BIBLIOMETRIC STUDY
2015

Science and Technology Knowledge Productivity in Malaysia

MOSTI

KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI
MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

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MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

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PREFACE

This Bibliometric Study 2015 is the fourth in a series of bibliometric studies commissioned by the Malaysian Science and Technology Information Centre (MASTIC), Ministry of Science, Technology and Innovation (MOSTI). Commissioning bibliometric studies suits MASTIC's role as the main reference authority with regards to strategic Science, Technology and Innovation(STI) and in providing information on STI.

Bibliometric methods are used as one of the main approaches to assess the scientific performance of countries, institutions and even individual scientists. The Bibliometric Study permits observation of the state of science and technology by surveying the overall production of scientific literature as well as patents, at a given level of specialisation. It also profiles the research performance of Malaysia in relation to the world.

MASTIC intends this report to be readily readable and comprehensible in order for the public to understand the scientific performance of Malaysia. In addition, a bibliometric study aids decision-making and research management processes. Specifically, it assists in:

i.   Planning and funding research grants, as well as in developing strategic research areas;

ii.   Monitoring the performance of productive institutions and researchers;

iii. Engaging in cooperation with other countries on priority areas;

iv.   Capitalising on strengths and tackling weaknesses of the research system;

v.   Targeting and focusing on areas and sectors of interest to the country; and

vi.   Justifying the investment in Research and Development (R&D).

ACKNOWLEDGEMENT

MASTIC would like to express its sincere appreciation to the top management of the Ministry of Science, Technology and Innovation (MOSTI), namely the Secretary-General, for their support and guidance in the preparation of the study report. MASTIC also thanks the technical committee for their feedback as well as insights in improving the quality of this report.

Special thanks go to those who have participated in the interviews and focus group discussions, as well as the consultants and researchers from Unit Perundingan Universiti Malaya (UPUM).

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EXECUTIVE SUMMARY

The Bibliometric Study 2015 aims to assess the status of research achievements at the national level, especially identifying research performance that includes publications and patents in the fields of Science, Technology and Innovation (STI) and Social Sciences. This study also compares Malaysian research performance in relation to the world, including identifying areas of focus and strength in the Malaysian research community. In addition, this study also maps the patterns of cooperation in the publication and patenting activities in Malaysia. This study covers the period of 2001 to 2014.

Specifically, this study aims to:

a) Measure the level of research output performance, with the main reference being scientific publications and patents that are released for use by fellow researchers, individuals, and organisations – nationally and internationally;

b) Identify the expertise of researchers and centres of excellence in the country, according to areas of research that are strategic to the country;

c) Assess the frequency of citations in scientific publications and patents, thus enabling the identification of factors that influenced the number of citations at the national and international level;

d) Report the h-index of universities and research institutions in Malaysia;

e) Map the networks of publications and patents by institutions;

f) Evaluate the level of collaboration between researchers as well as local and international institutions in Research and Development (R&D) activities;

g) Compare Malaysia against international levels to determine the position and contributions of the country in the generation of scientific publications globally; and

h) Present holistic suggestions and recommendations for policymakers to increase the performance of scientific knowledge in the areas of STI, as well as the competence of the country in R&D activities.

The scope of the study includes investigating:

a) Scientific publications (i.e. articles and proceedings) in the areas of STI and Social Sciences in the main Web of Science (WoS) databases, namely: (i) Science Citation Index Expanded (SCIE), (ii) Social Sciences Citation Index (SSCI), and (iii) Essential Science Indicators (ESI), as well as in SCOPUS databases;

b) Production of patents in the areas of STI in the Patent Cooperation Treaty (PCT) and Intellectual Property Corporation of Malaysia (MyIPO) databases; and

c) Institutions of Higher Learning (IHLs) (both public and private), Public Research Institutions (PRIs) as well as companies.

Compared to the previous studies, this current study provides additional information on:

a) Publication and patent mapping for local and international institutions;

b) Patent data analysis using the PCT and the MyIPO databases;

c) Patent analysis at the company level;

d) Relative Specialisation Index (RSI) and Relative Impact Index (RII); and

e) Network analysis based on co-publication and co-patenting.

The summary of the findings are as follows:

i. Publication Outputs

For the period of 2001 to 2014, a total of 90,128 international articles and proceedings were recorded. The publication output has grown exponentially since 2008, and has surpassed that of Singapore and Finland, for example. Of these papers, a total of 59,131 records are international articles produced by 118,357 authors across Malaysia in 224 subject categories, according to Thomson Reuters. Nearly 83% of these authors were affiliated with Research Universities (RUs) from the IHLs. The exponential growth in publication since 2008 is a direct consequence of objectives set under the 9MP, namely the increase in national R&D funding as well as the establishment of RUs to promote excellence in teaching and Research, Development and Innovation (R,D&I).

The field of Materials Science produced the highest number of articles (4,266 articles) followed by Crystallography (4,153 articles), which jointly contributed nearly 14% of all publications produced to date. In terms of collaboration, while England, the United States of America, India, Japan and Australia remain the top collaborating countries, there is a notable increase in collaborations among Middle-Eastern countries, particularly Iran and Saudi Arabia. Within Malaysia, there is a healthy collaboration effort among the research universities, especially between Universiti Malaya, Universiti Putra Malaysia and Universiti Kebangsaan Malaysia.

