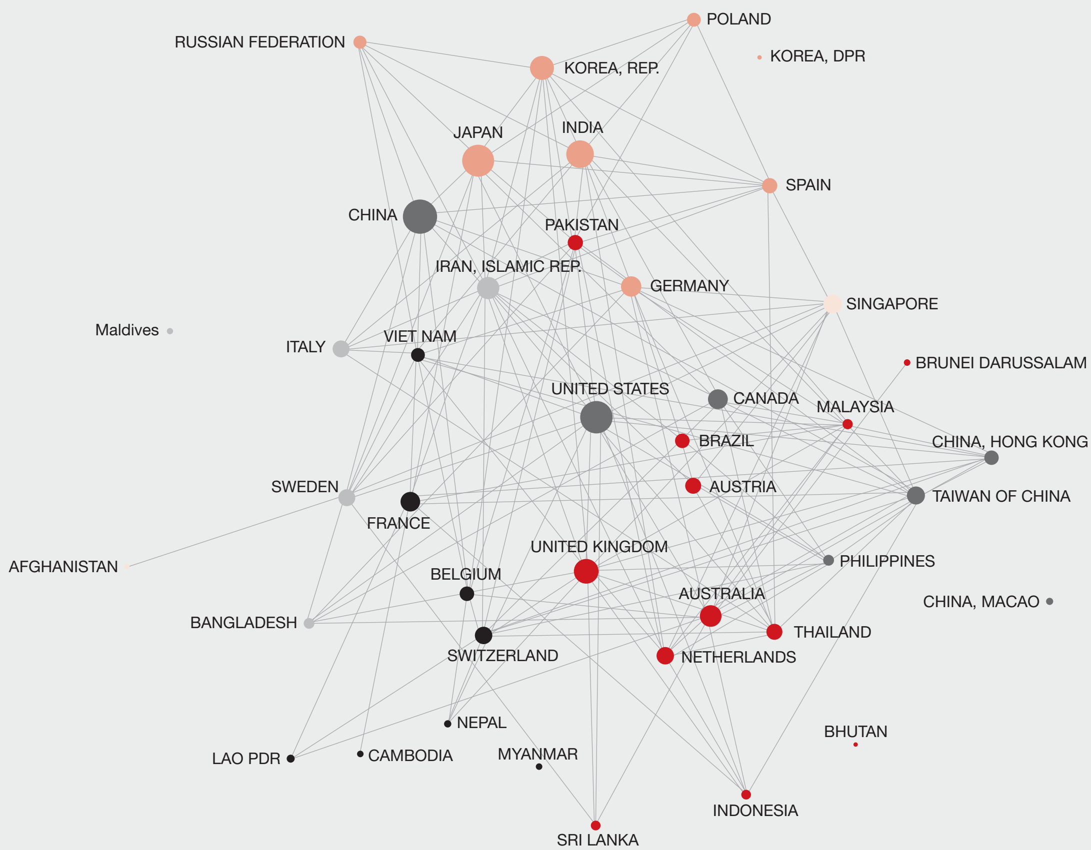
Notes: The map was re-produced from the output of VOS Viewer (http://www.vosviewer.com/), to create and explore maps based on network data. The distance between two countries reflects the strength of the scientific cooperation between the countries. A smaller distance indicates a stronger relation. The colours reflect different clusters based on a clustering routine implemented in VOS viewer. The size of circles reflects the weights of a country in co-authorship.

Figure 35. Distribution of collaboration partners on co-authored publications with Asian countries by collaboration partner countries outside the region, 1997-2012



Source: Scopus

Figure 36. International co-authorships between selected Asian and Western countries, 2008-2012



Notes: The map was re-produced from the output of VOS Viewer (http://www.vosviewer.com/), to create and explore maps based on network data. The distance between two countries reflects the strength of the scientific cooperation between the countries. A smaller distance indicates a stronger relation. The colours reflect different clusters based on a clustering routine implemented in VOS viewer. The size of circles reflects the weights of a country in co-authorship.

As illustrated in **Figure 36**, there are four pockets of international collaboration in the Asia region. Canada, Germany, Italy, Spain and the United States 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 Belgium, France and Switzerland, with Southeast Asian countries that display lower scientific output with the international community. The United Kingdom also serves as a bridge between Bangladesh, Bhutan, Cambodia, Lao People's Democratic Republic, Myanmar, Nepal and the European scientific community. Australia forms a third circle of collaborations, bridging across Brunei Darussalam, Indonesia, Malaysia, the Philippines and Sri Lanka. The Russian Federation is somewhat on the outliner forming single collaborations with India, Japan, Pakistan and the Republic of Korea.

When tracking the evolution of research collaboration between Asian and Western countries between 1997 and 2001, the international collaborative network was rather tightly concentrated around the more scientifically-active countries in the region. Canada and the United States were remotely connected to China, India and Nepal, while being closely connected to Hong Kong Special Administrative Region of China, Singapore and Taiwan of China. The more scientifically-active countries, such as China, Japan, Pakistan and the Republic of Korea,

Table 30. Main research disciplinary specialisation and collaboration partners, 1997-2012

Country or territory	Compound annual growth rate of publications (%)	Main scientific foci			Main international collaboration countries		
		1997-2001	2002-2007	2008-2012	1997-2001	2002-2007	2008-2012
AFGHANISTAN	34.6	Medicine	Medicine	Medicine	United Kingdom	United Kingdom	United Kingdom
		Social Sciences	Social Sciences	Social Sciences	United States	United States	United States
		Engineering	Engineering	Agriculture	Belgium	Switzerland	Pakistan
BANGLADESH	11	Medicine	Medicine	Medicine	United Kingdom	Japan	Japan
		Agriculture	Agriculture	Agriculture	United States	United States	United States
		Engineering	Engineering	Engineering	Japan	United Kingdom	United Kingdom
BHUTAN	14.3	Agriculture	Agriculture	Agriculture	Lao PDR	India	Australia
		Environmental Sciences	Environmental Sciences	Medicine	Philippines	United Kingdom	Thailand
		Social Sciences	Earth and Planetary Sciences	Environmental Sciences	India	Australia	United States
BRUNEI DARUSSALAM	11.7	Medicine	Medicine	Medicine	Australia	Australia	Malaysia
		Environmental Sciences	Engineering	Social Sciences	United States	United Kingdom	United States
		Earth and Planetary Sciences	Earth and Planetary Sciences	Agriculture	United Kingdom	United States	Australia
CAMBODIA	21.5	Medicine	Medicine	Medicine	United States	United States	United States
		Agriculture	Immunology and Microbiology	Agriculture	Australia	France	Thailand
		Social Sciences	Agriculture	Immunology and Microbiology	Philippines	Australia	France
CHINA	17.8	Engineering	Engineering	Engineering	United States	United States	United States
		Physics and Astronomy	Physics and Astronomy	Computer Science	Japan	China, Hong Kong	Japan
		Materials Sciences	Materials Sciences	Physics and Astronomy	China, Hong Kong	Japan	China, Hong Kong
CHINA, HONG KONG	6.2	Engineering	Engineering	Engineering	China	China	China
		Medicine	Medicine	Computer Science	United States	United States	United States
		Physics and Astronomy	Computer Science	Medicine	United Kingdom	United Kingdom	Australia
CHINA, MACAO	43.3	Engineering	Computer Science	Computer Science	China	China	China
		Computer Science	Engineering	Engineering	China, Hong Kong	China, Hong Kong	China, Hong Kong
		Agriculture	Mathematics	Medicine	Portugal	United States	United States
INDIA	10.3	Medicine	Medicine	Medicine	United States	United States	United States
		Chemistry	Chemistry	Engineering	Germany	Germany	United Kingdom
		Physics and Astronomy	Engineering	Chemistry	United Kingdom	United Kingdom	Germany
INDONESIA	12.3	Agriculture	Agriculture	Engineering	Argentina	Algeria	Albania
		Medicine	Medicine	Agriculture	Australia	Angola	Algeria
		Earth and planetary Sciences	Engineering	Computer Science	Austria	Argentina	Argentina
JAPAN	1.7	Medicine	Medicine	Medicine	United States	United States	United States
		Biochemistry	Engineering	Engineering	Germany	China	China
		Physics and Astronomy	Physics and Astronomy	Physics and Astronomy	United Kingdom	Germany	Germany
KOREA, DPR	9.1	Engineering	Engineering	Engineering	Republic of Korea	Republic of Korea	Republic of Korea
		Physics and Astronomy	Computer Science	Computer Science	United States	United States	China
		Computer Science	Physics and Astronomy	Materials Sciences	Japan	China	Germany

Country or territory	Compound annual growth rate of publications (%)	Main scientific foci			Main international collaboration countries		
		1997-2001	2002-2007	2008-2012	1997-2001	2002-2007	2008-2012
KOREA, REP.	n.a.	Engineering	Engineering	Engineering	United States	United States	United States
		Physics and Astronomy	Physics and Astronomy	Medicine	Japan	Japan	Japan
		Materials Sciences	Materials Sciences	Physics and Astronomy	China	China	China
LAO PDR	21.7	Medicine	Medicine	Medicine	Japan	Thailand	Thailand
		Agriculture	Agriculture	Agriculture	Thailand	United States	United Kingdom
		Immunology and Microbiology	Immunology and Microbiology	Immunology and Microbiology	United States	United Kingdom	Australia
MALAYSIA	21.5	Medicine	Engineering	Engineering	United Kingdom	United Kingdom	United Kingdom
		Agriculture	Medicine	Computer Science	United States	United States	India
		Engineering	Biochemistry	Physics and Astronomy	China	Japan	Australia
MALDIVES	23.6	Agriculture	Medicine	Earth and Planetary Sciences	India	United States	India
		Earth and Planetary Sciences	Earth and Planetary Sciences	Agriculture	Germany	Australia	New Caledonia
		Medicine	Agriculture	Medicine	United States	Japan	Nepal
MYANMAR	12.8	Medicine	Medicine	Computer Science	Japan	Japan	Japan
		Immunology and Microbiology	Agriculture	Medicine	Thailand	United States	Thailand
		Agriculture	Engineering	Agriculture	Australia	Thailand	United States
NEPAL	11.8	Medicine	Medicine	Medicine	United States	United States	India
		Agriculture	Agriculture	Agriculture	United Kingdom	India	United States
		Environmental Sciences	Environmental Sciences	Environmental Sciences	India	Japan	United Kingdom
PAKISTAN	15.8	Medicine	Medicine	Medicine	United States	United States	United States
		Agriculture	Agriculture	Agriculture	United Kingdom	United Kingdom	United Kingdom
		Chemistry	Engineering	Physics and Astronomy	Germany	Germany	China
PHILIPPINES	7.3	Agriculture	Agriculture	Agriculture	United States	United States	United States
		Medicine	Medicine	Medicine	Japan	Japan	Japan
		Biochemistry	Social Sciences	Social Sciences	Australia	Australia	Australia
SINGAPORE	10.2	Engineering	Engineering	Engineering	United States	United States	United States
		Physics and Astronomy	Physics and Astronomy	Computer Science	China	China	China
		Medicine	Computer Science	Medicine	United Kingdom	Australia	Australia
SRI LANKA	10.4	Agriculture	Medicine	Medicine	United Kingdom	United Kingdom	United Kingdom
		Medicine	Agriculture	Agriculture	United States	United States	Australia
		Environmental Sciences	Environmental Sciences	Computer Science	Japan	Japan	United States
THAILAND	14.5	Medicine	Medicine	Medicine	United States	United States	United States
		Agriculture	Engineering	Engineering	Japan	Japan	Japan
		Engineering	Agriculture	Agriculture	United Kingdom	United Kingdom	United Kingdom
VIET NAM	15.5	Agriculture	Medicine	Computer Science	France	Japan	Japan
		Medicine	Agriculture	Engineering	Japan	United States	United States
		Physics and Astronomy	Physics and Astronomy	Medicine	United States	France	Korea, Rep.

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collaborate closely and form a cluster with Italy, Poland and Spain. The United Kingdom forms a cluster very similar to the one shown in the overall map as does the Russian Federation. Afghanistan, Bhutan, the Democratic People's Republic of Korea, Lao People's Democratic Republic and Maldives are somewhat solitary and less active in the international collaborative community.

During 2002 to 2007, there was an expansion of international collaboration in the region. Afghanistan, Bhutan, the Democratic People's Republic of Korea, Lao People's Democratic Republic and Maldives, which had previously been somewhat outside of the network, became more closely connected to the within-region and international networks. Additionally, the Democratic People's Republic of Korea, which was not a part of the network, is now showing collaborative patterns through the Republic of Korea and the Russian Federation.

Between 2008 and 2012, a wider network had developed, with outlier countries more connected to both the within-region and international networks. Most notably, Bhutan, Cambodia, Myanmar, Nepal, Lao People's Democratic Republic and Sri Lanka entered into more international and within-region collaborations.

4.3.3.5 Highlights of country research trends

Table 30 summarises for each country in the region the increase in publication rates, their top three disciplinary foci over three periods of time between 1997 and 2012, and the extent of international research collaboration *(see **Appendix VII** for the highlights)*. For each country and year, the growth in the number of publications is calculated as the compound annual growth rate (CAGR).

4.3.4 Conclusions

Publishing in scientific journals is a primary mechanism through which researchers make their findings known to colleagues in their field, contribute to scientific progress, and draw on the experience of others to inform national development in their own countries. Publishing also plays an important role in international scientific networking and serves as a quality marker in assessments of institutional quality of higher education institutions. It is significant, then, that between 1997 and 2012 there has been a substantial increase in scientific output across Asian countries. At the same time, there are large differences between individual countries within the region. China has been a leader in increased scientific output, though other countries also showed impressive gains. For example, Malaysia and Pakistan had a compound annual publication growth rate of over 15% during that time.

The majority of publications focused on just a few disciplinary clusters. For example, China, Hong Kong Special Administrative Region of China, Singapore, India, Japan, Malaysia and the Republic of Korea have been leaders in conducting research in Engineering, Physics and Astronomy, Material and Computer Sciences. Cambodia, Lao People's Democratic Republic, Nepal and Thailand conduct considerable research on Medicine. Bhutan, Maldives and the Philippines conduct an impressive amount of research in Agriculture. These research areas have been quite stable and show constant activity through the years without significant changes.

Bibliometric analysis yield evidence of an increasing amount of scientific collaboration between countries within the region, as well as significant growth in international collaborations with the wider international scientific community. The regional co-authorship networks show that smaller countries just entering the scientific arena, such as Bhutan, Nepal and Sri Lanka, increasingly collaborate with larger countries in the region, thus gaining expertise and increased output. These countries also used these collaborations as a bridge to the international scientific community. Larger countries, such as China, Japan, and Thailand, show increased international collaboration ties in the form of co-authorships and are functioning as hubs for smaller countries in their international scientific endeavors.

Chapter 5

SUMMARY AND CONCLUSIONS

David Chapman and Chiao-Ling Chien

Middle-income countries across Asia have experienced explosive growth in undergraduate enrolment. To accommodate this increase, higher education systems have expanded out as countries have built more universities and hired more instructional staff. While extending access, this expansion put new financial pressure on many governments. In responding to these financial pressures, governments have sought ways to lower the cost of instruction in public universities and shift more of the cost of higher education to students and their families. Among other things, this has led many governments to allow and encourage the growth of private higher education.

These increases in undergraduate enrolment in public and private higher education institutions led to an enormous demand for additional instructional staff. It also created a demand for upgrading the preparation of existing instructors, in cases where underqualified personnel had been hired in a quick response to the fast-growing enrolment. So to expand out, higher education systems had to expand up. To meet the demand for additional and better prepared instructional staff, most middle-income countries across Asia have ventured into the provision of graduate education.

While the need for more and better-qualified instructional staff was the primary motivator for the expansion of graduate education in the region, governments began to promote university-based research as a route to national economic development. However, in many countries there is a very limited labour market demand for PhD graduates in the private sector. Universities were able to expand graduate programmes in order to incorporate this research agenda, in large part, because graduates – particularly at the doctoral level – have been able to find employment as instructors in higher education institutions. A possible implication of this pattern is that, as the demand for new university instructors tapers off, the economics of university-based research may need to find new legs.

Still, the willingness of governments to support the expansion of graduate education has been largely tied to the belief that it would promote more university-based research that would eventually pay off in national economic development. The tacit (or not so tacit) theory of change at the heart of some governments' willingness to financially support graduate education is that: i) research and innovation are the drivers of national economic development; and ii) in return for their public funding, universities should operate as centres of such research, which typically occurs in graduate programmes. Hence, some government and university personnel see a fairly direct line between the expansion of graduate education and national economic development. The prevalent belief is that investing in higher education will lead to an educated workforce and that, as evidence of an educated workforce becomes known, it will attract international investment that will contribute to the economic development of the nation.

A way to signal top-quality higher education is for a country's top universities to place high in international rankings. Rankings depend heavily on research productivity, widely measured by faculty publication rates. So there is a tendency for governments to pressure universities to raise their international standing, while university administrators pressure faculty to do more research. A secondary hope is that the commercialisation of university-based research can be a meaningful source of income for universities, thereby reducing their need for public funding. This can lead to a preference on campus for applied rather than basic research.

Universities have sought to raise research and publication rates by modifying incentive systems for individual faculty members and by creating structural arrangements that can facilitate more publication output. At the level of individual incentives, universities may offer bonuses for publications in top journals. In terms of organizational arrangements, a widely-advocated strategy for helping universities improve research quality and output is international collaboration. The premise is that, as university researchers from different countries work together, they are able to increase their productivity. Patterns of research collaboration across Asia were reported in this study. As such collaboration appears to be an effective way to boost both productivity and quality in university-based research, incentive systems may need to more fully acknowledge the value of collaboration in their reward structures.

While there is considerable evidence that countries that spend more on research benefit from the investment financially, that linkage can be complicated. In many countries, most research is not done at universities but by private sector enterprises. One reason is that private sector enterprises are reluctant to outsource their research. They tend to want proprietary rights over new findings that might have commercial applications. There are also a variety of contextual factors, such as unfavorable tax laws and limited access to capital, which may limit the economic return on university-based research. It is not clear, then, that university-based research necessarily leads to the economic payoffs that governments expect.

The emphasis on international university rankings warrants a closer look at ranking systems. One observation is that ranking systems tend to be based on overall institutional performance. Yet, as this report has shown, pockets of excellence can be found across a wide range of universities, not just in those that place near the top in world rankings. If governments are consolidating funding to support top-tier, world-class universities, they may be missing the subtler, but still substantial, contributions to high-quality research being made by a wider set of higher education institutions. One implication is that governments may benefit by targeting their research support to a swath of universities that may not yet have earned a position in the top overall rankings but which are doing particularly good work in niche areas. Governments and universities need to give greater recognition and support to these pockets of excellence in their efforts to garner international attention.

Every country has to find its own balance between expanding out and expanding up. The goal of this report is to provide further data and ideas relevant to those considerations.

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CHAPTER 4

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Appendix I

DEFINITIONS

Business enterprise sector in the context of R&D statistics includes: all firms, organizations and institutions whose primary activity is the market production of goods or services (other than higher education) for sale to the general public at an economically significant price; and the private non-profit institutions mainly serving them. This also includes public enterprises.

Distribution of R&D expenditure by type of activity. Total domestic intramural expenditure on R&D during a given period, broken down by different types of R&D activities (i.e. basic research, applied research and experimental development).

> **Basic research:** Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
>
> **Applied research:** Original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.
>
> **Experimental development:** Systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices; installing new processes, systems and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units.

Distribution of researchers by field of science. Number of researchers broken down by the fields of science and technology in which researchers carry out their main R&D activity. The fields included are: Natural Sciences; Engineering and Technology; Medical and Health Sciences; Agricultural Sciences; Social Sciences and Humanities.

> **Natural Sciences:** mathematics; computer and information sciences; physical sciences; chemical sciences; earth and related environmental sciences; biological sciences; and other natural sciences.
>
> **Engineering and Technology:** civil engineering; electrical, electronic, information engineering; mechanical engineering; chemical engineering; materials engineering; medical engineering; environmental engineering; environmental biotechnology; industrial biotechnology; nano-technology; and other engineering and technologies.
>
> **Medical and Health Sciences:** basic medicine; clinical medicine; health sciences; health biotechnology; and other medical sciences.