The scientific foci in Malaysia have seen several shifts throughout the years. While the 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 those years.

As a whole, a significant increase in publications was recorded in Malaysia, especially after the proactive measures taken by the Ministry of Higher Education (MOHE) including the establishment of RUs.

ii. Publication Citations

A total of 394,353 citations are recorded for the period of 2001 to 2014. The highest citation count of 46,275 is recorded in 2011, followed by 45,939 in 2010 and 41,447 in 2009 respectively. In general, the number of citations shows an increasing trend, in tandem with the increasing trend of publications. However, the number of citation counts has decreased since 2012 even though the number of papers published has grown exponentially over the years up to 2014. Nevertheless, citations per paper – measured as the ratio of citation counts to the total number of papers produced – displays a decreasing trend over the period under study.

Among 64 collaborating countries, Malaysia has a citations per paper ratio of 5.37 (For context, the highest citations per paper ratio is Iceland's at 19.48). The fields of research garnering the highest citations per paper for Malaysian articles are Immunology (10.86), followed by Environment/Ecology (8.72). The five research universities collectively contributed 77.27% of all citations produced in Malaysia over the period of 2001 to 2014.

iii.   Patent Outputs

For the period of 2001 to 2014, a total of 3,611 patents from Malaysia were filed under the PCT. The fields of Computer Technology and Digital Communication have the highest number of patents filed. MIMOS Berhad filed the most number of patents, followed by Universiti Putra Malaysia. Successful collaborations are seen between academic institutions and the industries.

On the other hand, MyIPO reveals a total of 2,461 patents from Malaysia during the years 2001 to 2014, led by the fields of Civil Engineering and Chemical Engineering with most patents granted. Among the institutions, MIMOS Berhad has the most patents granted, followed closely by Universiti Teknologi Malaysia.

From the RSI, many private firms – including Shell, PETRONAS and Schlumberger – appear to specialise in a portfolio of fields. Most institutions from public sectors such as MIMOS Berhad, Universiti Putra Malaysia (UPM), Universiti Sains Malaysia (USM), Universiti Malaya (UM) and Malaysian Palm Oil Board (MPOB) attained relative strength in many technological fields. Universiti Teknologi PETRONAS (UTP) stands out as a performing private institution in patenting activities.

While Malaysia are ahead of neighbouring countries such as Thailand, Indonesia, Philippines, and Vietnam; Malaysia are still significantly behind Singapore.

iv.   Patent Citations

During 2001-2014, Malaysia recorded a total of 3,611 patents in the PCT, World Intellectual Property Organisation (WIPO). These patents recorded 2,335 citations in total over the period of 2001-2014. Annually, on average Malaysia recorded 256 patents, 167 citations and 0.65 citations per patent. The highest citation count of 401 was recorded in 2008, followed by 385 citations in 2009 and 373 citations in 2010 respectively. In general, the number of citations showed an increasing trend from 2001 to 2008, after which the trend slowed down from 2009 to 2014 due to the time lag in recording patent citations. Citations per patent – measured as ratio of citation counts to the total number of patents produced – displayed a decreasing trend since 2009.

Relatively few of the Malaysian institutions are active in patenting activities, with notable exceptions such as MIMOS Berhad. Patent citations remains low, with even lower scores of citations per patent among the Malaysian institutions. In terms of total patent citations by field of research, Basic Materials Chemistry emerged as the dominant field, with the highest patent citations at 208. Interestingly, it seems that there is virtually no linkage in terms of co-patenting activities in Malaysia – most patents are assigned to individual organisations. The mapping exercise indicates that the main patent clusters include: (1) Mobile, Network, Quantum, Telephone, Optical; (2) Assembly, Pallet, Panel, Light, Vehicle; (3) Implant, Simulator, Produce, Joint, Virus; (4) Air, Engine, Valve, Water, Combustion; and (5) Pile, Panel, Wall, Frame, Gate.

v.   Research Performance: Drivers and Challenges

While the number of publications has experienced a sizable boom in the last decade, there is increasing concern about the quality of publications. A vibrant research culture in Malaysia only started since 2006 after the introduction of the Research University Agenda. R&D grants such as the Science Fund and the Fundamental Research Grant Scheme have also contributed to the increasing number and quality of publications. In addition, full commitment from the top management of the institutions in supporting publication activities – such as holding staff promotion exercises, establishing Key Performance Indicators (KPIs) and offering special incentive packages in rewarding productive researchers – are also key drivers in fostering publication activities amongst researchers.

There is a growing concern among the institutions about the quality of patents. They are selective in patent filing, and a more stringent process has been put in place with regards to screening and selection of patent applications by researchers. The main driving factor for patenting activities is attributed to the strategic partnership of universities and PRIs with the companies. The setting up of institutional supports for patenting activities among the universities and PRIs – such as Technology Transfer Office (TTO), Collaborative Research Centre, and University Commercialisation Unit – has contributed to the increasing awareness and motivation in research patenting activities.

Nevertheless, challenges in publication and patenting remain. Among them are:

a)   Deficiency in creating a more competitive research ecosystem;

b)   Lack of scholarly publication culture and skills;

c)   Need for a more holistic evaluation and reward system;

d)   Inconsistent funding, compounded by rising cost of patenting;

e)   Insufficient pool of researchers with industry and business exposure ;

f)   Limited research collaboration with industries;

g)   Low perceived importance of Intellectual Property Rights (IPRs); and

h)   Lack of patent experts and institutional support.

vi.   Conclusion and Recommendations

There are significant improvements in terms of total production of papers and patents. Strengths in the field of research – especially in terms of publications – currently reflects the availability of human resources in the universities and PRIs, while strengths in the field of patenting describes the availability of human resources in both the public institutions and the industrial sectors, especially in the areas related to information and communication technology. Nevertheless, the citations remained low for both publications and patents. Despite showing progressive performance especially since 2006, as a whole evidence from quantitative analysis suggests that three major challenges remain for Malaysia namely increasing the momentum of publication and patent production, low citation counts and the lack of local companies in patenting activities.

The policy direction and strategies to mitigate some of these challenges should focus on the following aspects:

a)   Optimising resources and improving research productivity;

b)   Establishing a consistent stream of funding;

c)   Creating a seamless research ecosystem;

d)   Promoting scholarly publication culture and skills;

e)   Improving research visibility;

f)   Expanding the international network – star researchers;

g)   Promoting outreach activities with industries;

h)   Leveraging genuine public-private collaboration;

i)   Establishing a national centralised patent administration and support unit;

j)   Nurturing patenting culture through tax incentives and finance supports; and

k)   Showcasing entrepreneurial science.

These recommendations serve as a broad policy direction and strategy that – although not mutually comprehensive – can be used as a way forward by policymakers in the future.

KEY INDICATORS

WoS Articles		2001 – 2008	2001 – 2012	2001 – 2014
Publications	SCIE	12,873	37,822	56,580
	SSCI	643	2,768	4,531
	Total*	13,152	39,382	59,131
Publication Citations	SCIE	182,717	342,910	374,022
	SSCI	8,579	18,576	20,331
	Total	191,296	361,486	394,353
Citations/ Publications	SCIE	14.19	9.07	6.61
	SSCI	13.34	6.71	4.49
	Total	14.15	8.91	6.45
Top 5 Research Areas	SCIE	Materials Science, Multidisciplinary Crystallography Engineering, Electrical & Electronic Engineering, Chemical Multidisciplinary Sciences		
	SSCI	Economics Management Public, Environmental & Occupational Health Business Education & Educational Research		
Top 5 Malaysian Institutions (Publications and Citations)		Universiti Malaya Universiti Sains Malaysia Universiti Putra Malaysia Universiti Kebangsaan Malaysia Universiti Teknologi Malaysia		

Data coverage : WoS – SCIE and SSCI, 2001-2014; data covers as of 31st December 2014

Note : * The total number of publications are not a direct sum of the number of publications in SCIE and SSCI due to journal overlapping issues. It reflects the total number of publications discussed in Chapter 3 after screening and accounting for duplication.

SCOPUS Articles		2001 – 2008	2001 – 2012	2001 – 2014
Publications	Sciences	16,525	55,261	84,614
	Social Sciences & Humanities	2,393	12,151	19,125
	Total	18,918	67,412	103,739
Top 5 Research Areas	Sciences	Engineering Medicine Materials Science Physics & Astronomy Agricultural & Biological Sciences		
	Social Sciences & Humanities	Social Sciences Multidisciplinary Business, Management & Accounting Economics, Econometrics & Finance Arts & Humanities		

SCOPUS Articles	2001 – 2008	2001 – 2012	2001 – 2014
Top 5 Malaysian Institutions (Publications and Citations)	Universiti Malaya Universiti Putra Malaysia Universiti Sains Malaysia Universiti Kebangsaan Malaysia Universiti Teknologi Malaysia		

Data coverage : SCOPUS, 2001-2014; data covers as of 31st December 2014.

Note : 'Sciences' alludes to Physical Sciences, Life Sciences and Health Sciences. The reported key statistics include the entire SCOPUS database while the study only analyses Malaysian publications in SCOPUS database.

Patents		2001 – 2008	2001 – 2012	2001 – 2014
Patents	PCT (filed)	809	2,728	3,611
	MyIPO (granted)	682	1,784	2,461
Patent Citations	PCT	1,243	2,308	2,335
	MyIPO	6	21	21
Citations/Patents	PCT	1.54	0.85	0.65
	MyIPO	0.01	0.01	0.01
Top 5 Patent Technology Specialisations	PCT	Computer Technology Digital Communication Measurement Semiconductors Telecommunications		
	MyIPO	Civil Engineering Chemical Engineering Furniture, Games Other Special Machines Basic Materials Chemistry		
Top 5 Malaysian Organisations (Patents)	PCT	MIMOS Berhad Universiti Putra Malaysia Intel Corporation Universiti Sains Malaysia Universiti Malaya		
	MyIPO	MIMOS Berhad Universiti Teknologi Malaysia Universiti Malaya Universiti Putra Malaysia Malaysian Palm Oil Board		