Agricultural Sciences: agriculture, forestry, and fishery; animal and dairy science; veterinary sciences; agricultural biotechnology; and other agricultural sciences.

Social Sciences: psychology; economics and business; educational sciences; sociology; law; political science; social and economic geography; media and communications; and other social sciences.

Humanities: history and archaeology; languages and literature; philosophy, ethics and religion; art; and other humanities.

For more information, see the "Revised fields of science and technology classification" in the Frascati Manual.

Education finance

Total public expenditure per student by education level as a percentage of GDP per capita. Total public expenditure per student in the specified level of education expressed as a percentage of GDP per capita.

Total public expenditure per student by education level in PPP dollars. Total public expenditure per student in the specified level of education expressed in U.S. dollars and adjusted in terms of purchasing power parity (PPP).

Total public expenditure on education as a percentage of GDP. Current and capital expenditure on education by local, regional and national governments, including municipalities (household contributions are excluded), expressed as a percentage of GDP.

Public expenditure on tertiary education as a percentage of total public education expenditure. Current and capital expenditure on education by local, regional and national governments, including municipalities (household contributions are excluded), expressed as a percentage of total government expenditure on all sectors (including health, education, social services, etc.).

Educational institutions (public and private). Educational institutions are defined as entities that provide instructional or education-related services to individuals and other educational institutions. Whether or not an entity qualifies as an educational institution is not contingent upon which public authority (if any) has responsibility for it. These are classified as either *public* or *private* according to whether a public agency or private entity has the ultimate power to make decisions concerning the institution's affairs.

An institution is classified as *public* if it is controlled and managed directly by a public education authority or agency; or controlled and managed either by a government agency directly or by a governing body (council, committee, etc.), most of whose members are either appointed by a public authority or elected by public franchise.

An institution is classified as *private* if it is controlled and managed by a non-governmental organization (e.g. a church, trade union or business enterprise), or if its governing board consists mostly of members not selected by a public agency. In general, the ultimate management control over an institution rests with who has the power to determine the general activity of the school and appoint the managing officers. The extent to which an institution receives its funding from public or private sources does not determine the classification status of the institution.

Enrolment. The number of students officially enrolled in a higher education institution, regardless of age.

Fields of education (broad)

Agriculture: agriculture, forestry and fishery; veterinary science.

Education: teacher training; education science.

Engineering, Manufacturing and Construction: engineering and engineering trades; manufacturing and processing; architecture and building.

Health and Welfare: medicine; medical services; nursing; dental services; social care; social work.

Humanities and Arts: religion and theology; foreign languages and cultures; native languages; interpretation and translation; linguistics; comparative literature; history; archaeology; philosophy; ethics. Fine arts; performing arts; graphic and audio-visual arts; design; craft skills.

Science: life sciences; physical sciences; mathematics and statistics; computer sciences.

Social Science, Business and Law: social and behavioural science; journalism and information; business and administration; law.

Services: personal services; transport services; environmental protection; security services.

Full-time equivalence (FTE) (for R&D data). Full-time equivalence (FTE) R&D data are a measure of the actual volume of human resources devoted to R&D and are especially useful for international comparisons. One full-time equivalent may be thought of as one person-year. Thus, a person who normally spends 30% of time on R&D and the rest on other activities (such as teaching, university administration and student counselling) should be considered as 0.3 FTE. Similarly, if a full-time R&D worker is employed at an R&D unit for only six months, this results in an FTE of 0.5.

Gender parity index (GPI). The ratio of female-to-male values of a given indicator. A GPI of 1 indicates parity between the sexes.

Government sector in the context of R&D statistics includes: All departments, offices and other bodies which furnish, but normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community. Public enterprises are included in the business enterprise sector. It also includes the non-profit institutions controlled and mainly financed by government but not administered by the higher education sector.

Graduate. A person who has successfully completed the final year of a level or sub-level of education.

Gross domestic expenditure on R&D (or total domestic intramural expenditure on R&D). Intramural expenditure is all expenditure on R&D performed within a statistical unit or sector of the economy during a specific period, whatever the source of funds.

Gross domestic expenditure on R&D as a percentage of GDP. Gross domestic expenditure on R&D (GERD) as a percentage of GDP is the total intramural expenditure on R&D performed in a national territory or region during a given year, expressed as a percentage of GDP of the national territory or region. It is the sum of gross value added by all resident producers in the economy, including distributive trades and transport, plus any product taxes and minus any subsidies not included in the value of the products.

Gross domestic expenditure on R&D per capita in constant PPP$. Gross domestic expenditure on R&D (GERD) per capita in constant purchasing power parity dollars is the total intramural expenditure on R&D performed in a national territory or region during a given year, expressed in PPP$ in constant prices per person, i.e. divided by total population of the national territory or region.

Gross domestic product (GDP). The sum of gross value added by all resident producers in the economy, including distributive trades and transport, plus any product taxes, minus any subsidies not included in the value of the products.

Gross domestic product (GDP) per capita. The gross domestic product divided by mid-year population.

Gross enrolment ratio (GER). The number of pupils or students enrolled in a given level of education, regardless of age, expressed as a percentage of the population in the theoretical age group for the same level of education. For the tertiary level, the population used is the five-year age group following the official secondary school graduation age. In this report, the gross enrolment ratio for Bachelor's programmes is calculated on the basis of a standard age range of five years that follows the typical age of completion of secondary education. Similarly, the gross enrolment ratio for Master's and doctoral programmes is calculated as the population of the ten-year age group following the typical age of completion of secondary education.

Gross graduation ratio. Total number of graduates, regardless of age, from a given level of education or programme expressed as a percentage of the population at the theoretical graduation age for that level of education or programme. In this report, the gross graduation ratio for Bachelor's programmes is calculated as a percentage of all graduates of Bachelor's programmes divided by the population of the age when they theoretically finish the most common first degree programme in the given country.

Gross national income (GNI). The sum of gross value added by all resident producers in the economy, including distributive trades and transport, plus any product taxes, minus any subsidies not included in the value of the products, plus net receipts of income from abroad. Since net receipts from abroad may be positive or negative, it is possible for GNI to be greater or smaller than GDP.

Headcount (HC) (for R&D data). Headcount data provide the total number of persons who are mainly or partially employed in R&D. This includes staff employed both full-time and part-time. Headcount data reflect the total number of persons employed in R&D, independently from their dedication. These data allow links to be made with other data series, such as education and employment data, or the results of population censuses. They are also the basis for calculating indicators analysing the characteristics of the R&D workforce with respect to age, gender or national origin.

Higher education sector in the context of R&D statistics includes: all universities, colleges of technology and other institutions of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control of or administered by or associated with higher education institutions.

Innovation. Implementation of a new or significantly improved product, process, a new organizational method, or a new marketing method by a firm. An innovation must be new to the firm, although it could already have been implemented by other firms.

Instructors (or teaching staff). Persons employed full-time or part-time in an official capacity for the purpose of guiding and directing the learning experience of students, irrespective of their qualification or the delivery mechanism (i.e. whether face-to-face or at a distance). At the tertiary level, instructors include personnel who hold an academic rank with such titles as professor, associate professor, assistant professor, instructor, lecturer or the equivalent of any of these academic ranks. This definition excludes educational personnel who have no active teaching duties or who work occasionally or in a voluntary capacity in educational institutions. Moreover, it excludes student teachers, teachers' aides and paraprofessionals.

International Standard Classification of Education (ISCED). A classification system that provides a framework for the comprehensive statistical description of national educational systems and a methodology that translates national educational programmes into internationally comparable levels of education. The basic unit of classification in ISCED is the educational programme. ISCED also classifies programmes by field of study, programme orientation and destination.

International (or internationally mobile) students. Students who have crossed a national or territorial border for the purpose of education and are now enrolled outside their country of origin.

Mobility ratios

> **Gross outbound enrolment ratio.** Total number of students from a given country studying abroad expressed as a percentage of the population of tertiary age in that country.
>
> **Inbound mobility rate.** Total number of students from abroad studying in a given country, expressed as a percentage of total tertiary enrolment in that country.
>
> **Outbound mobility ratio.** Total number of students from a given country studying abroad, expressed as a percentage of total tertiary enrolment in that country.
>
> **Net flow of mobile students.** The number of tertiary students from abroad (inbound students) studying in a given country minus the number of students at the same level from a given country studying abroad (outbound students).
>
> **Net flow ratio of mobile students.** Total number of tertiary students from abroad (inbound students) studying in a given country minus the number of students at the same level of education from that country studying abroad (outbound students), expressed as a percentage of total tertiary enrolment in that country.

Percentage of female researchers in headcounts. Number of female researchers expressed as a percentage of the total number of researchers (male and female) in a national territory or region during a given year, measured in headcounts.

Percentage of female students. Total number of female students in a given level of education, expressed as a percentage of the total number of students enrolled at that level of education.

Percentage of private enrolment. Total number of students at a given level of education enrolled in private institutions expressed as a percentage of the total number of students enrolled at the given level of education.

Private non-profit sector in the context of R&D statistics includes: Non-market, private non-profit institutions serving households (i.e. the general public). It also includes private individuals or households.

Purchasing power parity (PPP). The currency exchange rates that equalise the purchasing power of different currencies. This means that a given sum of money, when converted into U.S. dollars at the PPP exchange rate (PPP dollars), will buy the same basket of goods and services in all countries. In other words, PPPs are the rates of currency conversion which eliminate the differences in price levels among countries. Thus, comparisons between countries reflect only differences in the volume of goods and services purchased.

Research and experimental development (R&D). R&D is creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. The term R&D covers three activities: basic research, applied research and experimental development.

Researchers. Professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, as well as in the management of these projects.

Researchers per 1 million population. Number of researchers expressed as a proportion of a population of 1 million during a given year. Total population is the total of all persons present (de facto population) in a country as of 1 July of the reference year.

Share of researchers by sector of performance. Number of researchers employed in each of the following sectors of performance (i.e. business enterprise, government, higher education and private non-profit organizations) expressed as a percentage of the total number of researchers during a given year.

Student/instructor ratio. The average number of pupils per instructor at a given level of education, based on headcounts of both students and instructors.

Total number of female researchers. Total number of female researchers is the number of female researchers during a given year.

Total R&D personnel. All persons employed directly on R&D, as well as those providing direct services such as R&D managers, administrators and clerical staff. Persons providing an indirect service, such as canteen and security staff, are excluded. R&D personnel comprise researchers, technicians and equivalent staff, and other supporting staff.

Appendix II

READER'S GUIDE

REFERENCE YEAR

The reference year for education and finance data is the academic or financial year ending in 2011 or the most recent year available within the period 2008 to 2012.

The reference period for R&D data is 2011 or the most recent year available within the period 2001 to 2011. Time series data presented in the statistical tables refer to each year within the period 2001 to 2011 unless otherwise indicated.

Where a given reference period is spread across two calendar years, the later year is cited. For example, the school year 2010/2011 is presented as 2011.

Data presented in Chapters 1 and 3 may not always be included in the statistical tables but can be referenced at the UIS Data Centre which includes a wider range of data: **http://www.uis.unesco.org/datacentre**

DATA SOURCES

Bibliographic data

Scopus, produced by Elsevier, is a bibliographic database which contains abstract and citation data on peer-reviewed literature. For more information on Scopus, please visit **http://www.elsevier.com/online-tools/scopus**

Economic data

Data on economic indicators, such as gross domestic product (GDP) and purchasing power parity (PPP), are based on the World Bank's economic data release of September 2013. Where World Bank estimates are not available for a small group of countries, data are obtained from the United Nations Statistics Division (UNSD).

Economic-based indicators are listed as missing (…) when economic data are not available or not considered reliable.

Education data

The UIS compiles education statistics in aggregate form from official administrative sources at the national level. These include data on educational programmes, access, participation, progression, completion, internal efficiency, and human and financial resources. They cover:

- education in pre-primary, primary, basic and secondary schools, and in colleges, universities and other tertiary education institutions;
- education in public (or state) and private sectors; and
- special needs education (both in regular and special schools).

These data are collected annually by the UIS and its partner agencies through the following three major surveys: the UIS education questionnaires, the UNESCO, the Organisation for Economic Co-operation and Development (OECD), Eurostat (Statistical Office of the European Union) (UOE) Education Data Collection, and the World Education Indicators programme. These questionnaires can be downloaded from the UIS website: **http://www.uis.unesco.org/UISQuestionnaires**

It should be noted that from 2014 onwards, the UIS uses data on total general government expenditure (all sectors) from the International Monetary Fund's (IMF) World Economic Outlook database as the denominator for its indicator 'Expenditure on education as a percentage of total government expenditure'. For more information about the change in methodology, please visit **http://www.uis.unesco.org/Education**

Population data

Population data are based on the 2012 revision of the World Population Prospects by the United Nations Population Division. For more information on UN Population Division estimates, please visit **http://www.un.org/esa/population/unpop.htm**

Research and experimental development (R&D) data

The UIS collects data on resources devoted to research and experimental development (R&D) through its R&D statistics survey on a biennial basis. It can be downloaded at: **http://www.uis.unesco.org/UISQuestionnaires/Pages/ScienceTechnology.aspx**

In addition, the UIS obtains data directly from the OECD, Eurostat, the Network on Science and Technology Indicators–Ibero-American and Inter-American, the African Union and NEPAD Planning and Coordinating Agency for countries which participate in the data collections of these organizations.

University research performance data

The United Nations University–Institute for Software Technology and its partners developed the Global Research Benchmarking System (GRBS) to provide objective data and analyses to benchmark research performance in traditional disciplinary subject areas and in interdisciplinary areas for the purpose of strengthening the quality and impact of research. For more information on the GRBS, please visit **http://www.researchbenchmarking.org**

TECHNICAL NOTES

Education data and indicators

Due to rounding, gender parity indices (GPI) may differ from those based directly on the published values of indicators. Similarly, totals may not always be the sum of their component parts.

The percentage of females (% F) is included to provide information on the proportion of women in a given population (e.g. enrolment, graduates or teachers). For assessing gender parity, a more relevant measure is the GPI.

Student mobility

International (or internationally mobile) students are defined as those who have crossed a national border and moved to another country with the objective to study. This group is commonly categorised by three operational definitions: i) country of permanent or usual residence; ii) their country of prior education; or iii) their country of citizenship. The UIS uses the first two to define international (or internationally mobile) students. The UIS only accepts country of citizenship as a proxy for countries/territories where data based on residence or prior education are not available.

Data on internationally mobile students that are collected by the UIS, OECD and Eurostat include students who pursue a tertiary degree, and thus exclude students in exchange programmes.

Data on internationally mobile students reported by host countries are used by the UIS to estimate the number of outbound students from a given country. Not all host countries specify the country of origin of the internationally mobile students that they host, and thus the number of outbound students from a given country may be underestimated.

Countries by income level

Countries in this report are grouped by income level according to the World Bank's economic data release of September 2013:

Income level	Country or territory
High income	Brunei Darussalam; China, Hong Kong; China, Macao; Japan; Korea, Rep.; Singapore
Upper middle income	China; Iran, Islamic Rep.; Malaysia; Thailand; Maldives
Lower middle income	Bhutan; India; Indonesia; Lao PDR; Pakistan; Philippines; Sri Lanka; Timor-Leste; Viet Nam
Low income	Afghanistan; Bangladesh; Cambodia; Korea, DPR; Myanmar; Nepal

Appendix III

INDICATORS AND WEIGHTS USED IN THE THREE INTERNATIONAL UNIVERSITY RANKING SYSTEMS

Ranking system	Criteria	Indicator	Weight
Academic Ranking of World Universities (ARWU)	Quality of Faculty	Staff of an institution winning Nobel Prizes and Fields Medals	20%
		Highly cited researchers in 21 broad subject categories	20%
	Research Output	Papers published in Nature and Science*	20%
		Papers indexed in Science Citation Index-expanded and Social Science Citation Index	20%
	Per Capita Performance	Per capita academic performance of an institution	10%
	Quality of Education	Alumni of an institution winning Nobel Prizes and Fields Medals	10%
Quacquarelli Symonds (QS) World University Rankings	Academic reputation	QS Global Academic Survey	40%
	Employer reputation	QS Global Employer Survey	20%
	Citations	Citations per faculty	20%
	Teaching quality	Faculty student ratio	10%
	Internationalization	Proportion of faculty members that are international	5%
		Proportion of students that are international	5%
Times Higher Education (THE) World University Rankings	Teaching	Academic reputation survey (teaching)	15%
		Staff-to-student ratio	4.5%
		Doctoral to bachelor's degrees awarded	6%
		Number of doctorates awarded	2.25%
		Institutional income scaled per academic	2.25%
	Research	Academic reputation survey (research)	18%
		University research income	6%
		Number of papers published in the academic journals indexed by Thomson Reuters per academic	6%
	Citations	Citations (5 years)	30%
	Industry income	Industry income	2.5%
	International outlook	Ratio of international to domestic students	2.5%
		Ratio of international to domestic staff	2.5%
		Proportion of a university's total research journal publications that have at least one international co-author and reward higher volumes	2.5%

Sources: Academic Ranking of World Universities, QS World Universities Rankings and Times Higher Education World University Rankings.

Appendix IV

RESEARCH PERFORMANCE OF ASIAN UNIVERSITIES WHICH ACHIEVED ABOVE AVERAGE RATINGS BY BROAD SUBJECT AREA

This appendix provides more information on the universities which emerge as having pockets of excellence in 15 broad subject areas. This information will be of particular interest to faculty and administrators of the particular universities involved and government officials who must make budget allocation decisions that include a consideration of research excellence.

Universities listed in the table are those that have achieved ‘above average’ ratings in research performance in each broad subject area. Universities achieving Band 1 are considered to be ‘world class’ in those areas; those achieving Bands 2 and 3 are deemed to have ‘excellent’ research performance; those achieving Bands 4 and 5 are deemed to have ‘above average’.