Data coverage : PCT and MyIPO, 2001-2014; data covers as of 31st December 2014
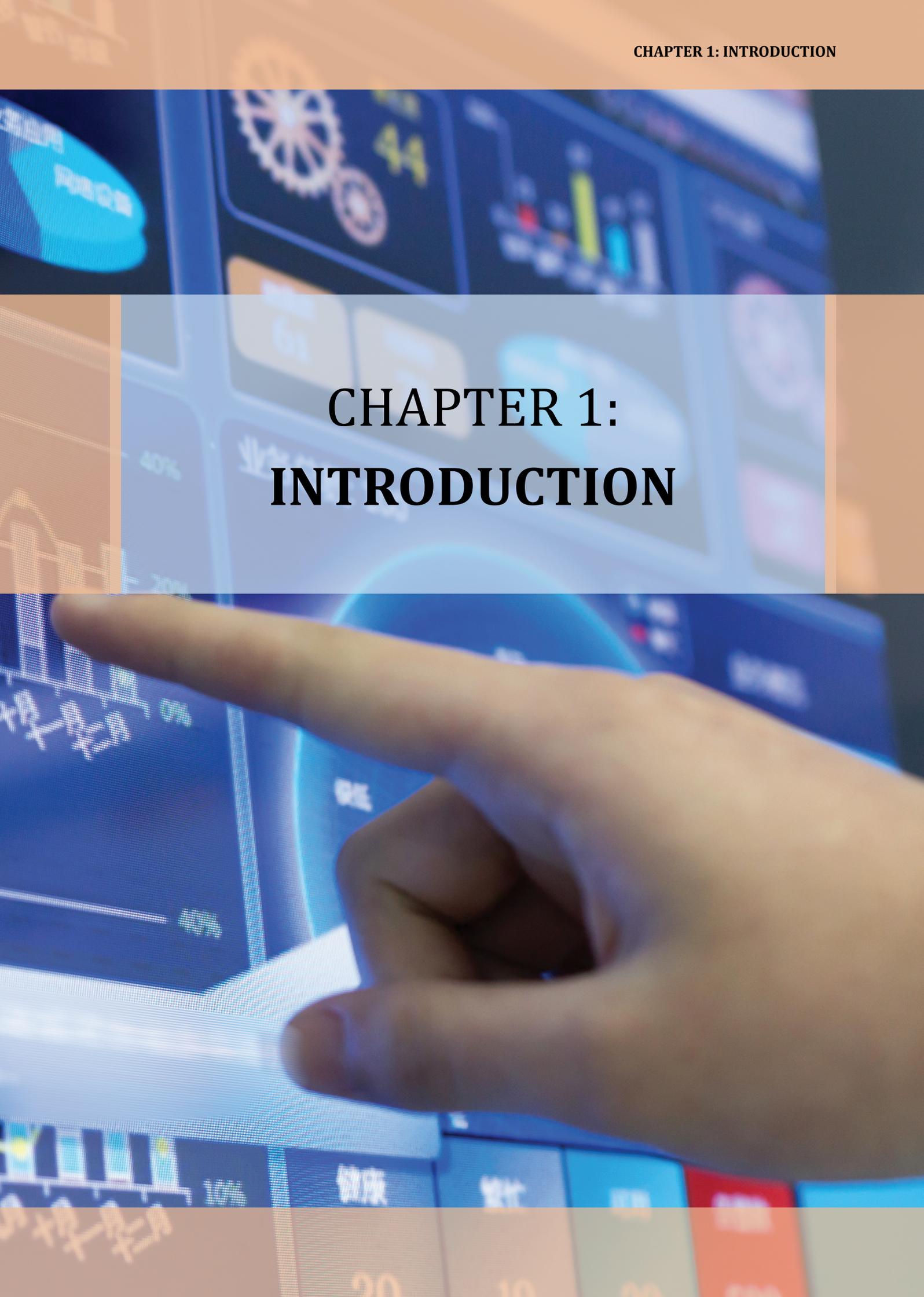
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CHAPTER 1:
INTRODUCTION

CHAPTER 1:   INTRODUCTION

1.1   Background

Bibliometric is a tool with which the state of Science and Technology (S&T) can be observed through the overall production of scientific literature, at a given level of specialisation. Specifically, its purpose is to measure the output of scientific and technological research through data derived not only from scientific literature, but from patents as well. Over the past decade, bibliometric methods have been used as one of the main approaches for assessing the scientific performance of a country in relation to the world, an institution in relation to a country, and even individual scientists in relation to their own communities.

Bibliometric approaches – whereby science can be portrayed through the results obtained – are based on the notion that the essence of scientific research is the production of 'knowledge', and that the scientific literature is the constituent manifestation of that knowledge. Hence, research publications in the field of Science, Technology and Innovation (STI) and Social Sciences are an indicator used in determining the status of knowledge advancement and achievement. The significance of these publications is observed through citations, which measures the overall impact of an article's influence (or that of its authors) in the scientific community. Early studies of citations have shown that a very high number of citations in a scholarly paper correlates well with the high standing of scientists among their peers and the recognition they receive nationally and internationally (Zuckerman, 1987; Garfield, 1979; Lawani, 1981). Despite criticism of its use as an evaluative tool, citations remains one of the important metrics to indicate research quality and scientific performance in universities and research organisations worldwide. The use of citation rate to rank journals by the Institute for Scientific Information (ISI), which started publishing the first Science Citation Index in 1963, has also strengthened the role of citations as an indicator of research quality. Patents – as a means of transfer of knowledge to industrial innovation, commercialisation and social value – constitute an indicator of the tangible benefits of an Intellectual Property (IP) and economic investment.

The Bibliometric Study 2015 is conducted to determine the status of research achievements at the national level, especially in identifying research performance that includes publications and patents in the fields of STI and Social Sciences. This study also compares Malaysian research performance in the international arena, and identifies areas of focus and strength in the research community within Malaysia. In addition, this study also maps the patterns of cooperation in the publication and patenting activities of Malaysia. The bibliometric approach implemented in this study assumes that the output of research activities is the 'knowledge' disseminated in the form of publications and patents. Thus, the publication and patent output analysis of a particular institution and country are assumed to provide a clear understanding of the nature of the scientific activities and progress. Indeed, these data and information are important indicators that show the specific attributes of the country's research activities.

In the past, the Ministry of Science, Technology and Innovation (MOSTI) had conducted three bibliometric studies, namely in 2003, 2008 and 2012. Over time, the approach and methodology of research in these bibliometric studies have been expanded and improved. The purpose is to provide a more comprehensive understanding of the research performance in Malaysia. For instance, in 2012 the scope of the study was expanded to include activities in the field of Social Sciences.

In an effort to further strengthen the existing bibliometric study, some improvements – particularly in terms of the scope of the study – are implemented in this study. The new additions to the Bibliometric 2015 study include:

    i.   Publication and patent mapping for local and international institutions;

    ii.   Patent data analysis using the Patent Cooperation Treaty (PCT) and the Intellectual Property Corporation of Malaysia (MyIPO) databases;

    iii.   Patent analysis at the company level;

    iv.   Relative Specialisation Index (RSI) and Relative Impact Index (RII); and

    v.   Network analysis based on co-publication and co-patenting.

Although there are some limitations, bibliometric study provides insights into the research performances – and alternatively, insights in designing and evaluating research results. By providing new information, bibliometric study aids decision-making and research management processes. Specifically, it assists in:

    i.   Planning and funding research grants, as well as developing strategic research areas;

    ii.   Monitoring the performance of productive institutions and researchers;

    iii.   Engaging in joint cooperation with other countries in priority areas;

    iv.   Capitalising on strengths and tackling weaknesses of the research system;

    v.   Targeting and focusing on areas and sectors of interest to the country; and

    vi.   Justifying the investment in Research and Development (R&D).

1.2   Progress of Bibliometric Study in Malaysia

In Malaysia, MOSTI has conducted three bibliometric studies in the years 2003, 2008 and 2012 respectively. The first Bibliometric Study 2003 was undertaken by the Malaysian Science and Technology Information Centre (MASTIC) with the aim of understanding the status of Malaysia's STI in relation to the world in terms of knowledge performance. The second Bibliometric Study 2008 investigated scientific publications not only in international journals, but also in Malaysian journals. In addition, the study examined the citations of research publications as a measure of research quality and impact. The scope of study for the third Bibliometric Study 2012 was expanded to include the h-index of Malaysian institutions as well as the international journals in the field of Social Sciences. These studies showed that there is a gradual increase in the number of research publications and citations over the years. Table 1.1 provides several salient findings of the three studies.

Table 1.1   Key Findings of Bibliometric Studies

Aspects	2003	2008	2012
Data coverage	1955 – 2002	1980 – 2008 (International); 1927 – 2008 (Malaysian)	2001 – 2011
Research publications	13,475	23,088 (International); 22,509 (Malaysian)	30,563
Number of fields	59	89 (International); 179 (Malaysian)	222
Number of authors	16,828 from 2,660 institutions	(International); 35,041 from 4,639 institutions (Malaysian); 24,018 from 2,504 institutions	45,687 from 8,229 institutions
Top fields of research	Physical Chemistry, Agriculture, Medical Research	(International); Physical Chemistry/Chemistry Physics, Materials Science & Engineering, Electrical & Electronic Engineering (Malaysian); Primary Products from Plants, Clinical Medicine, Wood & Non-Wood Forest Product	Crystallography (sub-field of Physical Chemistry), Materials Science, Electrical & Electronic Engineering
Fields with limited publications	Aerospace Engineering, Computer Science & Engineering, Nuclear Engineering	(International); Archaeology, Hematology, Architecture, Nuclear Engineering (Malaysian); Biopharmacy/ Biotechnology, Forensic Biotechnology, Marine Toxicology	Psychology, Medical Ethics, Criminology & Penology, Archaeology
Top contributors by institutions	Universiti Malaya (4,216 papers), Universiti Sains Malaysia (2,790), Universiti Putra Malaysia (2,489)	(International); Universiti Malaya (5,894 papers), Universiti Sains Malaysia (4,679), Universiti Putra Malaysia (3,511) (Malaysian); Universiti Kebangsaan Malaysia (2,645), Universiti Malaya (2,342), Universiti Teknologi Malaysia (2,091)	Universiti Malaya (7,508 papers), Universiti Sains Malaysia (7,073), Universiti Putra Malaysia (4,947)
Citations	Not in the scope of study	10,352 papers cited with 86,317 citations (International)	A total of 125,856 citations (Note: Number of cited papers is unavailable)