University	Country or territory	Band
1. Agricultural and Biological Sciences		
Beijing Jiaotong Daxue	China	3
China Agricultural University	China	4
Hohai University	China	4
Kyoto University	Japan	4
Nagoya University	Japan	4
Nara Institute of Science and Technology	Japan	4
National University of Singapore	Singapore	4
Shandong University of Science and Technology	China	4
Southwest Jiaotong University	China	4
University of Tokyo	Japan	4
Zhejiang University	China	4
Central South University China	China	4
Changsha University of Science and Technology	China	5
Chengdu University of Technology	China	5
Chiba University	Japan	5
China Three Gorges University	China	5
Fudan University	China	5
Graduate University of Chinese Academy of Sciences	China	5
Hokkaido University	Japan	5
Hong Kong Baptist University	China, Hong Kong	5
Hong Kong University of Science and Technology	China, Hong Kong	5
Huazhong Agricultural University	China	5
Hunan University	China	5
Korea Advanced Institute of Science and Technology	Korea, Rep.	5
Nanjing Agricultural University	China	5
National Chung Hsing University	Taiwan of China	5
National Taiwan University	Taiwan of China	5
National Yang Ming University	Taiwan of China	5

University	Country or territory	Band
Okayama University	Japan	5
Osaka University	Japan	5
Peking University	China	5
Seoul National University	Korea, Rep.	5
Shandong University	China	5
Sokendai Graduate University for Advanced Studies	Japan	5
South China University of Technology	China	5
Southeast University	China	5
The University of Hong Kong	China, Hong Kong	5
Tianjin University	China	5
Tohoku University	Japan	5
Tokyo Institute of Technology	Japan	5
Tongji University	China	5
Tsinghua University	China	5
University of Shizuoka	Japan	5
Wuhan University of Technology	China	5
Yokohama City University	Japan	5
Anhui Medical University	China	5
2. Biochemistry, Genetics and Molecular Biology		
University of Tokyo	Japan	4
Chung Yuan Christian University	Taiwan of China	5
National University of Singapore	Singapore	5
Korea Advanced Institute of Science and Technology	Korea, Rep.	5
Pohang University of Science and Technology	Korea, Rep.	5
Kyoto University	Japan	5
Osaka University	Japan	5
Nara Institute of Science and Technology	Japan	5
3. Chemistry		
Tsinghua University	China	2
University of Tokyo	Japan	2
Kyoto University	Japan	2
National University of Singapore	Singapore	2
University of Science and Technology, Korea	Korea, Rep.	3
Tohoku University	Japan	3
Nanyang Technological University	Singapore	3
Korea Advanced Institute of Science and Technology	Korea, Rep.	3
Nanjing University	China	3
Seoul National University	Korea, Rep.	3
University of Science and Technology of China	China	3
Graduate University of Chinese Academy of Sciences	China	3
Zhejiang University	China	3
Peking University	China	3
Tokyo Institute of Technology	Japan	3
Fudan University	China	3
Osaka University	Japan	3
National Taiwan University	Taiwan of China	3
Nankai University	China	4
National Chiao Tung University Taiwan	Taiwan of China	4
Hanyang University	Korea, Rep.	4
Xiamen University	China	4
Wuhan University	China	4

University	Country or territory	Band
Hokkaido University	Japan	4
Yonsei University	Korea, Rep.	4
East China University of Science and Technology	China	4
Jilin University	China	4
Shanghai Jiaotong University	China	4
National Tsing Hua University	Taiwan of China	4
Harbin Institute of Technology	China	4
Southeast University	China	4
Hong Kong University of Science and Technology	China, Hong Kong	4
Kyushu University	Japan	4
Nagoya University	Japan	4
Korea University	Korea, Rep.	4
Pohang University of Science and Technology	Korea, Rep.	4
Ewha Womans University	Korea, Rep.	5
King Mongkuts University of Technology Thonburi	Thailand	5
National Cheng Kung University	Taiwan of China	5
City University of Hong Kong	China, Hong Kong	5
Tianjin University	China	5
Indian Institute of Science	India	5
Hunan University	China	5
Wuhan University of Technology	China	5
Harbin Engineering University	China	5
Shandong University	China	5
Keio University	Japan	5
Fuzhou University	China	5
Yuan Ze University	Taiwan of China	5
Central South University China	China	5
Universiti Teknologi Malaysia	Malaysia	5
Shinshu University	Japan	5
Waseda University	Japan	5
Sichuan University	China	5
South China University of Technology	China	5
Chulalongkorn University	Thailand	5
Lanzhou University	China	5
Huazhong University of Science and Technology	China	5
Chinese University of Hong Kong	China, Hong Kong	5
Kobe University	Japan	5
National Chung Hsing University	Taiwan of China	5
Tokyo University of Science	Japan	5
The University of Hong Kong	China, Hong Kong	5
Gwangju Institute of Science and Technology	Korea, Rep.	5
University of Tsukuba	Japan	5
Sungkyunkwan University	Korea, Rep.	5
Feng Chia University	Taiwan of China	5
Tokyo Metropolitan University	Japan	5
National Taiwan Ocean University	Taiwan of China	5
Nanjing Agricultural University	China	5
Kyoto Institute of Technology	Japan	5
National Central University Taiwan	Taiwan of China	5
Sun Yat-Sen University	China	5
Hong Kong Polytechnic University	China, Hong Kong	5

University	Country or territory	Band
Chung Yuan Christian University	Taiwan of China	5
Beijing University of Chemical Technology	China	5
Chang Gung University	Taiwan of China	5
National Sun Yat-Sen University Taiwan	Taiwan of China	5
4. Computer Science		
National University of Singapore	Singapore	2
Hong Kong University of Science and Technology	China, Hong Kong	2
Nanyang Technological University	Singapore	2
City University of Hong Kong	China, Hong Kong	3
Hong Kong Polytechnic University	China, Hong Kong	3
Tsinghua University	China	3
Chinese University of Hong Kong	China, Hong Kong	3
National University of Tainan Taiwan	Taiwan of China	4
National Taiwan University	Taiwan of China	4
Shanghai Jiaotong University	China	4
National Tsing Hua University	Taiwan of China	4
National Taiwan University of Science and Technology	Taiwan of China	4
Southeast University	China	4
Harbin Institute of Technology	China	4
National Chiao Tung University Taiwan	Taiwan of China	4
Korea Advanced Institute of Science and Technology	Korea, Rep.	4
National Cheng Kung University	Taiwan of China	4
The University of Hong Kong	China, Hong Kong	4
Zhejiang University	China	5
Singapore Management University	Singapore	5
Chung Hua University	Taiwan of China	5
I-Shou University	Taiwan of China	5
Hong Kong Baptist University	China, Hong Kong	5
Seoul National University	Korea, Rep.	5
Northeastern University China	China	5
Feng Chia University	Taiwan of China	5
Indian Institute of Technology, Delhi	India	5
Indian Institute of Technology, Madras	India	5
Yuan Ze University	Taiwan of China	5
Yonsei University	Korea, Rep.	5
National Chung Hsing University	Taiwan of China	5
Xi’an Jiaotong University	China	5
National Chung Cheng University	Taiwan of China	5
Pohang University of Science and Technology	Korea, Rep.	5
National Central University Taiwan	Taiwan of China	5
Indian Institute of Science	India	5
5. Earth and Planetary Sciences		
University of Tokyo	Japan	3
China Three Gorges University	China	4
China University of Mining Technology	China	4
Beijing Jiaotong Daxue	China	4
Tongji University	China	4
Hohai University	China	4
Hong Kong University of Science and Technology	China, Hong Kong	4
Kyoto University	Japan	4
Shandong University	China	4

University	Country or territory	Band
Southwest Jiaotong University	China	4
Sichuan University	China	5
National Central University Taiwan	Taiwan of China	5
Southeast University	China	5
Seoul National University	Korea, Rep.	5
Gwangju Institute of Science and Technology	Korea, Rep.	5
Tokyo Institute of Technology	Japan	5
Kochi University	Japan	5
Tsinghua University	China	5
National Taiwan University	Taiwan of China	5
Chongqing University	China	5
Indian Institute of Technology, Kanpur	India	5
Hong Kong Polytechnic University	China, Hong Kong	5
Xi’an University of Technology	China	5
Yonsei University	Korea, Rep.	5
Northwest A&F University	China	5
Hokkaido University	Japan	5
Zhejiang University	China	5
Peking University	China	5
Wuhan University of Technology	China	5
Nagoya University	Japan	5
Asian Institute of Technology Thailand	Thailand	5
China Agricultural University	China	5
Okayama University	Japan	5
National Chung Hsing University	Taiwan of China	5
National Taiwan University of Science and Technology	Taiwan of China	5
Tohoku University	Japan	5
Sungkyunkwan University	Korea, Rep.	5
Lanzhou University of Technology	China	5
The University of Hong Kong	China, Hong Kong	5
China University of Geosciences	China	5
Kyushu University	Japan	5
Taiyuan University of Technology	China	5
Indian Institute of Science	India	5
Nanyang Technological University	Singapore	5
City University of Hong Kong	China, Hong Kong	5
6. Economic and Business Sciences		
Hong Kong Polytechnic University	China, Hong Kong	3
National University of Singapore	Singapore	4
Hong Kong University of Science and Technology	China, Hong Kong	4
City University of Hong Kong	China, Hong Kong	4
The University of Hong Kong	China, Hong Kong	5
Singapore Management University	Singapore	5
Xi’an Jiaotong University	China	5
National Chiao Tung University Taiwan	Taiwan of China	5
Tsinghua University	China	5
Fuzhou University	China	5
Northeastern University China	China	5
National Taiwan University of Science and Technology	Taiwan of China	5
National Cheng Kung University	Taiwan of China	5
Southeast University	China	5

University	Country or territory	Band
Chinese University of Hong Kong	China, Hong Kong	5
University of Science and Technology of China	China	5
Korea Advanced Institute of Science and Technology	Korea, Rep.	5
North China Electric Power University	China	5
Harbin Institute of Technology	China	5
University of Electronic Science and Technology of China	China	5
Peking University	China	5
Shanghai Jiaotong University	China	5
7. Engineering		
National University of Singapore	Singapore	2
Tsinghua University	China	2
Nanyang Technological University	Singapore	2
University of Tokyo	Japan	3
Kyoto University	Japan	3
University of Science and Technology, Korea	Korea, Rep.	3
Korea Advanced Institute of Science and Technology	Korea, Rep.	3
Zhejiang University	China	3
Southeast University	China	3
National Taiwan University	Taiwan of China	3
Seoul National University	Korea, Rep.	3
Harbin Institute of Technology	China	4
National Cheng Kung University	Taiwan of China	4
University of Science and Technology of China	China	4
Peking University	China	4
National Chiao Tung University Taiwan	Taiwan of China	4
Shanghai Jiaotong University	China	4
City University of Hong Kong	China, Hong Kong	4
Indian Institute of Science	India	4
Pohang University of Science and Technology	Korea, Rep.	4
Hong Kong University of Science and Technology	China, Hong Kong	4
Fudan University	China	4
Yonsei University	Korea, Rep.	4
Tohoku University	Japan	4
Tokyo Institute of Technology	Japan	4
Korea University	Korea, Rep.	4
Graduate University of Chinese Academy of Sciences	China	4
Osaka University	Japan	4
National Tsing Hua University	Taiwan of China	4
Hong Kong Polytechnic University	China, Hong Kong	4
The University of Hong Kong	China, Hong Kong	5
Ewha Womans University	Korea, Rep.	5
Yuan Ze University	Taiwan of China	5
Jilin University	China	5
National Chung Hsing University	Taiwan of China	5
Feng Chia University	Taiwan of China	5
National Taiwan University of Science and Technology	Taiwan of China	5
Chulalongkorn University	Thailand	5
Indian Institute of Technology, Madras	India	5
National Central University Taiwan	Taiwan of China	5
Shandong University	China	5
Xiamen University	China	5

University	Country or territory	Band
King Mongkuts University of Technology Thonburi	Thailand	5
Xi'an Jiaotong University	China	5
East China University of Science and Technology	China	5
Universiti Sains Malaysia	Malaysia	5
South China University of Technology	China	5
University of Tsukuba	Japan	5
Tianjin University	China	5
Sungkyunkwan University	Korea, Rep.	5
Hanyang University	Korea, Rep.	5
Indian Institute of Technology, Kanpur	India	5
Indian Institute of Technology, Kharagpur	India	5
Nanjing University	China	5
Nankai University	China	5
Wuhan University	China	5
Indian Institute of Technology, Bombay	India	5
Kyushu University	Japan	5
Khon Kaen University	Thailand	5
Nagoya University	Japan	5
Chinese University of Hong Kong	China, Hong Kong	5
Gwangju Institute of Science and Technology	Korea, Rep.	5
Gyeongsang National University	Korea, Rep.	5
Kyung Hee University	Korea, Rep.	5
Hokkaido University	Japan	5
Hong Kong Baptist University	China, Hong Kong	5
Indian Institute of Technology, Delhi	India	5
Sun Yat-Sen University	China	5
National University of Tainan Taiwan	Taiwan of China	5
8. Environmental Sciences		
Universiti Sains Malaysia	Malaysia	2
Pohang University of Science and Technology	Korea, Rep.	2
Tsinghua University	China	2
National University of Singapore	Singapore	3
Hong Kong Polytechnic University	China, Hong Kong	3
Harbin Institute of Technology	China	3
Shanghai Jiaotong University	China	3
Zhejiang University	China	3
National Cheng Kung University	Taiwan of China	3
University of Science and Technology, Korea	Korea, Rep.	3
Hong Kong University of Science and Technology	China, Hong Kong	3
Nanyang Technological University	Singapore	3
National Taiwan University	Taiwan of China	3
Peking University	China	3
University of Science and Technology of China	China	3
National Chiao Tung University Taiwan	Taiwan of China	4
National Central University Taiwan	Taiwan of China	4
Shandong University	China	4
Ehime University	Japan	4
National Chung Hsing University	Taiwan of China	4
National Tsing Hua University	Taiwan of China	4
Tohoku University	Japan	4
Kyoto University	Japan	4

University	Country or territory	Band
Tongji University	China	4
National Taiwan University of Science and Technology	Taiwan of China	4
Indian Institute of Technology Roorkee	India	4
King Mongkuts University of Technology Thonburi	Thailand	4
Nanjing University	China	4
Chulalongkorn University	Thailand	4
The University of Hong Kong	China, Hong Kong	4
Korea Advanced Institute of Science and Technology	Korea, Rep.	4
City University of Hong Kong	China, Hong Kong	4
Seoul National University	Korea, Rep.	4
University of Tokyo	Japan	4
Gwangju Institute of Science and Technology	Korea, Rep.	4
Graduate University of Chinese Academy of Sciences	China	4
Hong Kong Baptist University	China, Hong Kong	4
Wuhan University of Technology	China	4
Huazhong University of Science and Technology	China	4
Southeast University	China	4
East China University of Science and Technology	China	4
University of Ulsan	Korea, Rep.	4
Yuan Ze University	Taiwan of China	4
Nankai University	China	4
Fudan University	China	4
Kumamoto University	Japan	5
Indian Institute of Technology, Madras	India	5
Sejong University	Korea, Rep.	5
National Chung Cheng University	Taiwan of China	5
Dalian Maritime University	China	5
Inha University	Korea, Rep.	5
Chonbuk National University	Korea, Rep.	5
China Agricultural University	China	5
Universiti Teknologi Malaysia	Malaysia	5
National Pingtung University of Science and Technology	Taiwan of China	5
Fuzhou University	China	5
Central South University China	China	5
Indian Institute of Technology, Bombay	India	5
National Taiwan Ocean University	Taiwan of China	5
Harbin Engineering University	China	5
China Medical University Taichung	Taiwan of China	5
National Yunlin University of Science and Technology	Taiwan of China	5
Sun Yat-Sen University	China	5
Beijing Normal University	China	5
Kunming University of Science and Technology	China	5
Feng Chia University	Taiwan of China	5
Wuhan University	China	5
Asian Institute of Technology Thailand	Thailand	5
Chonnam National University	Korea, Rep.	5
Sungkyunkwan University	Korea, Rep.	5
National Taipei University of Technology	Taiwan of China	5
Kyushu University	Japan	5
Jilin University	China	5
Ajou University	Korea, Rep.	5

University	Country or territory	Band
Xiamen University	China	5
Beijing University of Chemical Technology	China	5
Yeungnam University	Korea, Rep.	5
Thammasat University	Thailand	5
Indian Institute of Technology, Kanpur	India	5
Hanyang University	Korea, Rep.	5
Chung Yuan Christian University	Taiwan of China	5
North China Electric Power University	China	5
Kyungpook National University	Korea, Rep.	5
Tunghai University	Taiwan of China	5
Indian Institute of Science	India	5
Tamkang University	Taiwan of China	5
China University of Petroleum - Beijing	China	5
Gyeongsang National University	Korea, Rep.	5
Tokyo Institute of Technology	Japan	5
University of Tsukuba	Japan	5
Nagoya University	Japan	5
Chung Shan Medical University	Taiwan of China	5
Indian Institute of Technology, Kharagpur	India	5
National Sun Yat-Sen University Taiwan	Taiwan of China	5
Tianjin University	China	5
Yonsei University	Korea, Rep.	5
University of Malaya	Malaysia	5
Hung Kuang University Taiwan	Taiwan of China	5
Xi’an Jiaotong University	China	5
South China University of Technology	China	5
Beijing Institute of Technology	China	5
Ewha Womans University	Korea, Rep.	5
Pusan National University	Korea, Rep.	5
Nanjing University of Technology	China	5
Hokkaido University	Japan	5
I-Shou University	Taiwan of China	5
Kangwon National University	Korea, Rep.	5
Chiang Mai University	Thailand	5
Tokyo University of Agriculture and Technology	Japan	5
Hunan University	China	5
Shanghai University	China	5
Shanghai Normal University	China	5
Qingdao University of Science and Technology	China	5
Korea University	Korea, Rep.	5
9. Health Professions and Nursing		
Hokkaido University	Japan	4
Chinese University of Hong Kong	China, Hong Kong	4
National Taiwan University	Taiwan of China	4
University of Tokyo	Japan	5
Peking University	China	5
Kyoto University	Japan	5
National Cheng Kung University	Taiwan of China	5
Ehime University	Japan	5
Seoul National University	Korea, Rep.	5
Hong Kong Polytechnic University	China, Hong Kong	5

University	Country or territory	Band
China Medical University Taichung	Taiwan of China	5
The University of Hong Kong	China, Hong Kong	5
University of Ulsan	Korea, Rep.	5
Taipei Medical University	Taiwan of China	5
Chang Gung University	Taiwan of China	5
Yonsei University	Korea, Rep.	5
National University of Singapore	Singapore	5
Tohoku University	Japan	5
National Tsing Hua University	Taiwan of China	5
Keio University	Japan	5
Osaka University	Japan	5
National Yang Ming University	Taiwan of China	5
Kyushu University	Japan	5
Sungkyunkwan University	Korea, Rep.	5
Fudan University	China	5
University of Tsukuba	Japan	5
China Agricultural University	China	5
National Taipei College of Nursing	Taiwan of China	5
Fu Jen Catholic University	Taiwan of China	5
10. Materials Sciences		
National University of Singapore	Singapore	1
University of Science and Technology, Korea	Korea, Rep.	1
Tohoku University	Japan	2
Nanyang Technological University	Singapore	2
Seoul National University	Korea, Rep.	2
University of Tokyo	Japan	2
Tsinghua University	China	2
Jilin University	China	3
National Tsing Hua University	Taiwan of China	3
Fudan University	China	3
Graduate University of Chinese Academy of Sciences	China	3
Kyoto University	Japan	3
National Chiao Tung University Taiwan	Taiwan of China	3
Harbin Institute of Technology	China	3
Osaka University	Japan	3
Korea Advanced Institute of Science and Technology	Korea, Rep.	3
Zhejiang University	China	3
Peking University	China	3
University of Science and Technology of China	China	3
Pohang University of Science and Technology	Korea, Rep.	3
Tokyo Institute of Technology	Japan	3
National Taiwan University	Taiwan of China	3
Shanghai Jiaotong University	China	3
Southeast University	China	3
National Cheng Kung University	Taiwan of China	4
Hong Kong University of Science and Technology	China, Hong Kong	4
Gwangju Institute of Science and Technology	Korea, Rep.	4
Indian Institute of Science	India	4
Sungkyunkwan University	Korea, Rep.	4
Hanyang University	Korea, Rep.	4
Kyushu University	Japan	4

University	Country or territory	Band
Nanjing University	China	4
Nankai University	China	4
Hokkaido University	Japan	4
Hong Kong Polytechnic University	China, Hong Kong	4
Yonsei University	Korea, Rep.	4
Korea University	Korea, Rep.	4
Wuhan University	China	4
City University of Hong Kong	China, Hong Kong	4
Hunan University	China	5
Renmin University of China	China	5
Chinese University of Hong Kong	China, Hong Kong	5
Beijing Institute of Technology	China	5
University of Tsukuba	Japan	5
Soochow University	China	5
South China University of Technology	China	5
Northwestern Polytechnical University	China	5
Chang Gung University	Taiwan of China	5
Central South University China	China	5
Indian Institute of Technology, Madras	India	5
Xi'an Jiaotong University	China	5
Xiamen University	China	5
Nanjing Agricultural University	China	5
National Central University Taiwan	Taiwan of China	5
Sun Yat-Sen University	China	5
Lanzhou University	China	5
National Chung Hsing University	Taiwan of China	5
Tokyo University of Science	Japan	5
Inha University	Korea, Rep.	5
East China University of Science and Technology	China	5
Tokyo Women's Medical University	Japan	5
Indian Institute of Technology, Kharagpur	India	5
University of Science and Technology Beijing	China	5
Ewha Womans University	Korea, Rep.	5
Soongsil University	Korea, Rep.	5
Tianjin University	China	5
Huazhong University of Science and Technology	China	5
Beijing University of Chemical Technology	China	5
Wuhan University of Technology	China	5
Pusan National University	Korea, Rep.	5
Nagoya University	Japan	5
Sichuan University	China	5
Shinshu University	Japan	5
Kyung Hee University	Korea, Rep.	5
Shandong University	China	5
Indian Institute of Technology, Bombay	India	5
The University of Hong Kong	China, Hong Kong	5
11. Mathematics		
National University of Singapore	Singapore	2
Shanghai Jiaotong University	China	3
Southeast University	China	3
City University of Hong Kong	China, Hong Kong	3