Table continued on next page

Aspects	2003	2008	2012
International comparison	Malaysia (ranked 55 out of 178 countries) contributed 10,538 papers out of the world total of 13,278,112 papers between 1981 – 2002	Malaysia (ranked 47 out of 145 countries) contributed 15,636 papers between 1999 – 2009 (Note: The world total number of publications is unavailable)	Malaysia (ranked 45 out of 147 countries) contributed 29,815 papers between 2001 – 2011 (Note: The world total number of publications is unavailable)

1.3   Areas of Improvement of Bibliometric Study 2015

Table 1.2 shows the areas of improvements in the 2015 study. Among other improvements, the scope of coverage has been extended.

1.4   Objectives of the Study

The main objectives for the Bibliometric Study 2015 are:

i.   Measure the level of research output performance, with the main reference being scientific publications and patents that are released for use by fellow researchers, individuals, and organisations – nationally and internationally;

ii.   Identify the expertise of researchers and centres of excellence in the country, according to areas of research that are strategic to the country;

iii.   Assess the frequency of citations in scientific publications and patents, thus, enabling the identification of factors that influenced the number of citations at the national and international level;

iv.   Report the h-index of universities and research institutions in Malaysia;

v.   Map the networks of publications and patents by institutions;

vi.   Evaluate the level of collaboration between researchers as well as local and international institutions in R&D activities;

vii.   Compare Malaysia against international levels to determine the position and contributions of the country in the generation of scientific publications globally; and

viii.   Present holistic suggestions and recommendations for policymakers to increase the performance of scientific knowledge in the areas of STI, as well as the competence of the country in R&D activities.

Table 1.2   Areas of Improvement of Bibliometric Study 2015

Domains	Measurements	2003	2008	2012	2015
Scientific Publication	Publications in international journals	Articles indexed by international databases	Articles indexed by WoS and SCOPUS	Articles indexed by WoS	Articles indexed by WoS. RII to measure the share of the country in world publications
	Publications in Malaysian journals	Not in the scope of the study	Articles published by Malaysian universities and research institutes	Articles published in Malaysian journals indexed by WoS	Articles published in Malaysian journals indexed by WoS and SCOPUS
	Citations in international journals	Not in the scope of the study	Citations indexed by SCI	Citations and h-index as indexed by SCI	Citations and h-index as indexed by SCIE and SSCI, RII to show the quality of country publication in world publications
	Data and subject coverage	1955 – 2002	1980 – 2008 (International); 1927 – 2008 (Malaysian)	2001 – 2011	2001 – 2014
	Sources of data	Major nternational databases covering S&T publications	WoS and SCOPUS (International); field works (Malaysian)	WoS and ESI	WoS: SCIE, SSCI and ESI; and Elsevier's SciVal and SCOPUS
	Research outputs mapping	Not covered	Not covered	Not covered	Publication network mapping
Patent	Data and coverage	Not covered	Not covered	Not covered	Patent outputs and citations from years 2001 – 2014, RII and RSI as performance indicators
	Sources of data	Not covered	Not covered	Not covered	MyIPO and PCT
	Research outputs mapping	Not covered	Not covered	Not covered	Patent network mapping and 3D landscape mapping

1.5   Scope of the Study

The Bibliometric Study 2015 will investigate:

i.   Scientific publications (i.e. articles and proceedings) in the areas of STI and Social Sciences in the main Web of Science (WoS) databases, namely (i) Science Citation Index Expanded (SCIE), (ii) Social Sciences Citation Index (SSCI), and (iii) Essential Science Indicators (ESI), as well as in SCOPUS databases[1];

ii.   Production of patents in the areas of STI in the PCT and MyIPO databases; and

iii.   Institutions of Higher Learning (IHLs) (both public and private), Public Research Institutions (PRIs) as well as companies.

1.6   Summary

This chapter provides an overview of the bibliometric study and sets the objectives and scope of the present study. The new features of the present study are discussed and the scope is extended to include patent analysis, as well as better institutional coverage that includes companies. The new features of the study will add significant value to the present study, especially for policymakers to identify the research performances of the universities, PRIs and companies. This is crucial given the fact that Malaysia aspires to be a high income nation by 2020.

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1   SCIE and SSCI are used to analyse international publication output, while ESI is used for citation analysis. SCOPUS database is only used to cover Malaysian journal publication output. As for international publication output, to be consistent in terms of analysis the study only uses WoS. Indeed, SCOPUS only allows 3,000 records to be retrieved at any point of time, and the fields of research covered under SCOPUS and WoS are different.