University	Country or territory	Band
Nanyang Technological University	Singapore	3
Tsinghua University	China	3
Harbin Institute of Technology	China	4
Hong Kong University of Science and Technology	China, Hong Kong	4
National Cheng Kung University	Taiwan of China	4
National University of Tainan Taiwan	Taiwan of China	4
National Taiwan University of Science and Technology	Taiwan of China	4
Chinese University of Hong Kong	China, Hong Kong	4
Hong Kong Polytechnic University	China, Hong Kong	4
Korea Advanced Institute of Science and Technology	Korea, Rep.	4
Feng Chia University	Taiwan of China	4
Huazhong University of Science and Technology	China	5
Peking University	China	5
University of Tokyo	Japan	5
Indian Institute of Science	India	5
National Chiao Tung University Taiwan	Taiwan of China	5
Zhejiang University	China	5
Xi'an Jiaotong University	China	5
National Tsing Hua University	Taiwan of China	5
Chung-Ang University	Korea, Rep.	5
Yuan Ze University	Taiwan of China	5
Seoul National University	Korea, Rep.	5
National Chung Hsing University	Taiwan of China	5
The University of Hong Kong	China, Hong Kong	5
Beijing University of Aeronautics and Astronautics	China	5
Kyoto University	Japan	5
National Taiwan University	Taiwan of China	5
Yonsei University	Korea, Rep.	5
12. Medicine		
Sokendai Graduate University for Advanced Studies	Japan	5
Korea Advanced Institute of Science and Technology	Korea, Rep.	5
Seoul National University	Korea, Rep.	5
Pohang University of Science and Technology	Korea, Rep.	5
National University of Singapore	Singapore	5
The University of Hong Kong	China, Hong Kong	5
University of Tokyo	Japan	5
Chinese University of Hong Kong	China, Hong Kong	5
Osaka University	Japan	5
Kyoto University	Japan	5
National Taiwan University	Taiwan of China	5
Nara Institute of Science and Technology	Japan	5
13. Multidisciplinary		
Osaka University	Japan	4
Kyoto University	Japan	4
University of Tokyo	Japan	4
University of Tsukuba	Japan	5
Hokkaido University	Japan	5
University of Science and Technology, Korea	Korea, Rep.	5
Keio University	Japan	5
Tokyo Institute of Technology	Japan	5
Hiroshima University	Japan	5

University	Country or territory	Band
Tokyo Medical and Dental University	Japan	5
Tohoku University	Japan	5
Kobe University	Japan	5
Seoul National University	Korea, Rep.	5
Nagoya University	Japan	5
National Taiwan University	Taiwan of China	5
Yonsei University	Korea, Rep.	5
Kyushu University	Japan	5
National University of Singapore	Singapore	5
14. Other Life and Health Sciences		
Korea Advanced Institute of Science and Technology	Korea, Rep.	5
Sokendai Graduate University for Advanced Studies	Japan	5
Osaka University	Japan	5
University of Tokyo	Japan	5
Pohang University of Science and Technology	Korea, Rep.	5
Nanjing University of Science and Technology	China	5
Seoul National University	Korea, Rep.	5
National University of Singapore	Singapore	5
Kyoto University	Japan	5
15. Physics and Astronomy		
University of Tokyo	Japan	1
Kyoto University	Japan	3
National University of Singapore	Singapore	3
Tohoku University	Japan	3
Tsinghua University	China	3
University of Science and Technology, Korea	Korea, Rep.	3
Peking University	China	4
Korea Advanced Institute of Science and Technology	Korea, Rep.	4
Tokyo Institute of Technology	Japan	4
Osaka University	Japan	4
Seoul National University	Korea, Rep.	4
University of Science and Technology of China	China	4
Pohang University of Science and Technology	Korea, Rep.	4
Zhejiang University	China	4
National Taiwan University	Taiwan of China	4
Yonsei University	Korea, Rep.	4
Nanyang Technological University	Singapore	4
National Chiao Tung University Taiwan	Taiwan of China	5
Fudan University	China	5
The University of Hong Kong	China, Hong Kong	5
Panjab University	India	5
Hokkaido University	Japan	5
Feng Chia University	Taiwan of China	5
Harbin Institute of Technology	China	5
Jilin University	China	5
Nanjing University	China	5
Indian Institute of Technology, Madras	India	5
King Mongkuts University of Technology Thonburi	Thailand	5
Pusan National University	Korea, Rep.	5
Hong Kong University of Science and Technology	China, Hong Kong	5
National Central University Taiwan	Taiwan of China	5

University	Country or territory	Band
Kyungpook National University	Korea, Rep.	5
Kyushu University	Japan	5
Southeast University	China	5
Gwangju Institute of Science and Technology	Korea, Rep.	5
Indian Institute of Technology, Bombay	India	5
Sungkyunkwan University	Korea, Rep.	5
Indian Institute of Technology, Kharagpur	India	5
Nagoya University	Japan	5
National Chung Hsing University	Taiwan of China	5
University of Tsukuba	Japan	5
Hiroshima University	Japan	5
National Tsing Hua University	Taiwan of China	5
Hanyang University	Korea, Rep.	5
National University of Tainan Taiwan	Taiwan of China	5
Chinese University of Hong Kong	China, Hong Kong	5
City University of Hong Kong	China, Hong Kong	5
Nippon Dental University	Japan	5
National Cheng Kung University	Taiwan of China	5
Indian Institute of Science	India	5
Korea University	Korea, Rep.	5
Graduate University of Chinese Academy of Sciences	China	5
Hong Kong Polytechnic University	China, Hong Kong	5
Waseda University	Japan	5
Shandong University	China	5
Shanghai Jiaotong University	China	5

Appendix V

NUMBER OF NICHE SUBJECT AREAS OF ASIAN UNIVERSITIES BY PERFORMANCE BAND

This appendix lists the number of niche subject areas in each performance category for the Asian universities included in this study. Universities listed are sorted by number of niche subject areas with world class performance then excellent performance.

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
National University of Singapore	Singapore	21	31	67	12
Nanyang Technological University	Singapore	16	32	21	10
Tsinghua University	China	12	43	29	24
University of Science and Technology, Korea	Korea, Rep.	11	22	32	35
Hong Kong Polytechnic University	China, Hong Kong	11	13	36	16
Zhejiang University	China	10	25	43	67
Southeast University	China	7	28	34	38
City University of Hong Kong	China, Hong Kong	7	22	28	11
University of Tokyo	Japan	6	29	94	30
Kyoto University	Japan	6	20	87	38
Universiti Sains Malaysia	Malaysia	6	2	7	39
Hong Kong University of Science and Technology	China, Hong Kong	4	20	32	9
Graduate University of Chinese Academy of Sciences	China	4	16	32	52
Tokyo Institute of Technology	Japan	3	11	37	23
Feng Chia University	Taiwan of China	3	3	10	11
Seoul National University	Korea, Rep.	2	39	75	42
National Taiwan University	Taiwan of China	2	38	80	35
Shanghai Jiaotong University	China	2	35	44	66
Harbin Institute of Technology	China	2	24	30	19
University of Science and Technology of China	China	2	18	33	29
Shandong University	China	2	10	33	66
Jilin University	China	2	10	23	48
National Cheng Kung University	Taiwan of China	1	30	43	36
Tohoku University	Japan	1	18	55	59
Nanjing University	China	1	14	33	52
Yonsei University	Korea, Rep.	1	13	64	43
Wuhan University	China	1	11	30	58
Tongji University	China	1	10	16	56
National Chung Hsing University	Taiwan of China	1	7	31	29
Indian Institute of Technology, Delhi	India	1	6	18	17
Huazhong University of Science and Technology	China	1	5	39	66
National Taiwan University of Science and Technology	Taiwan of China	1	5	18	12
Chongqing University	China	1	4	13	46
China University of Mining Technology	China	1	4	4	20
China Medical University Taichung	Taiwan of China	1	3	10	34

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Hohai University	China	1	3	1	22
China University of Geosciences	China	1	2	17	22
Yuan Ze University	Taiwan of China	1	2	13	8
Taiyuan University of Technology	China	1	2	2	16
Xidian University	China	1	0	10	18
Korea Advanced Institute of Science and Technology	Korea, Rep.	0	30	30	16
Peking University	China	0	24	57	66
National Chiao Tung University Taiwan	Taiwan of China	0	18	36	9
Pohang University of Science and Technology	Korea, Rep.	0	18	29	7
National Tsing Hua University	Taiwan of China	0	18	28	18
Fudan University	China	0	17	37	68
Chinese University of Hong Kong	China, Hong Kong	0	15	62	33
Osaka University	Japan	0	13	59	50
Korea University	Korea, Rep.	0	11	43	57
Xi’an Jiaotong University	China	0	10	31	50
Hanyang University	Korea, Rep.	0	9	36	40
Indian Institute of Technology, Madras	India	0	9	16	14
The University of Hong Kong	China, Hong Kong	0	8	85	32
Tianjin University	China	0	8	28	30
Nankai University	China	0	8	24	37
Hunan University	China	0	8	22	33
China Agricultural University	China	0	8	13	35
South China University of Technology	China	0	7	29	29
Indian Institute of Science	India	0	7	28	26
Sungkyunkwan University	Korea, Rep.	0	6	43	45
Xiamen University	China	0	6	26	37
Central South University China	China	0	6	21	71
Hokkaido University	Japan	0	5	59	60
Nagoya University	Japan	0	5	55	55
Kyushu University	Japan	0	5	53	61
Sichuan University	China	0	5	31	69
East China University of Science and Technology	China	0	5	26	20
Indian Institute of Technology, Kharagpur	India	0	5	25	24
Gwangju Institute of Science and Technology	Korea, Rep.	0	5	16	11
Chulalongkorn University	Thailand	0	5	14	34
King Mongkuts University of Technology Thonburi	Thailand	0	5	7	7
Southwest Jiaotong University	China	0	5	5	23
Sun Yat-Sen University	China	0	4	45	70
Northeastern University China	China	0	4	18	19
Chung Yuan Christian University	Taiwan of China	0	4	12	10
Lanzhou University	China	0	3	23	49
Indian Institute of Technology, Bombay	India	0	3	21	16
Beijing University of Chemical Technology	China	0	3	20	13
Beijing Normal University	China	0	3	19	41
University of Science and Technology Beijing	China	0	3	15	24
Chonbuk National University	Korea, Rep.	0	3	13	42
Indian Institute of Technology Roorkee	India	0	3	12	18
National Taipei University of Technology	Taiwan of China	0	3	12	18
Nanjing Agricultural University	China	0	3	11	14

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Donghua University	China	0	3	9	19
Beijing Jiaotong Daxue	China	0	3	6	29
Shenyang Pharmaceutical University	China	0	3	2	9
Beijing University of Aeronautics and Astronautics	China	0	2	17	32
Nanjing University of Technology	China	0	2	15	21
Hong Kong Baptist University	China, Hong Kong	0	2	15	17
Wuhan University of Technology	China	0	2	14	16
National Chung Cheng University	Taiwan of China	0	2	9	16
Nara Institute of Science and Technology	Japan	0	2	7	14
North China Electric Power University	China	0	2	4	21
Hung Kuang University Taiwan	Taiwan of China	0	2	3	1
Mie University	Japan	0	2	1	25
Chengdu University of Technology	China	0	2	1	5
National Central University Taiwan	Taiwan of China	0	1	29	22
Kyung Hee University	Korea, Rep.	0	1	22	54
Chiba University	Japan	0	1	21	45
Inha University	Korea, Rep.	0	1	17	29
Chonnam National University	Korea, Rep.	0	1	14	49
Ocean University of China	China	0	1	13	30
Fuzhou University	China	0	1	13	19
China University of Petroleum - Beijing	China	0	1	12	23
Soochow University	China	0	1	11	50
Kaohsiung Medical University	Taiwan of China	0	1	11	27
University of Electronic Science and Technology of China	China	0	1	9	32
Northwestern Polytechnical University	China	0	1	8	31
Huazhong Agricultural University	China	0	1	8	18
Northeast Normal University	China	0	1	8	18
Jadavpur University	India	0	1	7	25
China Pharmaceutical University	China	0	1	7	9
Banaras Hindu University	India	0	1	6	45
Nanjing Normal University	China	0	1	5	27
Harbin Engineering University	China	0	1	5	26
South China Normal University	China	0	1	2	26
China Three Gorges University	China	0	1	2	6
Xi’an University of Technology	China	0	1	1	21
Xi’an University of Architecture and Technology	China	0	1	1	13
Yamaguchi University	Japan	0	1	0	23
PLA University of Science and Technology	China	0	1	0	17
Kochi University	Japan	0	1	0	10
Chang Gung University	Taiwan of China	0	0	35	44
Keio University	Japan	0	0	35	41
National Sun Yat-Sen University Taiwan	Taiwan of China	0	0	31	22
University of Tsukuba	Japan	0	0	30	64
Hiroshima University	Japan	0	0	28	56
Beijing Institute of Technology	China	0	0	26	43
Pusan National University	Korea, Rep.	0	0	22	45
Okayama University	Japan	0	0	19	60
Kobe University	Japan	0	0	18	56
Kyungpook National University	Korea, Rep.	0	0	18	46

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
National Yang Ming University	Taiwan of China	0	0	18	37
University of Ulsan	Korea, Rep.	0	0	18	33
Chungnam National University	Korea, Rep.	0	0	17	37
Mahidol University	Thailand	0	0	15	38
Waseda University	Japan	0	0	15	38
East China Normal University	China	0	0	15	37
Tokyo Medical and Dental University	Japan	0	0	15	31
Shanghai University	China	0	0	14	45
Kanazawa University	Japan	0	0	12	48
Ewha Womans University	Korea, Rep.	0	0	12	26
Indian Institute of Technology, Kanpur	India	0	0	12	19
Tokyo University of Science	Japan	0	0	11	33
Taipei Medical University	Taiwan of China	0	0	11	30
University of Malaya	Malaysia	0	0	10	46
Kumamoto University	Japan	0	0	10	31
Tokyo University of Agriculture and Technology	Japan	0	0	9	32
Shinshu University	Japan	0	0	9	30
Gyeongsang National University	Korea, Rep.	0	0	8	36
Second Military Medical University	China	0	0	8	33
Nanjing University of Aeronautics and Astronautics	China	0	0	8	32
Shaanxi Normal University	China	0	0	8	17
National Taiwan Ocean University	Taiwan of China	0	0	8	15
Yokohama National University	Japan	0	0	8	12
Ajou University	Korea, Rep.	0	0	7	33
Niigata University	Japan	0	0	7	33
Ehime University	Japan	0	0	7	32
Nanjing University of Science and Technology	China	0	0	7	32
Osaka City University	Japan	0	0	7	32
Southwest China Normal University	China	0	0	7	29
Tokyo Women's Medical University	Japan	0	0	7	29
Jiangnan University	China	0	0	7	28
Zhejiang University of Technology	China	0	0	7	28
Gunma University	Japan	0	0	7	27
Yangzhou University	China	0	0	7	18
Sogang University	Korea, Rep.	0	0	7	16
Japan Advanced Institute of Science and Technology	Japan	0	0	7	8
Konkuk University	Korea, Rep.	0	0	6	43
The Catholic University of Korea	Korea, Rep.	0	0	6	42
The Fourth Military Medical University	China	0	0	6	40
Nagasaki University	Japan	0	0	6	39
Chung-Ang University	Korea, Rep.	0	0	6	37
Yeungnam University	Korea, Rep.	0	0	6	30
Juntendo University	Japan	0	0	6	28
Northwest A&F University	China	0	0	6	22
Chung Shan Medical University	Taiwan of China	0	0	6	17
Huazhong Normal University	China	0	0	6	14
Nagoya Institute of Technology	Japan	0	0	6	14
National Yunlin University of Science and Technology	Taiwan of China	0	0	6	11
I-Shou University	Taiwan of China	0	0	6	9

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Universiti Putra Malaysia	Malaysia	0	0	5	49
University of Delhi	India	0	0	5	44
Zhengzhou University	China	0	0	5	42
Jiangsu University	China	0	0	5	40
Kangwon National University	Korea, Rep.	0	0	5	35
Osaka Prefecture University	Japan	0	0	5	31
Pukyoung National University	Korea, Rep.	0	0	5	26
Anna University	India	0	0	5	25
Tokyo Metropolitan University	Japan	0	0	5	20
Qingdao University of Science and Technology	China	0	0	5	17
Yamagata University	Japan	0	0	5	16
Kasetsart University	Thailand	0	0	5	14
Prince of Songkla University	Thailand	0	0	5	12
National University of Tainan Taiwan	Taiwan of China	0	0	5	1
University of Tokushima	Japan	0	0	4	35
Kagoshima University	Japan	0	0	4	31
Chiang Mai University	Thailand	0	0	4	25
XiangTan University	China	0	0	4	20
Yokohama City University	Japan	0	0	4	20
Sejong University	Korea, Rep.	0	0	4	19
Chang'an University	China	0	0	4	16
University of Yamanashi	Japan	0	0	4	14
Shandong University of Science and Technology	China	0	0	4	13
Iwate University	Japan	0	0	4	12
National Taiwan Normal University	Taiwan of China	0	0	4	12
Shanghai Normal University	China	0	0	4	12
Kyoto Institute of Technology	Japan	0	0	4	11
Sokendai Graduate University for Advanced Studies	Japan	0	0	4	11
Anhui Normal University	China	0	0	4	9
Indian Statistical Institute	India	0	0	4	9
National Pingtung University of Science and Technology	Taiwan of China	0	0	4	6
Liaoning Technical University	China	0	0	4	5
Hefei University of Technology	China	0	0	3	30
South China Agricultural University	China	0	0	3	24
National University Corporation Shizuoka University	Japan	0	0	3	23
Yanshan University	China	0	0	3	23
Guangxi University	China	0	0	3	22
Qingdao University	China	0	0	3	22
Nagoya City University	Japan	0	0	3	20
Tamkang University	Taiwan of China	0	0	3	18
Universiti Teknologi Malaysia	Malaysia	0	0	3	18
Henan Polytechnic University	China	0	0	3	12
Chung Hua University	Taiwan of China	0	0	3	5
Soongsil University	Korea, Rep.	0	0	3	5
National University Corporation Tokyo University of Marine Science and Technology	Japan	0	0	3	4
Singapore Management University	Singapore	0	0	3	1
Capital Medical University China	China	0	0	2	52
Kinki University	Japan	0	0	2	39

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Inje University	Korea, Rep.	0	0	2	35
Peking Union Medical College	China	0	0	2	33
University of Toyama	Japan	0	0	2	32
Universiti Kebangsaan Malaysia	Malaysia	0	0	2	30
Annamalai University	India	0	0	2	29
Chosun University	Korea, Rep.	0	0	2	28
Nanchang University	China	0	0	2	27
Beijing University of Posts and Telecommunications	China	0	0	2	21
Kyoto Prefectural University of Medicine	Japan	0	0	2	20
University of Electro-Communications	Japan	0	0	2	19
Kurume University	Japan	0	0	2	18
Soonchunhyang University	Korea, Rep.	0	0	2	16
Jeju National University	Korea, Rep.	0	0	2	15
Shenzhen University	China	0	0	2	15
University of Occupational and Environmental Health	Japan	0	0	2	15
Zhejiang Normal University	China	0	0	2	15
Shandong Agricultural University	China	0	0	2	14
Panjab University	India	0	0	2	13
Shanghai University of Traditional Chinese Medicine	China	0	0	2	9
Osaka Medical College	Japan	0	0	2	7
Renmin University of China	China	0	0	2	7
Fukushima Medical University	Japan	0	0	2	6
Tunghai University	Taiwan of China	0	0	2	6
Anhui University of Science and Technology	China	0	0	2	4
Asian Institute of Technology Thailand	Thailand	0	0	2	3
Nanjing Hydraulic Research Institute	China	0	0	2	1
Jinan University	China	0	0	1	41
China Medical University Shenyang	China	0	0	1	35
Nanjing Medical University	China	0	0	1	33
Kitasato University	Japan	0	0	1	30
Tianjin Medical University	China	0	0	1	30
National University of Defense Technology	China	0	0	1	29
Gifu University	Japan	0	0	1	28
Aligarh Muslim University	India	0	0	1	26
Northeast Forestry University	China	0	0	1	24
Hallym University	Korea, Rep.	0	0	1	22
Jichi Medical University	Japan	0	0	1	21
Khon Kaen University	Thailand	0	0	1	21
Henan University	China	0	0	1	20
Jikei University	Japan	0	0	1	19
Toho University	Japan	0	0	1	19
Hebei Medical University	China	0	0	1	18
Kyushu Institute of Technology	Japan	0	0	1	18
Teikyo University	Japan	0	0	1	18
Kagawa University	Japan	0	0	1	17
Showa University	Japan	0	0	1	17
Anhui University	China	0	0	1	16
Beijing Forestry University	China	0	0	1	16
Capital Normal University	China	0	0	1	16

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Tokyo Medical University	Japan	0	0	1	15
University of Hyderabad	India	0	0	1	15
Kunming University of Science and Technology	China	0	0	1	14
Lanzhou University of Technology	China	0	0	1	13
Wonkwang University	Korea, Rep.	0	0	1	13
Hyogo College of Medicine	Japan	0	0	1	12
Shiga University of Medical Science	Japan	0	0	1	12
Hunan University of Science and Technology	China	0	0	1	11
University of Rajasthan	India	0	0	1	11
Kansai Medical University	Japan	0	0	1	10
University of Shizuoka	Japan	0	0	1	10
Kawasaki Medical College	Japan	0	0	1	8
Wakayama Medical University	Japan	0	0	1	8
Hoshi University	Japan	0	0	1	7
National Institute of Pharmaceutical Education and Research India	India	0	0	1	7
Sapporo Medical University	Japan	0	0	1	6
Beijing University of Chinese Medicine	China	0	0	1	5
Chongqing Jiaotong University	China	0	0	1	5
Fu Jen Catholic University	Taiwan of China	0	0	1	5
Dr. Harisingh Gour University Sagar	India	0	0	1	4
Nihon University	Japan	0	0	0	61
Chungbuk National University	Korea, Rep.	0	0	0	40
All India Institute of Medical Sciences	India	0	0	0	39
Chongqing University of Medical Sciences	China	0	0	0	34
Third Military Medical University	China	0	0	0	33
Dongguk University	Korea, Rep.	0	0	0	31
Harbin Medical University	China	0	0	0	30
Postgraduate Institute of Medical Education and Research	India	0	0	0	29
Yunnan University	China	0	0	0	27
Southern Medical University	China	0	0	0	26
Hebei University	China	0	0	0	23
Tottori University	Japan	0	0	0	23
University of Calcutta	India	0	0	0	23
Dong-A University	Korea, Rep.	0	0	0	20
Hebei University of Technology	China	0	0	0	20
Hubei University	China	0	0	0	20
Nippon Medical School	Japan	0	0	0	20
Saitama Medical University	Japan	0	0	0	20
University of the Ryukyus	Japan	0	0	0	20
Harbin University of Science and Technology	China	0	0	0	19
Wenzhou Medical College	China	0	0	0	19
Dalian Maritime University	China	0	0	0	18
Shimane University	Japan	0	0	0	18
Changsha University of Science and Technology	China	0	0	0	17
North University of China	China	0	0	0	17
Naval University of Engineering	China	0	0	0	16
Ningbo University	China	0	0	0	16
Shanxi University	China	0	0	0	16

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Tianjin Polytechnic University	China	0	0	0	16
Hangzhou Dianzi University	China	0	0	0	15
University of Madras	India	0	0	0	15
University of Miyazaki	Japan	0	0	0	15
Fujian Medical University	China	0	0	0	14
Nanjing University of Information Science and Technology	China	0	0	0	14
Nantong University	China	0	0	0	14
Air Force Engineering University China	China	0	0	0	13
Anhui Medical University	China	0	0	0	13
Dalian Medical University	China	0	0	0	13
Guangzhou University	China	0	0	0	13
Guilin University of Electronic Technology	China	0	0	0	13
Nanjing University of Post and TeleCommunications	China	0	0	0	13
Nara Medical University	Japan	0	0	0	13
Hongik University	Korea, Rep.	0	0	0	12
Northwest Normal University	China	0	0	0	12
Shenyang University of Technology	China	0	0	0	12
Xi’an University of Engineering Science and Technology	China	0	0	0	12
Asia University Taiwan	Taiwan of China	0	0	0	11
Manipal University	India	0	0	0	11
Sanjay Gandhi Postgraduate Institute of Medical Sciences Lucknow	India	0	0	0	11
Shanxi Medical University	China	0	0	0	11
Sichuan Agricultural University	China	0	0	0	11
Iwate Medical University	Japan	0	0	0	10
Jawaharlal Nehru Technological University	India	0	0	0	10
Northeast Agricultural University	China	0	0	0	10
Qufu Normal University	China	0	0	0	10
Shaanxi University of Science and Technology	China	0	0	0	10
Tianjin University of Science & Technology	China	0	0	0	10
Henan Agricultural University	China	0	0	0	9
Jamia Hamdard University	India	0	0	0	9
Multimedia University	Malaysia	0	0	0	9
Naval Aeronautical Engineering Academy Yantai	China	0	0	0	9
The Catholic University of Daegu	Korea, Rep.	0	0	0	9
Christian Medical College Vellore	India	0	0	0	8
Dokkyo Medical University	Japan	0	0	0	8
Guangxi Medical University	China	0	0	0	8
Information Engineering University China	China	0	0	0	8
Nanjing University of Traditional Chinese Medicine	China	0	0	0	8
Second Artillery Engineering College Xi An	China	0	0	0	8
Shenyang Agricultural University	China	0	0	0	8
Tokyo University of Pharmacy and Life Sciences	Japan	0	0	0	8
Andong National University	Korea, Rep.	0	0	0	7
Hamamatsu University School of Medicine	Japan	0	0	0	7
Hebei Agricultural University	China	0	0	0	7
Jiangsu Polytechnic University	China	0	0	0	7
Kyoto Pharmaceutical University	Japan	0	0	0	7
Obihiro University of Agriculture and Veterinary Medicine	Japan	0	0	0	7

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Tokushima Bunri University	Japan	0	0	0	7
University of South China	China	0	0	0	7
Xuzhou Normal University	China	0	0	0	7
Guangzhou Medical College	China	0	0	0	6
Hunan Agricultural University	China	0	0	0	6
Liaoning University of Petroleum and Chemical Technology	China	0	0	0	6
Nanjing Forestry University	China	0	0	0	6
Punjab Agricultural University India	India	0	0	0	6
St. Marianna University	Japan	0	0	0	6
Thammasat University	Thailand	0	0	0	6
The Maharaja Sayajirao University of Baroda	India	0	0	0	6
Tohoku Pharmaceutical University	Japan	0	0	0	6
Central South University of Forestry & Technology	China	0	0	0	5
Chengdu University of Traditional Chinese Medicine	China	0	0	0	5
International Islamic University Malaysia	Malaysia	0	0	0	5
Kunming Medical College	China	0	0	0	5
National Chengchi University	Taiwan of China	0	0	0	5
Shanghai Ocean University	China	0	0	0	5
Southwest Petroleum University	China	0	0	0	5
Tianjin University of Traditional Chinese Medicine	China	0	0	0	5
Xinjiang Medical University	China	0	0	0	5
Zhejiang Forestry University	China	0	0	0	5
CCS Haryana Agricultural University	India	0	0	0	4
Government Medical College	India	0	0	0	4
Guangdong Medical College	China	0	0	0	4
Jiangxi University of Traditional Chinese Medicine	China	0	0	0	4
Korea Maritime University	Korea, Rep.	0	0	0	4
Liaoning Medical University	China	0	0	0	4
Luoyang Normal University	China	0	0	0	4
National Dairy Research Institute India	India	0	0	0	4
Shanghai University of Finance and EcoNomics	China	0	0	0	4
Shenyang Jianzhu University	China	0	0	0	4
Sree Chitra Tirunal Institute for Medical Sciences and Technology	India	0	0	0	4
Tamilnadu Agricultural University	India	0	0	0	4
Xi'an Shiyou University	China	0	0	0	4
International University of Health and Welfare	Japan	0	0	0	3
Inter-University Centre for Astronomy and Astrophysics India	India	0	0	0	3
Luzhou Medical College	China	0	0	0	3
National Institute of Mental Health and Neuro Sciences	India	0	0	0	3
Anand Agricultural University	India	0	0	0	2
Asahikawa Medical University	Japan	0	0	0	2
Central University of Finance	China	0	0	0	2
G B Pant University of Agriculture & Technology	India	0	0	0	2
Guangzhou University of Traditional Chinese Medicine	China	0	0	0	2
Heilongjiang University of Traditional Chinese Medicine	China	0	0	0	2
Hitotsubashi University	Japan	0	0	0	2
Ming Chuan University	Taiwan of China	0	0	0	2
Shandong University of Traditional Chinese Medicine	China	0	0	0	2
Aichi Gakuin University	Japan	0	0	0	1

University	Country or territory	Number of niche subject areas by performance band			
		World class	Excellent	Above average	Below average
Assam Agricultural University	India	0	0	0	1
Azabu University	Japan	0	0	0	1
Guru Angad Dev Veterinary and Animal Sciences University	India	0	0	0	1
Health Sciences University of Hokkaido	Japan	0	0	0	1
Kagawa Nutrition University	Japan	0	0	0	1
Lingnan University	China, Hong Kong	0	0	0	1
Mackay Medicine Nursing and Management College Taiwan	Taiwan of China	0	0	0	1
Matsumoto Dental University	Japan	0	0	0	1
Nippon Dental University	Japan	0	0	0	1
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir	India	0	0	0	1
Tamil Nadu Veterinary and Animal Sciences University	India	0	0	0	1
Tokyo Dental College	Japan	0	0	0	1
Tsurumi University	Japan	0	0	0	1
West Bengal University of Animal and Fishery Sciences	India	0	0	0	1

Appendix VI

ASIAN UNIVERSITIES WITH THE HIGHEST GROWTH RATES AND IN-REGION COLLABORATION IN RESEARCH BY BROAD SUBJECT AREA

Table A1. Top 15 Asian universities with high publication growth rates and in-region collaboration in Agricultural and Biological Sciences

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Universiti Teknologi Malaysia	Malaysia	119	Universiti Putra Malaysia	Malaysia	369	20
Capital Medical University China	China	117	Kyoto University	Japan	338	14
Third Military Medical University	China	84	Hokkaido University	Japan	279	14
University of Malaya	Malaysia	76	Kyushu University	Japan	249	19
Harbin Medical University	China	76	University of Tokyo	Japan	241	11
Nanjing Medical University	China	69	China Agricultural University	China	203	5
Universiti Sains Malaysia	Malaysia	60	Kasetsart University	Thailand	179	17
Xi'an Jiaotong University	China	54	Seoul National University	Korea, Rep.	176	11
Shanghai University	China	48	The University of Hong Kong	China, Hong Kong	174	28
National Yang Ming University	Taiwan of China	47	Zhejiang University	China	159	6
Chang Gung University	Taiwan of China	46	University of Tsukuba	Japan	132	16
Universiti Putra Malaysia	Malaysia	46	Universiti Sains Malaysia	Malaysia	121	19
China Medical University Taichung	Taiwan of China	42	University of Malaya	Malaysia	116	20
Second Military Medical University	China	39	Chiang Mai University	Thailand	115	25
Fudan University	China	39	Chulalongkorn University	Thailand	114	14

Table A2. Top 15 Asian universities with high publication growth rates and in-region collaboration in Biochemistry, Genetics and Molecular Biology

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
International Islamic University Malaysia	Malaysia	65	The University of Hong Kong	China, Hong Kong	570	31
Shenzhen University	China	56	Chinese University of Hong Kong	China, Hong Kong	569	36
Universiti Sains Malaysia	Malaysia	55	University of Tokyo	Japan	368	7
Zhejiang Normal University	China	53	Kyoto University	Japan	323	6
Universiti Teknologi Malaysia	Malaysia	51	Seoul National University	Korea, Rep.	311	7
Beijing Forestry University	China	50	Kyushu University	Japan	304	10
Sree Chitra Tirunal Institute for Medical Sciences and Technology	India	50	Osaka University	Japan	297	7
University of Malaya	Malaysia	49	Zhejiang University	China	244	6
Nanjing University of Science and Technology	China	48	Peking University	China	237	7
Tianjin University of Traditional Chinese Medicine	China	45	Sun Yat-Sen University	China	235	8
Liaoning Medical University	China	45	Tohoku University	Japan	232	8
Universiti Putra Malaysia	Malaysia	45	Hong Kong Polytechnic University	China, Hong Kong	226	47
Jiangsu University	China	44	Hokkaido University	Japan	220	8
Ningbo University	China	43	Okayama University	Japan	197	11
Anhui University	China	43	Yonsei University	Korea, Rep.	192	9

Table A3. Top 15 Asian universities with high publication growth rates and in-region collaboration in Chemistry

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Third Military Medical University	China	92	Universiti Sains Malaysia	Malaysia	821	44
Universiti Putra Malaysia	Malaysia	69	University of Malaya	Malaysia	636	34
Asia University Taiwan	Taiwan of China	56	City University of Hong Kong	China, Hong Kong	528	58
Universiti Teknologi Malaysia	Malaysia	51	Hong Kong University of Science and Technology	China, Hong Kong	501	47
Southern Medical University	China	50	Tohoku University	Japan	400	13
Lanzhou University of Technology	China	50	Osaka University	Japan	387	11
China Medical University Taichung	Taiwan of China	47	Hong Kong Polytechnic University	China, Hong Kong	370	50
Northwest A&F University	China	47	Chinese University of Hong Kong	China, Hong Kong	342	50
Hebei Agricultural University	China	46	Hong Kong Baptist University	China, Hong Kong	317	58
Universiti Kebangsaan Malaysia	Malaysia	46	The University of Hong Kong	China, Hong Kong	317	36
Nanjing University of Post and TeleCommunications	China	46	University of Science and Technology, Korea	Korea, Rep.	305	7
Henan Polytechnic University	China	46	Zhejiang University	China	286	6
University of Malaya	Malaysia	43	Kyoto University	Japan	268	7
Shandong Agricultural University	China	43	Nanjing University	China	263	7
National Yang Ming University	Taiwan of China	41	Prince of Songkla University	Thailand	250	50

Table A4. Top 15 Asian universities with high publication growth rates and in-region collaboration in Computer Science

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Taiyuan University of Technology	China	89	City University of Hong Kong	China, Hong Kong	797	50
Universiti Teknologi Malaysia	Malaysia	88	Hong Kong Polytechnic University	China, Hong Kong	682	46
Universiti Putra Malaysia	Malaysia	58	Chinese University of Hong Kong	China, Hong Kong	437	37
Kasetsart University	Thailand	56	Hong Kong University of Science and Technology	China, Hong Kong	397	35
China University of Mining Technology	China	55	The University of Hong Kong	China, Hong Kong	300	33
Universiti Kebangsaan Malaysia	Malaysia	53	Tsinghua University	China	293	5
Nanjing University of Information Science and Technology	China	51	Southeast University	China	214	6
Nanjing University of Post and TeleCommunications	China	46	Harbin Institute of Technology	China	189	6
Northeast Normal University	China	46	Shanghai Jiaotong University	China	183	6
University of Ulsan	Korea, Rep.	43	Zhejiang University	China	169	6
Jinan University	China	43	University of Tokyo	Japan	150	10
Chongqing University	China	42	Hong Kong Baptist University	China, Hong Kong	129	44
Southwest China Normal University	China	41	University of Science and Technology of China	China	124	10
Soochow University	China	39	Beijing Institute of Technology	China	122	5
Anna University	India	39	Huazhong University of Science and Technology	China	121	4

Table A5. Top 15 Asian universities with high publication growth rates and in-region collaboration in Earth and Planetary Sciences

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Kyung Hee University	Korea, Rep.	61	University of Tokyo	Japan	347	12
Annamalai University	India	56	The University of Hong Kong	China, Hong Kong	283	48
Changsha University of Science and Technology	China	56	Kyoto University	Japan	230	15
University of Calcutta	India	48	University of Science and Technology, Korea	Korea, Rep.	214	26
Universiti Putra Malaysia	Malaysia	46	Seoul National University	Korea, Rep.	199	23
Jilin University	China	45	Nagoya University	Japan	186	16
Kunming University of Science and Technology	China	38	Hong Kong Polytechnic University	China, Hong Kong	169	57
Shandong University	China	38	Hokkaido University	Japan	144	13
Capital Normal University	China	37	Tohoku University	Japan	127	12
Nanyang Technological University	Singapore	37	Peking University	China	127	8
Nanjing Normal University	China	36	Kyushu University	Japan	123	18
Northwest A&F University	China	34	Hong Kong University of Science and Technology	China, Hong Kong	107	42
Hanyang University	Korea, Rep.	33	China University of Geosciences	China	105	4
Hunan University of Science and Technology	China	32	Nanjing University	China	95	7
Nanjing University of Information Science and Technology	China	31	Ocean University of China	China	88	9

Table A6. Top 15 Asian universities with high publication growth rates and in-region collaboration in Economic and Business Sciences

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Universiti Sains Malaysia	Malaysia	73	Hong Kong Polytechnic University	China, Hong Kong	201	35
Universiti Kebangsaan Malaysia	Malaysia	70	City University of Hong Kong	China, Hong Kong	200	39
University of Malaya	Malaysia	48	Chinese University of Hong Kong	China, Hong Kong	140	30
China Agricultural University	China	47	The University of Hong Kong	China, Hong Kong	133	29
Central University of Finance	China	47	Hong Kong University of Science and Technology	China, Hong Kong	97	23
Universiti Putra Malaysia	Malaysia	45	Hong Kong Baptist University	China, Hong Kong	95	44
Beijing Institute of Technology	China	43	Tsinghua University	China	50	13
Zhejiang University	China	40	Fudan University	China	42	17
Shanghai University of Finance and EcoNomics	China	33	Sun Yat-Sen University	China	37	28
Renmin University of China	China	33	Shanghai Jiaotong University	China	37	13
Xiamen University	China	32	Zhejiang University	China	36	17
Fudan University	China	27	Peking University	China	36	9
Yuan Ze University	Taiwan of China	26	Korea University	Korea, Rep.	32	10
Nankai University	China	25	Seoul National University	Korea, Rep.	31	11
Beijing University of Aeronautics and Astronautics	China	22	Xiamen University	China	30	20

Table A7. Top 15 Asian universities with high publication growth rates and in-region collaboration in Engineering

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
University Malaysia Pahang	Malaysia	131	Hong Kong Polytechnic University	China, Hong Kong	1543	44
University of Malaya	Malaysia	68	City University of Hong Kong	China, Hong Kong	1408	51
Universiti Kebangsaan Malaysia	Malaysia	67	Hong Kong University of Science and Technology	China, Hong Kong	750	36
Beijing Forestry University	China	63	Tohoku University	Japan	742	13
Universiti Putra Malaysia	Malaysia	58	The University of Hong Kong	China, Hong Kong	660	35
Northeast Forestry University	China	57	Southeast University	China	611	4
Universiti Teknologi Malaysia	Malaysia	56	Tsinghua University	China	553	4
Liaoning Medical University	China	53	University of Tokyo	Japan	534	9
Sichuan Agricultural University	China	53	University of Science and Technology, Korea	Korea, Rep.	503	6
Tianjin Polytechnic University	China	48	Chinese University of Hong Kong	China, Hong Kong	473	36
Central South University of Forestry & Technology	China	47	Zhejiang University	China	452	4
The Maharaja Sayajirao University of Baroda	India	46	Osaka University	Japan	438	9
Shaanxi University of Science and Technology	China	43	Harbin Institute of Technology	China	433	3
Nanjing Forestry University	China	42	Kyoto University	Japan	386	8
Southwest China Normal University	China	40	Tokyo Institute of Technology	Japan	382	9