CHAPTER 2:
FRAMEWORK AND METHODOLOGY

CHAPTER 2:   FRAMEWORK AND METHODOLOGY

2.1   Introduction

This chapter reports the framework and methodology of the study. It elaborates the terminology of S&T and operational definition of the indicators, as well as methods for both quantitative and qualitative analyses.

2.2   Framework of the Study

The progression of science plays an important role in technological and knowledge-based economic development (Schmoch, 1997; Grupp, 1998). 'Science' basically represents the body of knowledge and it has been a useful tool in understanding the laws of nature. The outputs of basic research activities conducted by different public research organisations have led to scientific knowledge that can be rationally explained and reliably implemented for various applications. Although it rarely produces direct economic value or profit to the enterprises, further R&D may eventually result in new commercial products for the market (Wong and Goh, 2010a,b).

For the quantitative description of science, the frequently used indicators are:

    i.   Publications; and

    ii.   Publication citations.

Publications that report theoretical works and research findings are the main channel for documentation of scientific knowledge. The word 'technology' represents the body of knowledge about techniques, and is characterised by conception and development of 'product'. It is capable of diffusing services and has market demand. It is noteworthy that there are many areas of modern technology – such as biotechnology, artificial intelligence and nanotechnology – which are rooted in the progression of science (Schmoch, 1997; Wong, 2013). Therefore, universities and PRIs as the most common contributors of scientific knowledge have been playing a significant role in contributing towards the progress of technology.

For the quantitative description of technology, the frequently used indicators are:

    i.   Patents; and

    ii.   Patent citations.

Patents emerged to be the most frequently used indicator for technology. It has been useful as an indicator to provide a measurement of inventive and innovative activities. It also reflects the interest of the research enterprises in commercialisation of their inventive and innovative activities.

A direct measure of scientific and technological knowledge is counting the number of publications and patents respectively, while their impacts on 'development' can be measured by the citation frequency of papers and patents. The term 'development' of S&T refers to formation, progression and perfection of scientific and technological knowledge. Furthermore, a high citation of papers in the documentation of patents can be considered to indicate a close relationship between S&T (Grupp, 1998). Figure 2.1 presents the framework of this study.

Figure 2.1   Framework of the Study
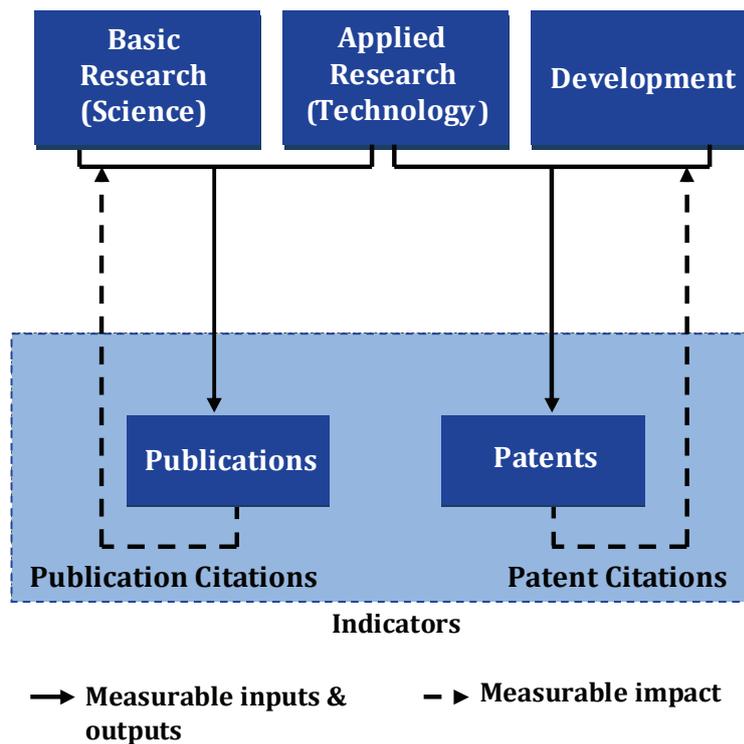
Source :   Adapted from Grupp (1998)

2.3   Terminology and Operational Definitions

This study adopts international operational definitions and standards. Among them are:

i.   Scientific Outputs: Publications and Patents

Publication and patent indicators are used as proxies to measure the scientific and technology stock and the impact of national scientific R&D outputs. These parameters are indirect measures of the capacity and networks of the scientific community. Publication indicators reflect the scientific literature output measured by 'article and proceeding' counts. The term 'paper' is used interchangeably with 'publication' to reflect the scientific outputs. Meanwhile, patent statistics indicate trends in technical change over time (Okubo, 1997). Patents can be either filed or granted. Patents can be further distinguished by the assignees and the filing office.

ii.   Research Performance

Research performance is measured based on the publication and patent output counts. Other areas of performance – namely citations, h-index, co-publication and co-patenting, RSI and RII – were also examined in this study. These indicators also measure the impact of publications and patents.