Table A8. Top 15 Asian universities with high publication growth rates and in-region collaboration in Environmental Sciences

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Jiangsu University	China	91	Hong Kong Polytechnic University	China, Hong Kong	223	42
Central South University China	China	74	University of Tokyo	Japan	171	17
University of Malaya	Malaysia	70	City University of Hong Kong	China, Hong Kong	167	38
National Taiwan University of Science and Technology	Taiwan of China	61	Kyoto University	Japan	159	16
Universiti Putra Malaysia	Malaysia	58	The University of Hong Kong	China, Hong Kong	129	26
Northeastern University China	China	57	Universiti Putra Malaysia	Malaysia	123	22
Chongqing University	China	56	Hong Kong University of Science and Technology	China, Hong Kong	115	29
Beijing University of Aeronautics and Astronautics	China	54	Tsinghua University	China	112	6
Universiti Teknologi Malaysia	Malaysia	50	Tohoku University	Japan	97	20
Sungkyunkwan University	Korea, Rep.	46	Hong Kong Baptist University	China, Hong Kong	96	36
Shandong University	China	45	Zhejiang University	China	94	6
Aligarh Muslim University	India	45	University of Science and Technology, Korea	Korea, Rep.	87	9
South China University of Technology	China	42	Hokkaido University	Japan	85	12
Xi'an Jiaotong University	China	42	Chinese University of Hong Kong	China, Hong Kong	79	37
Kangwon National University	Korea, Rep.	41	Sun Yat-Sen University	China	78	11

Table A9. Top 15 Asian universities with high publication growth rates and in-region collaboration in Health Professions and Nursing

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Universiti Kebangsaan Malaysia	Malaysia	50	Chinese University of Hong Kong	China, Hong Kong	85	20
Chungbuk National University	Korea, Rep.	45	Hong Kong Polytechnic University	China, Hong Kong	53	13
Chung Shan Medical University	Taiwan of China	45	The University of Hong Kong	China, Hong Kong	41	13
Kaohsiung Medical University	Taiwan of China	39	Sun Yat-Sen University	China	24	17
Kyung Hee University	Korea, Rep.	36	Peking University	China	18	10
University of Malaya	Malaysia	35	Seoul National University	Korea, Rep.	18	4
The Catholic University of Korea	Korea, Rep.	34	University of Tokyo	Japan	17	5
Taipei Medical University	Taiwan of China	34	Mahidol University	Thailand	16	11
Konkuk University	Korea, Rep.	31	Shanghai Jiaotong University	China	15	8
Inje University	Korea, Rep.	31	Sichuan University	China	13	12
National Cheng Kung University	Taiwan of China	30	University of Malaya	Malaysia	13	11
Waseda University	Japan	30	Fudan University	China	13	8
Chungnam National University	Korea, Rep.	29	Tohoku University	Japan	12	7
Sungkyunkwan University	Korea, Rep.	27	Capital Medical University China	China	12	6
Ewha Womans University	Korea, Rep.	27	Pusan National University	Korea, Rep.	11	10

Table A10. Top 15 Asian universities with high publication growth rates and in-region collaboration in Materials Sciences

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Universiti Putra Malaysia	Malaysia	56	City University of Hong Kong	China, Hong Kong	811	58
Universiti Kebangsaan Malaysia	Malaysia	52	Universiti Sains Malaysia	Malaysia	799	38
University of Malaya	Malaysia	50	Tohoku University	Japan	796	15
Chang'an University	China	47	Hong Kong Polytechnic University	China, Hong Kong	755	49
Chongqing University	China	46	University of Malaya	Malaysia	614	30
The Maharaja Sayajirao University of Baroda	India	41	Hong Kong University of Science and Technology	China, Hong Kong	513	45
Universiti Teknologi Malaysia	Malaysia	38	University of Science and Technology, Korea	Korea, Rep.	422	7
Taipei Medical University	Taiwan of China	38	Osaka University	Japan	410	10
Xi'an Shiyou University	China	36	The University of Hong Kong	China, Hong Kong	359	42
Nantong University	China	35	University of Tokyo	Japan	326	8
Guangzhou University	China	35	Tokyo Institute of Technology	Japan	323	10
Tianjin Medical University	China	32	Southeast University	China	315	6
Capital Normal University	China	31	Zhejiang University	China	292	6
Universiti Sains Malaysia	Malaysia	30	Chinese University of Hong Kong	China, Hong Kong	284	51
Naval University of Engineering	China	30	Tsinghua University	China	265	5

Table A11. Top 15 Asian universities with high publication growth rates and in-region collaboration in Mathematics

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Nantong University	China	65	City University of Hong Kong	China, Hong Kong	694	56
Universiti Putra Malaysia	Malaysia	62	Hong Kong Polytechnic University	China, Hong Kong	510	54
University of Malaya	Malaysia	61	Chinese University of Hong Kong	China, Hong Kong	357	41
Universiti Teknologi Malaysia	Malaysia	58	The University of Hong Kong	China, Hong Kong	335	41
King Mongkuts University of Technology Thonburi	Thailand	47	Gyeongsang National University	Korea, Rep.	274	59
Taiyuan University of Technology	China	41	Hong Kong Baptist University	China, Hong Kong	237	55
China University of Mining Technology	China	39	Hong Kong University of Science and Technology	China, Hong Kong	214	31
Banaras Hindu University	India	37	Tsinghua University	China	201	5
Universiti Kebangsaan Malaysia	Malaysia	35	Southeast University	China	158	4
Kunming University of Science and Technology	China	34	University of Tokyo	Japan	133	8
Nanjing University of Post and TeleCommunications	China	33	Zhejiang University	China	125	6
Aligarh Muslim University	India	32	University of Science and Technology of China	China	120	8
Dong-A University	Korea, Rep.	32	Shanghai Jiaotong University	China	112	5
China Three Gorges University	China	32	Fudan University	China	111	9
China Agricultural University	China	30	Harbin Institute of Technology	China	111	5

Table A12. Top 15 Asian universities with high publication growth rates and in-region collaboration in Medicine

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Hubei University	China	93	Chinese University of Hong Kong	China, Hong Kong	1,196	28
University of Hyderabad	India	60	The University of Hong Kong	China, Hong Kong	924	21
University of Electronic Science and Technology of China	China	57	Mahidol University	Thailand	487	15
Ningbo University	China	53	Sun Yat-Sen University	China	396	7
Jamia Hamdard University	India	53	Peking University	China	378	5
University of Rajasthan	India	43	Seoul National University	Korea, Rep.	344	4
Anhui University	China	41	University of Tokyo	Japan	324	5
Universiti Putra Malaysia	Malaysia	38	Yonsei University	Korea, Rep.	290	5
Shenzhen University	China	37	Osaka University	Japan	257	5
Kyung Hee University	Korea, Rep.	37	University of Malaya	Malaysia	241	15
Sogang University	Korea, Rep.	37	Hong Kong Polytechnic University	China, Hong Kong	238	27
Dr. Harisingh Gour University Sagar	India	36	Fudan University	China	231	4
Sokendai Graduate University for Advanced Studies	Japan	35	Shanghai Jiaotong University	China	228	3
Huazhong Agricultural University	China	35	Kyoto University	Japan	216	4
Northeast Agricultural University	China	34	China Medical University Shenyang	China	209	7

Table A13. Top 15 Asian universities with high publication growth rates and in-region collaboration in Multidisciplinary

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
International Islamic University Malaysia	Malaysia	140	Universiti Putra Malaysia	Malaysia	102	14
Universiti Sains Malaysia	Malaysia	115	Universiti Kebangsaan Malaysia	Malaysia	57	5
Universiti Putra Malaysia	Malaysia	106	University of Tokyo	Japan	53	13
Chiang Mai University	Thailand	102	The University of Hong Kong	China, Hong Kong	42	42
Universiti Teknologi Malaysia	Malaysia	97	Universiti Teknologi Malaysia	Malaysia	42	16
Universiti Kebangsaan Malaysia	Malaysia	90	University of Malaya	Malaysia	35	9
Seoul National University	Korea, Rep.	51	Kyoto University	Japan	28	11
Beijing University of Aeronautics and Astronautics	China	46	Shanghai Jiaotong University	China	28	2
University of Science and Technology of China	China	31	Tongji University	China	25	2
The University of Hong Kong	China, Hong Kong	29	Universiti Sains Malaysia	Malaysia	23	8
Beijing Jiaotong Daxue	China	27	Peking University	China	23	3
University of Malaya	Malaysia	21	Osaka University	Japan	19	8
University Malaysia Pahang	Malaysia	19	Tohoku University	Japan	18	16
Hokkaido University	Japan	19	Nagoya University	Japan	18	15
China University of Geosciences	China	15	Sun Yat-Sen University	China	17	4

Table A14. Top 15 Asian universities with high publication growth rates and in-region collaboration in Other Life and Health Sciences

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Sichuan Agricultural University	China	60	Chinese University of Hong Kong	China, Hong Kong	419	36
Northeast Forestry University	China	51	The University of Hong Kong	China, Hong Kong	324	30
Hubei University	China	44	Mahidol University	Thailand	234	18
Universiti Putra Malaysia	Malaysia	43	University of Tokyo	Japan	208	8
Government Medical College	India	42	Seoul National University	Korea, Rep.	195	6
Yangzhou University	China	41	Osaka University	Japan	190	9
Guangxi University	China	41	Hong Kong Polytechnic University	China, Hong Kong	184	51
Harbin Institute of Technology	China	36	University of Science and Technology, Korea	Korea, Rep.	172	9
Southern Medical University	China	33	Sun Yat-Sen University	China	167	9
Shanxi University	China	31	Zhejiang University	China	157	6
Nanchang University	China	29	Universiti Putra Malaysia	Malaysia	147	19
Tongji University	China	29	Chulalongkorn University	Thailand	142	20
University of Calcutta	India	27	Peking University	China	135	6
Guangdong Medical College	China	26	Shenyang Pharmaceutical University	China	127	10
Liaoning Medical University	China	24	Tohoku University	Japan	127	8

Table A15. Top 15 Asian universities with high publication growth rates and in-region collaboration in Physics and Astronomy

University	Country or territory	Publication growth rate (%)	University	Country or territory	In-region collaboration (number)	In-region collaboration (%)
Northwest A&F University	China	93	Tohoku University	Japan	1,010	13
University of Malaya	Malaysia	57	City University of Hong Kong	China, Hong Kong	1,008	58
Universiti Putra Malaysia	Malaysia	54	University of Tokyo	Japan	999	10
Nantong University	China	48	University of Science and Technology, Korea	Korea, Rep.	798	12
Universiti Teknologi Malaysia	Malaysia	46	Hong Kong Polytechnic University	China, Hong Kong	778	50
Chang'an University	China	42	Universiti Sains Malaysia	Malaysia	768	45
Shaanxi University of Science and Technology	China	40	University of Science and Technology of China	China	732	14
Nanjing University of Post and TeleCommunications	China	34	Osaka University	Japan	716	11
Kangwon National University	Korea, Rep.	34	Seoul National University	Korea, Rep.	691	18
Kochi University	Japan	33	University of Malaya	Malaysia	648	29
Universiti Sains Malaysia	Malaysia	31	Tokyo Institute of Technology	Japan	636	14
Universiti Kebangsaan Malaysia	Malaysia	29	Sungkyunkwan University	Korea, Rep.	617	24
Yeungnam University	Korea, Rep.	29	Kyungpook National University	Korea, Rep.	562	34
Hohai University	China	27	Kyoto University	Japan	542	8
Chonnam National University	Korea, Rep.	27	Peking University	China	523	11

Appendix VII

MAIN DISCIPLINARY FOCI, INTERNATIONAL SCIENTIFIC COLLABORATION AND GROWTH IN PUBLICATIONS IN ASIAN COUNTRIES

Afghanistan: Afghanistan displays stable disciplinary foci concentrated on Medicine, Social Sciences and Engineering. Between 2008 and 2012, the focus shifted from Engineering to Agriculture in the Top 3 research disciplines. Afghanistan engages in strong and constant international collaboration, mostly with the United Kingdom and the United States, as well as Belgium and Switzerland. Afghanistan's scientific output of Afghanistan has increased dramatically between the time periods 1997-2001 and 2008-2012. The compound annual growth rate of its publications is 34.6%.

Bangladesh: Bangladesh displays constant disciplinary foci on Medicine, Agriculture and Engineering throughout the years studied. It collaborates mostly with the United Kingdom, followed by the United States and Japan. From 2002, Japan took the lead in collaborative co-authorships with this country, followed by the United States and the United Kingdom. The compound annual growth rate of its publications is 11%.

Bhutan: Bhutan's core scientific foci is on Agriculture and Environmental Sciences. However, between 1997 and 2001, Social Sciences ranked in the third place but was replaced by Earth and Planetary Sciences between 2002 and 2007. In 2008, Bhutan's focus was on Agriculture, Medicine and Environmental Sciences, with core activities in disciplines related to Environment and Agriculture, which eventually shifted to Medicine in later years. The country has expanded its collaborations greatly. Between 1997 and 2001, its collaborations were mostly within the region (i.e. India, Lao People's Democratic Republic and the Philippines). However, between 2002 and 2007 collaboration expanded internationally to include Australia and the United Kingdom, and in 2008, the United States. The compound annual growth rate of its publications is 14.3%.

Brunei Darussalam: The scientific focus in Brunei Darussalam is on Medicine, and this focus has been stable through the years. However, between 1997 and 2001, this country also focused on Environmental Sciences and Earth and Planetary Science. In 2002, Engineering took the place of Environmental Sciences, which was replaced by Social Sciences and Agriculture in the 2008-2012 period. Brunei Darussalam collaborates mostly with Australia, the United Kingdom and the United States. However, between 2008 and 2012, collaborations with the United Kingdom were replaced by Malaysia. Brunei Darussalam displays a stable growth in its scientific output. The compound annual growth rate of its publications is 11.7%.

Cambodia: Medicine and Agriculture have been Cambodia's main scientific foci through the years. While Social Sciences lead the subject area between 1997 and 2001, in 2002 the field was replaced by Immunology and Microbiology, which have remained top foci since. Cambodia has strong collaboration with the United States, followed by Australia. Since 2002, collaboration with France have showed strong links and stayed constant. Within the region, Cambodia collaborated strongly with the Philippines from 1997 to 2001, and then with Thailand from 2008 on. Cambodia's largest increase in scientific output occurred between the time period 1997-

2001 and 2002-2007, publishing five times more articles than previously. Between 2008 and 2012, this country almost doubled its previous years' output. The compound annual growth rate of its publications is 21.5%.

China: Historically China has focused on Engineering, Physics and Materials Sciences. In 2008, the focus shifted to Computer Science, replacing Material Sciences in the Top 3 disciplines. The United States is China's top scientific partner, followed by Hong Kong Special Administrative Region of China and Japan. China's publication output has doubled through the years studied. The compound annual growth rate of its publications is 17.8%.

Hong Kong Special Administrative Region of China: The focus in this territory has traditionally been on Engineering, in addition to Medicine and Computer Science. The top collaborators with this territory are China and the United States, followed by the United Kingdom. In 2008, collaboration with Australia began to grow. Between the periods 1997-2001 and 2002-2007, the publications output in Hong Kong Special Administrative Region of China surged, but then slowed down between 2008 and 2012. The compound annual growth rate of its publications is 6.2%.

India: India's scientific focus is on Medicine and Chemistry, followed by Engineering and Physics. India's collaborations are foremost with the United States, followed by Germany and the United Kingdom. Its scientific output grew steadily through the time periods studied. The compound annual growth rate of its publications is 10.3%.

Indonesia: Agriculture and Medicine are Indonesia's top scientific foci, followed by Earth ad Planetary Sciences, Engineering and Computer Science. Its main collaborations are with Albania, Algeria and Argentina. Indonesia's scientific output surged between the periods 2002-2007 and 2008-2012, during which time the number of publications produced more than doubled. The compound annual growth rate of its publications is 12.3%.

Japan: Japan's scientific foci has historically been on Medicine, Engineering and Physics. Its main collaborations are with the United States, followed by China and Germany. Between 1997 and 2001, however, the United Kingdom was one of the Top 3 countries to collaborate with Japan; the country was replaced by China in 2002. Japan's scientific output has seen some decline between 2008 and 2012. The compound annual growth rate of its publications is 1.7%.

Lao People's Democratic Republic: The scientific foci of this country have remained Medicine, Agriculture and Immunology. Its collaborations have seen some shifts through the years. Between 1997 and 2001, Japan, Thailand and the United States were the main collaborators. During 2002-2008, Thailand took the lead, followed by the United States and the United Kingdom. However, during 2008-2012, Thailand, the United Kingdom and Australia were the leading collaborative countries co-publishing with Lao People's Democratic Republic. Its scientific output has increased with the years and doubled between 2008 and 2012. The compound annual growth rate of its publications is 21.7%.

Macao Special Administrative Region of China: The scientific foci are Computer Science and Engineering. However, between 2008 and 2012, the top discipline Medicine. Its main collaborators are China and Hong Kong Special Administrative Region of China, followed by the United States. The territory's publication output more than doubled between 1997 and 2007. The compound annual growth rate of its publications is 43.3%.

Malaysia: The scientific foci in Malaysia have seen several shifts throughout the years. While focus has generally been on Engineering and Medicine, between 1997 and 2001 Malaysia also concentrated on Agriculture, followed by Biochemistry between 2002 and 2007, and Physics between 2008 and 2012. Malaysia's scientific output has more than doubled over the years. It collaborates mostly with the United Kingdom, followed by the United States, Australia, China and Japan. The compound annual growth rate of its publications is 21.5%.

Maldives: The scientific foci are on Agriculture and Medicine, followed by Earth and Planetary Sciences. The Maldives collaborates mostly with India, the United States and Australia. Its scientific output is among the lowest in the region but has seen significant growth. The compound annual growth rate of its publications is 23.6%.

Myanmar: Medicine and Agriculture have been Myanmar's scientific foci over the years studied. A shift from Immunology to Engineering occurred during 2002 and 2007. From 2008, Myanmar shifted its focus to Computer Science. Japan is Myanmar's main collaborator, followed by Thailand. Since 2007, Myanmar has had increased collaboration with the United States. Although its share of publication output is overall low, it has increased significantly over the years. The compound annual growth rate of its publications is 12.8%.

Nepal: Nepal's scientific foci lay in Medicine, Agriculture and Environmental Science. Nepal mostly collaborates with the United States, India and United Kingdom. Its scientific output grew significantly between 2001 and 2007 and continued to grow through 2012. The compound annual growth rate of its publications is 11.8%.

Democratic People's Republic of Korea: Engineering and Computer Science have been the country's foci over the years. In 2008, the Democratic People's Republic of Korea shifted its focus from Physics to Materials Sciences. Its most prominent collaborator is the Republic of Korea. The United States also played a leading role until 2008, when China and Germany become top collaborators. Its scientific output is relatively low, although there was a surge in publication output between 2002 and 2007. Since 2008, the publication output has declined significantly. The compound annual growth rate of its publications is 9.1%.

Republic of Korea: Engineering has been the Republic of Korea's top scientific focus through the years studied, followed by Physics and Astronomy. Over time, the Republic of Korea shifted it scientific focus from Materials Sciences to Medicine. It collaborates mainly with the United States, Japan and China. The Republic of Korea's scientific output has seen significant growth through the years.

Pakistan: Medicine and Agriculture are Pakistan's leading scientific foci. Over the years, Pakistan shifted its focus from Chemistry to Engineering, and in 2008, to Physics and Astronomy. Its collaborations are led by the United States and United Kingdom, followed by Germany and, from 2008, by China. Pakistan has witnessed significant growth in its publication output. The compound annual growth rate of its publications is 15.8%.

Philippines: Agriculture and Medicine are the top scientific foci of the Philippines. Since 2002, there was a shift from Biochemistry to Social Science. The United States, Japan and Australia are the leading collaborators with this country.The Philippines has shown steady growth in scientific output. The compound annual growth rate of its publications is 7.3%.

Singapore: Singapore's scientific focus is mainly on Engineering. Over the years, the focus shifted from Physics to Medicine and Computer Science. The United States and China are Singapore's leading collaborators. While the United Kingdom was one of Singapore top collaborators between 1997 and 2001, Australia took that leading role from 2002. Singapore has a steady growth in scientific output. The compound annual growth rate of its publications is 10.2%.

Sri Lanka: Medicine and Agriculture are the main scientific foci in Sri Lanka. From 2002, the focus shifted from Environmental Sciences to Computer Science. The United Kingdom, the United States and Japan were Sri Lanka's leading collaborators until 2008. Since then, Australia took a leading collaborative role in place of Japan. The compound annual growth rate of its publications is 10.4%.

Thailand: Thailand displays unchanging scientific foci and collaborations over the years. Medicine, Engineering and Agriculture and the foci and leading collaborators include the United States, Japan and the United Kingdom. Thailand's scientific output has grown steadily. The compound annual growth rate of its publications is 14.5%.

Viet Nam: Viet Nam's scientific foci from 1997 to 2007 were Agriculture, Medicine and Physics. From 2008, Viet Nam has shifted its focus to Computer Science and Engineering, along with Medicine. Japan and the United States are the top collaborators with Viet Nam, followed by France and the Republic of Korea. The compound annual growth rate of its publications is 15.5%.

Appendix VIII

STATISTICAL TABLES

LIST OF STATISTICAL TABLES

THE FOLLOWING SYMBOLS ARE USED IN THE STATISTICAL TABLES

Symbol	Interpretation
...	No data available
*	National estimation
**	For country data: UIS estimation
–	Magnitude nil or negligible
.	Not applicable
x(y)	Data are included in column (y) of the table
+n	Data refer to the school or financial year *n* years after the reference year
-n	Data refer to the school or financial year *n* years prior to the reference year

THE FOLLOWING FOOTNOTES ARE USED IN THE STATISTICAL TABLES

[a] Data on internationally mobile students (Statistical Tables B2 and B3) reported by host countries are used to estimate the number of outbound students from a given country. Not all host countries specify the country of origin of the internationally mobile students that they host, and thus the number of outbound students from a given country may be underestimated.

[b] These countries have completed the UNESCO/OECD/Eurostat (UOE) or World Education Indicators (WEI) programme questionnaires. Data by field of study refer to graduations rather than graduates (Statistical Table B4).

[c] PPP rates used in Statistical Table B5 and B6 are based on GDP to reflect how much governments spend on education or R&D.

Table B1. TERTIARY EDUCATION / Enrolment and teaching staff / 2011

Country or territory	Total enrolment			Gross enrolment ratio					
	2011			2000				2011	
	MF (000) (1)	% F (2)	% private (3)	MF (4)	M (5)	F (6)	GPI (7)	MF (8)	M (9)
Afghanistan	98	24	1	...	...	...	...	4	6
Bangladesh	2,008	40	45	5	7	4	0.49	13	16
Bhutan	7	40	...	3$^{**,-1}$	3$^{**,-1}$	2$^{**,-1}$	0.58$^{**,-1}$	9	10
Brunei Darussalam	8^{+1}	62^{+1}	11^{+1}	13	9	16	1.69	24^{+1}	18^{+1}
Cambodia	223	38	60	2	4	1	0.32	16	20
China	31,308	50	...	8	...	...	...	24	23
China, Hong Kong SAR	271	51*	17	...	...	...	...	60	59*
China, Macao SAR	31	51	63	26	27	25	0.91	64	64
India	26,651	42	...	10	11	7	0.66	23	26
Indonesia	5,364	46	62	15	16	14	0.88	27	29
Iran (Islamic Republic of)	4,405^{+1}	50^{+1}	45^{+1}	19	21	18	0.86	55^{+1}	55^{+1}
Japan	3,881	46	79	49	52	45	0.85	60	63
Korea, DPR	...	...	...	...	...	...	...	...	...
Korea, Republic of	3,356	40	81	79	96	59	0.61	101	114
Lao PDR	125	42	26	3	4	2	0.52	17	20
Malaysia	1,036	56	37	26	25	26	1.06	36	33
Maldives	5^{-3}	53^{-3}	...	.	.	.	.	13^{-3}	12^{-3}
Myanmar	660	58	.	10^{+1}	...	...	...	14	12
Nepal	385	42	62	4	7	2	0.36	14	18
Pakistan	1,817^{+1}	48^{+1}	...	...	...	...	...	10^{+1}	10^{+1}
Philippines	2,625^{-2}	54^{-2}	63^{-2}	30^{+1}	29^{+1}	32^{+1}	1.10^{+1}	28^{-2}	25^{-2}
Singapore	244^{+1}	50^{+1}	65^{+1}	...	...	...	...	...	...
Sri Lanka	232	64	-	...	...	...	...	14	10
Thailand	2,430^{+1}	56^{+1}	16^{+1}	35	32	38	1.19	51^{+1}	45^{+1}
Timor-Leste	19^{-1}	41^{-1}	...	9$^{*,+2}$	8$^{*,+2}$	10$^{*,+2}$	1.23$^{*,+2}$	18^{-1}	21^{-1}
Viet Nam	2,261^{+1}	...	15^{+1}	9	11	8	0.73	25^{+1}	...

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b1

Gross enrolment ratio		Distribution of students by type of programme (%)				Female students by type of programme (%)				Teaching staff	
2011		2011				2011				2011	
F (10)	GPI (11)	ISCED 5B (12)	ISCED 5A, first degree (13)	ISCED 5A, second degree (14)	ISCED 6 (15)	ISCED 5B (16)	ISCED 5A, first degree (17)	ISCED 5A, second degree (18)	ISCED 6 (19)	MF (000) (20)	%F (21)
2	0.33	38.3	...	...	-	11	...	...	.	3	20
11	0.69	8.2	73.1	18.4	0.4	32	41.6	40	39	77	17
7	0.68	21.4	78.6	-	.	31	42.0	-	.	1	24
31[+1]	1.74[+1]	34.6[+1]	52.5[+1]	11.8[+1]	1.1[+1]	56[+1]	64.5[+1]	70[+1]	35[+1]	1[+1]	46[+1]
12	0.61	9.9	83.3	6.4	0.5	33	39.7	20	6	11	12
26	1.11	42.8	...	...	...	51	...	...	...	1,607	45
61[*]	1.05[*]	34.1	44.0	18.9	3.0	49[*]	...[*]	...[*]	44[*]	...	...
64	0.99	7.5	65.9	24.5	2.1	62	55.3	40	32	2	35
20	0.78	13.9	74.4	11.4	0.3	29	43.7	45	41	...	...
25	0.85	...	...	...	...	...	...	...	...	239	41
55[+1]	1.00[+1]	22.7[+1]	67.0[+1]	9.2[+1]	1.1[+1]	38[+1]	54.2[+1]	47[+1]	38[+1]	256[+1]	27[+1]
57	0.90	19.7	73.1	5.3	1.9	62	43.4	30	33	532	...
...	...	...	...	...	...	...	...	...	...	...	...
85	0.75	24.2	66.0	8.1	1.8	39	38.5	50	37	230	34
14	0.73	64.4	34.5	1.0	-	45	35.1	35	.	7	31
39	1.20	42.0	50.1	5.1	2.8	54	57.4	58	45	69	53
14[-3]	1.13[-3]	...	...	...	...	...	...	...	...	...	...
16	1.34	4.2	93.7	1.6	0.5	70	56.5	79	80	23	81
11	0.64	.	80.5	19.3	0.1	.	44.2	31	11	...	...
9[+1]	0.95[+1]	5.1[+1]	77.6[+1]	16.1[+1]	1.3[+1]	48[+1]	49.3[+1]	41[+1]	29[+1]	90[*, +1]	37[*, +1]
31[-2]	1.24[-2]	9.6[-3]	...[-3]	...[-3]	0.3[-3]	53[-3]	...[-3]	...[-3]	61[-3]	...	...
...	...	37.4[+1]	50.2[+1]	9.0[+1]	3.5[+1]	48[+1]	52.3[+1]	43[+1]	39[+1]	18[+1]	38[+1]
19	1.79	...	...	...	...	...	...	...	...	5	43
58[+1]	1.31[+1]	14.4[+1]	76.7[+1]	8.1[+1]	0.8[+1]	44[+1]	58.4[+1]	61[+1]	51[+1]	122	69
15[-1]	0.73[-1]	...	...	...	...	...	...	...	...	1[-2]	25[-2]
...	...	37.6[+1]	...[+1]	...[+1]	0.3[+1]	...	...	...	18[+1]	84[+1]	49[+1]

Table B2. TERTIARY EDUCATION / Internationally (degree-seeking) mobile students[a] by host country and region of origin / 2011

Country or territory	Students from abroad studying in given country (inbound mobile students)			Mobile students by region of origin								
	MF (1)	% F (2)	Inbound mobility rate (%) (3)	Arab States (4)	Central and Eastern Europe (5)	Central Asia (6)	East Asia and the Pacific (7)	Latin America and the Caribbean (8)	North America and Western Europe (9)	South and West Asia (10)	Sub-Saharan Africa (11)	Unspecified (12)
Afghanistan	–$^{-2}$	.$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$	–$^{-2}$
Bangladesh	1,589^{-2}	...	0.1^{-2}	...	...	...	...	...	...	...	...	...
Bhutan	...	...	...	...	-	...	...	...	...	...	...	...
Brunei Darussalam	354^{+1}	47^{+1}	4.2^{+1}	11^{+1}	4^{+1}	-$^{+1}$	215^{+1}	-$^{+1}$	7^{+1}	68^{+1}	22^{+1}	27^{+1}
Cambodia	...	...	...	...	...	...	...	...	...	...	...	...
China	79,638	45	0.3	...	...	...	...	...	...	...	...	...
China, Hong Kong SAR	17,959	56	6.6	3	29	1	16,366	32	295	210	20	1,003
China, Macao SAR	13,623	45	44.6	-	12	4	13,384	17	133	8	61	4
India	27,531	...	0.1	3,376	157	305	3,483	84	1,974	12,820	4,154	1,178
Indonesia	6,437^{-1}	...	0.1^{-1}	...	76^{-1}	...	5,915^{-1}	...	67^{-1}	...	...	379^{-1}
Iran (Islamic Republic of)	4,512^{+1}	46^{+1}	0.1^{+1}	867^{+1}	47^{+1}	70^{+1}	50^{+1}	4^{+1}	16^{+1}	3,330^{+1}	6^{+1}	122^{+1}
Japan	151,461	49	3.9	941	1,293	1,700	134,142	1,578	5,762	5,304	726	15
Korea, DPR	...	...	...	...	...	...	...	...	...	...	...	...
Korea, Republic of	62,675	52	1.9	307	566	3,215	52,825	374	1,864	1,955	690	879
Lao PDR	786	35	0.6	–	9	18	756	–	3	–	–	–
Malaysia	64,749^{-1}	35^{-1}	6.1^{-1}	11,420^{-1}	365^{-1}	771^{-1}	20,836^{-1}	299^{-1}	592^{-1}	14,366^{-1}	10,975^{-1}	5,125^{-1}
Maldives	...	...	...	...	...	...	...	...	...	...	...	...
Myanmar	65	52	0.01	–	–	–	63	–	–	2	–	–
Nepal	107	55	0.03	–	–	–	54	1	13	38	–	1
Pakistan	...	...	...	...	...	...	...	...	...	...	...	...
Philippines	2,665^{-3}	...	0.1^{-3}	35^{-3}	19^{-3}	1^{-3}	1,559^{-3}	46^{-3}	335^{-3}	438^{-3}	80^{-3}	152^{-3}
Singapore	52,959^{+1}	47^{+1}	21.7^{+1}	...	...	...	...	...	...	...	...	...
Sri Lanka	435	...	0.2	...	...	...	...	...	...	...	...	...
Thailand	20,309^{+1}	...	0.8^{+1}	64^{+1}	198^{+1}	57^{+1}	15,276^{+1}	70^{+1}	2,461^{+1}	1,718^{+1}	443^{+1}	22^{+1}
Timor-Leste	...	...	...	...	...	...	...	...	...	...	...	...
Viet Nam	3,996^{+1}	27^{+1}	0.2^{+1}	-$^{+1}$	9^{+1}	29^{+1}	3,205^{+1}	10^{+1}	17^{+1}	-$^{+1}$	-$^{+1}$	726^{+1}

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b2

Table B3. TERTIARY EDUCATION / International flows of (degree-seeking) mobile students[a] by country of origin / 2011

Country or territory	Students from abroad studying in given country (outbound mobile students)			Top five destinations (host countries) for outbound mobile students (the number of students from given country studying in the host countries is shown in brackets)	Number of students from abroad studying in given country (inbound mobile students)	Net flow of mobile students (inbound - outbound)	
	MF	Outbound mobility ratio (%)	Gross outbound enrolment ratio			MF	Net flow ratio (%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Afghanistan	9,073 **	9.3 **	0.3 **	Iran, Islamic Rep. (2,782), India (2,166), Turkey (885), Saudi Arabia (459), United States (421)	– $^{-2}$	5,385 $^{-2}$	5.7 $^{-2}$
Bangladesh	22,055 **	1.1 **	0.1 **	United Kingdom (4,058), Australia (3,046), United States (2,818), Cyprus (2,256), Malaysia (1,722)$^{-1}$	1,589 $^{-2}$	-17,548 $^{-2}$	-1.1 $^{-2}$
Bhutan	2,085 **	30.4 **	2.7 **	India (1,253), Australia (360), Thailand (217), United States (113), Canada (24)$^{-1}$	...	...	...
Brunei Darussalam	3,305 **	49.9 **	9.8 **	United Kingdom (2,046), Australia (675), Malaysia (310)$^{-1}$, New Zealand (74), United States (65)	354 $^{+1}$	-2,933	-44.3
Cambodia	4,194 **	1.9 **	0.3 **	Thailand (944), France (636), Viet Nam (482), Australia (467), United States (334)	...	...	...
China	649,542 **	2.1 **	0.5 **	United States (178,890), Japan (94,382), Australia (90,175), United Kingdom (65,906), Korea, Rep. (47,477)	79,638	-569,904	-1.8
China, Hong Kong SAR	31,637 **	11.7 **	7.0 **	Australia (10,976), United Kingdom (10,341), United States (7,981), Canada (1,770)$^{-1}$, China, Macao (213)	17,959	-13,678	-5.1
China, Macao SAR	1,826 **	6.0 **	3.8 **	Australia (724), United States (488), United Kingdom (265), Canada (102)$^{-1}$, China, Hong Kong (98)	13,623	11,797	38.7
India	196,241 **	0.7 **	0.2 **	United States (101,909), United Kingdom (38,677), Australia (14,091), New Zealand (7,517), Canada (5,868)$^{-1}$	27,531	-168,710	-0.8
Indonesia	33,905 **	0.6 **	0.2 **	Australia (9,702), Malaysia (8,955)$^{-1}$, United States (6,809), Japan (2,176), Germany (1,359)	6,437 $^{-1}$	-28,053 $^{-1}$	-0.6 $^{-1}$
Iran (Islamic Republic of)	46,591 **	1.1 **	0.6 **	Malaysia (7,397)$^{-1}$, United States (5,519), United Kingdom (3,463), Sweden (3,068), Canada (2,958)$^{-1}$	4,512 $^{+1}$	-42,249	-1.0
Japan	35,971 **	0.9 **	0.6 **	United States (20,883), United Kingdom (3,206), Australia (2,117), France (1,685), Germany (1,562)	151,461	115,490	3.0
Korea, DPR	1,484 **	...	...	Canada (303)$^{-1}$, Australia (196), France (168), Philippines (142)$^{-3}$, Russian Federation (115)$^{-2}$	...	...	...
Korea, Republic of	128,122 **	3.8 **	3.8 **	United States (71,949), Japan (25,961), Australia (7,900), United Kingdom (4,527), Canada (4,320)$^{-1}$	62,675	-65,447	-1.9
Lao PDR	4,122 **	3.3 **	0.6 **	Viet Nam (1,936), Thailand (1,311), Japan (268), Australia (170), France (112)	786	-3,336	-2.8
Malaysia	54,899 **	5.3 **	1.9 **	Australia (18,312), United Kingdom (12,175), United States (6,606), Russian Federation (2,671)$^{-2}$, Indonesia (2,516)$^{-1}$	64,749 $^{-1}$	10,115 $^{-1}$	1.0 $^{-1}$
Maldives	1,868 **	39.1 **, $^{-3}$	5.1 **, $^{-3}$	Malaysia (1,197)$^{-1}$, India (315), Australia (201), United Kingdom (131), Saudi Arabia (97)	...	...	...
Myanmar	6,815 **	1.0 **	0.1 **	Russian Federation (1,627)$^{-2}$, Thailand (1,310), Japan (1,115), United States (781), Australia (655)	65	-6,750	-1.0
Nepal	29,418 **	7.6 **	1.1 **	United States (10,104), Australia (6,397), India (5,044), Japan (1,826), United Kingdom (1,498)	107	-29,311	-7.6
Pakistan	36,378 **	2.3 **	0.2 **	United Kingdom (10,122), United States (4,949), Sweden (3,165), Australia (3,104), United Arab Emirates (1,874)	...	...	...
Philippines	11,457 **	0.4 **, $^{-2}$	0.1 **, $^{-2}$	United States (3,535), Australia (2,098), United Kingdom (1,738), Japan (635), New Zealand (426)	2,665 $^{-3}$	-6,207 $^{-3}$	-0.2 $^{-3}$
Singapore	21,072 **	8.9 **	...	Australia (9,767), United Kingdom (4,370), United States (4,234), Malaysia (840)$^{-1}$, Canada (384)$^{-1}$	52,959 $^{+1}$	26,843	11.3
Sri Lanka	16,534 **	7.1 **	1.0 **	United Kingdom (4,033), Australia (3,766), United States (2,908), Malaysia (1,076)$^{-1}$, India (878)	435	-16,099	-5.9
Thailand	25,195 **	1.0 **	0.5 **	United States (8,079), United Kingdom (5,760), Australia (3,694), Japan (2,476), Malaysia (1,316)$^{-1}$	20,309 $^{+1}$	-5,040	-0.2
Timor-Leste	3,671 **	20.0 **, $^{-1}$	3.5 **, $^{-1}$	Indonesia (2,675)$^{-1}$, Cuba (685), Australia (128), United States (47), Portugal (37)$^{-1}$	...	...	...
Viet Nam	52,577 **	2.4 **	0.6 **	United States (14,603), Australia (10,591), France (6,194), Japan (3,672), United Kingdom (3,192)	3,996 $^{+1}$	-48,860	-2.2

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b3

Table B4. TERTIARY EDUCATION / Graduates by broad fields of education / 2011

Country or territory	Total number of graduates		Distribution of tertiary graduates by type of programme (%)				Gross graduation ratio, ISCED 5A, first degree				Distribution of graduates by field of education (%) Education	
	MF (000) (1)	% F (2)	ISCED 5B (3)	ISCED 5A, first degree (4)	ISCED 5A, second degree (5)	ISCED 6 (6)	MF (7)	M (8)	F (9)	GPI (10)	MF (11)	% F (12)
Afghanistan	10 [-2]	19 [-2]	…	…	…	…	…	…	…	…	…	…
Bangladesh	303	…	9	70	21	0.4	7	…	…	…	4	…
Bhutan	…	…	…	…	…	…	…	…	…	…	…	…
Brunei Darussalam	2 [+1]	65 [+1]	32 [+1]	51 [+1]	17 [+1]	0.1 [+1]	14 [+1]	9 [+1]	21 [+1]	2 [+1]	29 [+1]	69 [+1]
Cambodia	32	42	…	…	…	…	…	…	…	…	…	…
China [b]	9136 [+1]	50 [+1]	50 [+1]	…	…	…	…	…	…	…	…	…
China, Hong Kong SAR	…	…	…	…	…	…	…	…	…	…	…	…
China, Macao SAR	6	59	14	73	11	2.4	38	32	44	1	5	52
India	…	…	…	…	…	…	…	…	…	…	…	…
Indonesia [b]	811 [-1]	…	23 [-1]	71 [-1]	6 [-1]	0.3 [-1]	15 [-1]	…	…	…	20 [-1]	…
Iran (Islamic Republic of)	571 [+1]	38 [+1]	36 [+1]	55 [+1]	8 [+1]	0.7 [+1]	18 [+1]	19 [+1]	17 [+1]	1 [+1]	6 [+1]	65 [+1]
Japan [b]	969	48	31	59	9	1.6	43	46	39	1	7	72
Korea, DPR	…	…	…	…	…	…	…	…	…	…	…	…
Korea, Republic of [b]	618 [+1]	51 [+1]	32 [+1]	53 [+1]	13 [+1]	2.0 [+1]	50 [+1]	49 [+1]	51 [+1]	1 [+1]	7 [+1]	76 [+1]
Lao PDR	31 [+1]	44 [+1]	76 [+1]	23 [+1]	1 [+1]	- [+1]	5 [+1]	7 [+1]	4 [+1]	1 [+1]	25 [+1]	48 [+1]
Malaysia [b]	205	58	46	47	6	1.4	17	13	20	2	10	67
Maldives	…	…	…	…	…	…	…	…	…	…	…	…
Myanmar	135	65	9	88	3	0.4	12	9	16	2	3	81
Nepal	48	…	.	80	20	0.1	7	…	…	…	33	…
Pakistan	…	…	…	…	…	…	…	…	…	…	…	…
Philippines [b]	470 [-2]	57 [-2]	…	…	…	…	…	…	…	…	…	…
Singapore	…	…	…	…	…	…	…	…	…	…	…	…
Sri Lanka [b]	27 [+1]	57 [+1]	15 [+1]	51 [+1]	33 [+1]	1.4 [+1]	4 [+1]	4 [+1]	5 [+1]	1 [+1]	17 [+1]	72 [+1]
Thailand [b]	535 [-1]	57 [-1]	24 [-1]	59 [-1]	16 [-1]	0.6 [-1]	…	…	…	…	…	…
Timor-Leste	5 [-2]	36 [-2]	. [-2]	100 [-2]	. [-2]	. [-2]	26 [-2]	32 [-2]	19 [-2]	1 [-2]	…	…
Viet Nam	417 [+1]	37 [+1]	38 [+1]	59 [+1]	3 [+1]	0.1 [+1]	14 [+1]	16 [+1]	12 [+1]	1 [+1]	23 [+1]	52 [+1]

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b4

Distribution of graduates by field of education (%)															
Humanities and Arts		Social Science, Business and Law		Science		Engineering, Manufacturing and Construction		Agriculture		Health and Welfare		Services		Not known or unspecified	
MF (13)	% F (14)	MF (15)	% F (16)	MF (17)	% F (18)	MF (19)	% F (20)	MF (21)	% F (22)	MF (23)	% F (24)	MF (25)	% F (26)	MF (27)	% F (28)
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
35	...	43	...	11	...	4	...	1	...	2	...	-	...	-	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14^{+1}	72^{+1}	18^{+1}	62^{+1}	9^{+1}	58^{+1}	9^{+1}	41^{+1}	.$^{+1}$	.$^{+1}$	8^{+1}	76^{+1}	.$^{+1}$	.$^{+1}$	13^{+1}	71^{+1}
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	71	52	58	5	19	2	11	-	.	6	70	19	69	-	.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0^{-1}	...	39^{-1}	...	6^{-1}	...	17^{-1}	...	6^{-1}	...	6^{-1}	...	-$^{-1}$	.$^{-1}$	6^{-1}	...
8^{+1}	56^{+1}	29^{+1}	44^{+1}	6^{+1}	67^{+1}	41^{+1}	21^{+1}	4^{+1}	40^{+1}	3^{+1}	65^{+1}	3^{+1}	38^{+1}	-$^{+1}$	.$^{+1}$
15	69	27	39	3	26	17	13	3	38	12	63	9	78	7	58
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18^{+1}	68^{+1}	22^{+1}	48^{+1}	7^{+1}	39^{+1}	24^{+1}	24^{+1}	1^{+1}	41^{+1}	14^{+1}	71^{+1}	7^{+1}	48^{+1}	–$^{+1}$	.$^{+1}$
9^{+1}	44^{+1}	43^{+1}	50^{+1}	4^{+1}	37^{+1}	8^{+1}	7^{+1}	6^{+1}	30^{+1}	2^{+1}	61^{+1}	2^{+1}	61^{+1}	–$^{+1}$	.$^{+1}$
6	64	33	69	10	59	27	36	1	55	8	79	4	53	0	65
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
38	63	16	65	32	67	6	61	1	52	3	81	1	37	0	77
22	...	28	...	9	...	3	...	1	...	5	...	-	.	-	.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27^{+1}	65^{+1}	29^{+1}	51^{+1}	11^{+1}	48^{+1}	6^{+1}	28^{+1}	4^{+1}	54^{+1}	6^{+1}	50^{+1}	0^{+1}	-$^{+1}$	-$^{+1}$	.$^{+1}$
...	...	...	...	...	...	...	...	...	...	...	...	...	.$^{-1}$	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	.$^{-2}$	...	...
4^{+1}	38^{+1}	34^{+1}	38^{+1}	–$^{+1}$	.$^{+1}$	24^{+1}	25^{+1}	6^{+1}	35^{+1}	4^{+1}	38^{+1}	3^{+1}	20^{+1}	2^{+1}	27^{+1}

Table B5. Public expenditure on education / Financial year ending in 2011

Country or territory	Total public expenditure per student						Total public expenditure on education		Public expenditure on higher education as a % of total public education expenditure
	as a % of GDP per capita			in PPP[c] dollars					
	Primary (ISCED 1)	Secondary (ISCED 2-3)	Tertiary (ISCED 5-6)	Primary (ISCED 1)	Secondary (ISCED 2-3)	Tertiary (ISCED 5-6)	as a % of GDP	as a % of total government expenditure	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Afghanistan	…	…	…	…	…	…	…	…	…
Bangladesh	…	13.9	20.0	…	224	323	2.2[-2]	13.8[-2]	13.5[-2]
Bhutan	9.5	31.5	67.0	527	1,745	3,706	4.7	11.3	11.0
Brunei Darussalam	5.2[-1]	7.8[-1]	32.2[-1]	2,545	3,873	15,905	3.3[+1]	…	…
Cambodia	6.9[-1]	…	27.8[-1]	150	…	605	2.6[-1]	13.1[-1]	14.5[-1]
China	…	…	…	…	…	…	…	…	…
China, Hong Kong SAR	14.7	17.6	25.6	6,939	8,275	12,091	3.4	17.4	28.9
China, Macao SAR	…	…	28.5	…	…	22,455	2.7	…	59.5
India	6.9	12.6	51.4	236	432	1,765	3.2	10.4	35.9
Indonesia	8.8	7.7	23.8	401	350	1,088	2.8	15.0	18.9
Iran (Islamic Republic of)	14.5	16.4	19.9	…	…	…	4.1	15.4	27.2
Japan	23.4	25.3	24.2	7,867	8,511	8,134	3.8	9.7	19.5
Korea, DPR	…	…	…	…	…	…	…	…	…
Korea, Republic of	23.3[-2]	23.8[-2]	13.2[-2]	6,367	6,513	3,600	5.0[-2]	…	17.1[-2]
Lao PDR	…	…	…	…	…	…	2.8[-1]	13.2[-1]	…
Malaysia	17.1	19.9	60.9	2,737	3,179	9,753	5.9	20.9	37.0
Maldives	18.0[-3]	…	–[-3]	1,492	…	-[-3]	6.8	15.8	6.6
Myanmar	…	…	11.8	…	…	…	0.8	4.4	19.1
Nepal	16.1[-2]	12.2[-2]	50.7[-2]	199	151	627	4.7[-1]	22.7[-1]	10.7[-1]
Pakistan	…	…	…	…	…	…	2.2	10.0	…
Philippines	9.0[-3]	9.1[-3]	9.7[-3]	341	346	366	2.7[-2]	13.2[-2]	12.0[-2]
Singapore	11.2[-1]	17.0[-1]	27.9[-1]	5,701	8,677	14,232	3.1	20.5	35.6
Sri Lanka	5.8	8.3	31.8	321	460	1,760	2.0	9.3	17.8
Thailand	…	25.9	21.3	…	2,315	1,909	5.8	24.0	13.8
Timor-Leste	…	…	67.4[-1]	…	…	1,033	9.4	…	19.8
Viet Nam	25.3[-1]	…	39.8[-1]	845[-1]	…	1,353	6.3[-1]	20.9[-1]	14.7[-1]

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b5

Table B6. Total R&D efforts / 2011

Country or territory	R&D expenditure		Researchers	
	in billions of constant 2005 PPP$[c]	as a % of GDP	in full-time equivalent	per 1 million inhabitants
Afghanistan	…	…	…	…
Bangladesh	…	…	…	…
Bhutan	…	…	…	…
Brunei Darussalam	6 $^{-7}$	0.04 $^{-7}$	102 $^{-7}$	282 $^{-7}$
Cambodia	7 $^{-9}$	0.05 $^{-9}$	223 $^{-9}$	18 $^{-9}$
China	183,164	1.84	1,318,086	963
China, Hong Kong	2,254 $^{-1}$	0.75 $^{-1}$	20,622 $^{-1}$	2,925 $^{-1}$
China, Macao	17	0.04	260	476
India	31,064	0.81	192,819 $^{-1}$	160 $^{-1}$
Indonesia	731 $^{-2}$	0.08 $^{-2}$	21,275 $^{-2}$	90 $^{-2}$
Iran (Islamic Republic of)	5,925 $^{-3}$	0.79 $^{-3}$	54,268 $^{-3}$	751 $^{-3}$
Japan	133,226	3.39	656,651	5,137
Korea, DPR				
Korea, Republic of	55,288	4.03	288,901	5,804
Lao PDR	3 $^{-9}$	0.04 $^{-9}$	87 $^{-9}$	16 $^{-9}$
Malaysia	4,374	1.07	47,242	1,643
Maldives	…	…	…	…
Myanmar	…	0.16 $^{-9}$	837 $^{-9}$	17 $^{-9}$
Nepal	98 $^{-9}$	0.30 $^{-9}$	1,500 $^{-1}$	62 $^{-1}$
Pakistan	1,429	0.33	26,223	149
Philippines	321 $^{-4}$	0.11 $^{-4}$	6,957 $^{-4}$	78 $^{-4}$
Singapore	6,224	2.23	33,719	6,505
Sri Lanka	149 $^{-1}$	0.16 $^{-1}$	2,140 $^{-1}$	103 $^{-1}$
Thailand	1,233 $^{-2}$	0.25 $^{-2}$	22,000 $^{-2}$	332 $^{-2}$
Timor-Leste	…	…	…	…
Viet Nam	274 $^{-9}$	0.19 $^{-9}$	9,328 $^{-9}$	113 $^{-9}$

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b6

Table B7. Researchers in full-time equivalents by sector of employment, 2011

Country or territory	Business	Higher education	Government	Private non-profit
Afghanistan	…	…	…	…
Bangladesh	…	…	…	…
Bhutan	…	…	…	…
Brunei Darussalam	16.3 $^{-8}$	59.2 $^{-8}$	24.5 $^{-8}$	– $^{-8}$
Cambodia	15.7 $^{-9}$	12.5 $^{-9}$	50.7 $^{-9}$	21.2 $^{-9}$
China	62.1	18.9	19.0	–
China, Hong Kong	41.0 $^{-1}$	56.6 $^{-1}$	2.4 $^{-1}$	– $^{-1}$
China, Macao	…	…	…	…
India	38.7 $^{-1}$	11.5 $^{-1}$	45.6 $^{-1}$	4.2 $^{-1}$
Indonesia	35.7 $^{-2}$	29.6 $^{-2}$	34.8 $^{-2}$	– $^{-2}$
Iran (Islamic Republic of)	15.0 $^{-3}$	51.5 $^{-3}$	33.6 $^{-3}$	– $^{-3}$
Japan	74.8	19.2	4.9	1.1
Korea, DPR	…	…	…	…
Korea, Republic of	77.4	14.1	7.3	1.2
Lao PDR	29.9 $^{-9}$	34.5 $^{-9}$	35.6 $^{-9}$	– $^{-9}$
Malaysia	11.5	80.8	7.7	–
Maldives	…	…	…	…
Myanmar	…	…	…	…
Nepal	…	…	…	…
Pakistan	…	…	…	…
Philippines	39.0 $^{-4}$	31.8 $^{-4}$	28.4 $^{-4}$	0.8 $^{-4}$
Singapore	51.7	42.9	5.4	–
Sri Lanka	31.7 $^{-1}$	27.1 $^{-1}$	41.0 $^{-1}$	0.2 $^{-1}$
Thailand	29.6 $^{-2}$	54.5 $^{-2}$	15.7 $^{-2}$	0.2 $^{-2}$
Timor-Leste	…	…	…	…
Viet Nam	10.4 $^{-9}$	32.4 $^{-9}$	56.5 $^{-9}$	0.7 $^{-9}$

Notes: Partial data for Indonesia, Brunei Darussalam, Cambodia, Lao People's Democratic Republic and Myanmar. Macao Special Administrative Region of China and Pakistan are excluded from this table because the business sector is not covered.

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b7

Table B8. R&D expenditure by type of R&D activity (%), 2011

Country or territory	Experimental development	Applied research	Basic research	Not specified
Afghanistan	…	…	…	…
Bangladesh	…	…	…	…
Bhutan	…	…	…	…
Brunei Darussalam	…	…	…	…
Cambodia	…	…	…	…
China	78.0 -5	16.8 -5	5.2 -5	– -5
China, Hong Kong	…	…	…	…
China, Macao	…	…	…	…
India	22.0 -6	25.1 -6	18.1 -6	34.8 -6
Indonesia	…	…	…	…
Iran (Islamic Republic of)	…	…	…	…
Japan	61.9 -1	21.2 -1	12.1 -1	4.7 -1
Korea, DPR	…	…	…	…
Korea, Republic of	61.8 -1	19.9 -1	18.2 -1	– -1
Lao PDR	…	…	…	…
Malaysia	16.4	66.4	17.2	-
Maldives	…	…	…	…
Myanmar	…	…	…	…
Nepal	…	…	…	…
Pakistan	…	…	…	…
Philippines	…	…	…	…
Singapore	46.5 -1	32.9 -1	20.6 -1	– -1
Sri Lanka	40.1 -1	49.0 -1	10.9 -1	– -1
Thailand	47.9 -2	37.6 -2	14.5 -2	– -2
Timor-Leste	…	…	…	…
Viet Nam	…	…	…	…

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b8

Table B9. Female researchers in headcounts as a percentage of the total number of researchers, 2011

Country or territory	All sectors	Higher education sector
Afghanistan	…	…
Bangladesh	…	…
Bhutan	…	…
Brunei Darussalam	40.6 $^{-8}$	24.2 $^{-8}$
Cambodia	20.7 $^{-9}$	18.2 $^{-9}$
China	…	…
China, Hong Kong	…	…
China, Macao	37.7	37.8
India	14.3 $^{-1}$	13.0 $^{-1}$
Indonesia	30.6 $^{-2}$	36.3 $^{-2}$
Iran (Islamic Republic of)	26.6 $^{-3}$	27.6 $^{-3}$
Japan	13.8 $^{-1}$	24.3 $^{-1}$
Korea, DPR	…	…
Korea, Republic of	16.7 $^{-1}$	26.6 $^{-1}$
Lao PDR	23.0 $^{-9}$	34.1 $^{-9}$
Malaysia	48.7	50.3
Maldives	…	…
Myanmar	85.5 $^{-9}$	…
Nepal	7.8 $^{-1}$	20.9 $^{-1}$
Pakistan	27.2	30.4
Philippines	52.3 $^{-4}$	56.0 $^{-4}$
Singapore	29.3 $^{-1}$	33.0 $^{-1}$
Sri Lanka	36.9 $^{-1}$	41.9 $^{-1}$
Thailand	51.1 $^{-2}$	54.3 $^{-2}$
Timor-Leste	…	…
Viet Nam	42.8 $^{-9}$	45.8 $^{-9}$

Note: Data for India are for full-time equivalent researchers.

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

DataLink http://dx.doi.org/10.15220/2014/ed/sd/2/b9

Table B10. Researchers in headcounts in the higher education sector by field of science (%), 2011

Country or territory	Natural sciences	Engineering and technology	Medical sciences	Agricultural sciences	Social sciences	Humanities	Not specified
Afghanistan	…	…	…	…	…	…	…
Bangladesh	…	…	…	…	…	…	…
Bhutan	…	…	…	…	…	…	…
Brunei Darussalam	…	…	…	…	…	…	…
Cambodia	…	…	…	…	…	…	…
China	…	…	…	…	…	…	…
China, Hong Kong	…	…	…	…	…	…	…
China, Macao	1.8	13.9	11.1	-	38.9	23.2	11.1
India	…	…	…	…	…	…	…
Indonesia	11.1 [-6]	11.1 [-6]	7.3 [-6]	13.4 [-6]	18.2 [-6]	7.3 [-6]	31.6 [-6]
Iran (Islamic Republic of)	15.0 [-3]	23.1 [-3]	19.2 [-3]	14.2 [-3]	26.0 [-3]	- [-3]	2.4 [-3]
Japan	13.5 [-1]	53.4 [-1]	14.1 [-1]	4.2 [-1]	4.1 [-1]	3.8 [-1]	7.0 [-1]
Korea, DPR	…	…	…	…	…	…	…
Korea, Republic of	13.3	67.0	5.5	2.7	6.4	5.1	–
Lao PDR	…	…	…	…	…	…	…
Malaysia	36.0	29.9	11.6	4.6	12.1	5.7	-
Maldives	…	…	…	…	…	…	…
Myanmar	14.1 [-9]	34.4 [-9]	4.7 [-9]	1.8 [-9]	42.5 [-9]	2.5 [-9]	– [-9]
Nepal	…	…	…	…	…	…	…
Pakistan	23.4	17.8	15.6	14.6	15.7	9.5	3.5
Philippines	15.6 [-4]	34.9 [-4]	8.2 [-4]	22.4 [-4]	15.2 [-4]	2.3 [-4]	1.3 [-4]
Singapore	15.7 [-1]	62.2 [-1]	16.0 [-1]	1.4 [-1]	– [-1]	– [-1]	4.7 [-1]
Sri Lanka	28.3 [-1]	22.2 [-1]	16.4 [-1]	20.3 [-1]	7.8 [-1]	– [-1]	5.0 [-1]
Thailand	12.7 [-6]	11.8 [-6]	14.0 [-6]	11.4 [-6]	25.7 [-6]	4.1 [-6]	20.4 [-6]
Timor-Leste	…	…	…	…	…	…	…
Viet Nam	…	…	…	…	…	…	…

Please refer to the Reader's Guide for more information on the data and symbols used in each table.

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As demand for tertiary education continues to rise across Asia, countries are expanding their higher education systems outwards by constructing new universities, hiring more faculty and encouraging private provision. Many of these systems are also moving upwards by introducing new graduate programmes to ensure that there are enough qualified professors and researchers for the future.

Based on data from the UNESCO Institute for Statistics (UIS) and a diverse range of national and international sources, this report provides a comprehensive view to evaluate different strategies to expand graduate education. Special focus is given to middle-income countries in the region which have recently experienced the most dramatic growth through an innovative mix of policies. For example, interventions aimed at improving university rankings may be controversial but are nonetheless reshaping university reforms. The report highlights the pros and cons by comparing the three most commonly-used university ranking systems.

Across the region, countries are not simply seeking to accommodate more students – they are striving to build top-quality universities that can produce the research and workforce needed for national economic development. So this report presents a range of data to better evaluate the economic benefits flowing from university research, as well as the spillover effects to the private sector. The authors also analyse the ways in which international collaboration can boost the productivity and quality of university-based research. Overall, this report provides the data and analysis to help countries weigh the balance of different policies to expand their higher education systems.

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