iii.   Citations

Citation analysis is a legitimate and practical tool for assessing the impact of publishing and patenting activities (Garfield, 1979; Sampat and Ziedonis, 2004). Citations for a publication is a measurement of the overall impact of the influence of an article – or of its authors – on the scientific community (Seglen, 1992). Citations can be used to trace networks of influence between different scientific communities. Such interactions highlight peer evaluations of past and ongoing scientific work (Okubo, 1997). In order to measure the quantity of a scientific stock, data of uniform quality must be used. On the other hand, the number of patent citations measures the impact of technology (Okubo, 1997). Analysis of patent citations informs scholars and policymakers on two important impacts of scientific outputs: (a) Potential technology linkages – patent citations of earlier patents which illustrate linkages at a detailed level; and (b) Co-classifications which can identify linkages at broader levels. Citations of a patent suggests that there is a cumulative process of development built upon the knowledge embodied in a patent. This indicates the interest of a patent holder in commercial exploitation of a patent. Citations reflect entry into profitable areas of technological research and indicate the market interest in a technological area (Sampat and Ziedonis, 2004; OECD, 1994).

iv.   h-Index

h-Index is a computable index which gives an estimate of the importance, significance, and broad impact of a scientist's (or organisation's) cumulative research contributions (Hirsch, 2005). The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other publications. An author has index h if h of his or her total number of publications (N_p) has at least h citations each (i.e. h-core), and the other ($N_p - h$) papers have $\leq h$ citations each (h-tail). While h-tail of Figure 2.2 represents the less cited or uncited papers or patents, h-core represents highly cited papers or patents (Kuan *et al.*, 2011). h-Index can be extracted from Thomson Reuter's WoS or Elsevier's SCOPUS, or be computed manually in other databases that provide citation information. However, each source may determine a different value of the h-index for each individual or organisation. Sometimes, the variation in the h-index between databases can be large. h-Index is insensitive to the number of less cited articles (or a few highly cited articles), and this measure avoids some of the skewness problems associated with other citations measures (Sandström, 2009).

Figure 2.2   Rank-Citation Curve
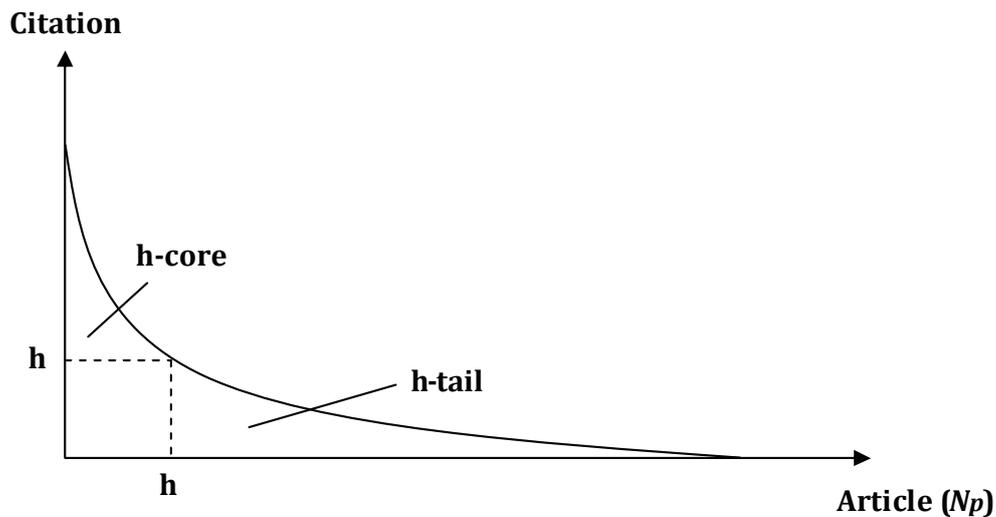
Source : Adapted from Kuan, *et al.* (2011 p. 304)

v.   Co-Publication

Scientific collaboration networks can be reliably tracked by analysing co-authorship networks. This indicator measures interactions and scientific relationships between networks, teams, institutions and countries (Okubo, 1997). The networks of co-publication can be illustrated through the concepts of component and cluster. Component refers to a group of directly or indirectly interconnected nodes in a network. The size of the nodes reflects the number of papers published by each author, and the thickness of the ties reflects the intensity of the collaboration (González-Teruel *et al.*, 2015).

vi.   Relative Specialisation Index

RSI indicates whether a country or an organisation has a relatively higher or lower share of publications or patents in a particular science or technology field than its overall share in the national total (Glänzel, 2001). RSI < 1 indicates a lower-than-average activity, while RSI > 1 indicates higher-than-average. RSI = 1 reflects a completely balanced situation. Thus, a value above one indicates relative strength over the national average, and a value below one indicates relative weakness over the national average. RSI is calculated as follows:

$$RSI_{it} = (\frac{Pub_{it}}{\sum_i Pub_{it}})/(\frac{\sum_t Pub_{it}}{\sum_{it} Pub_{it}}),$$

where the above formula indicates the ratio of the number of publications of an institution *i* in a particular field *t*, divided by the total number of publications at the national level in this field, and the number of publications of an institution under study in the whole field, divided by the total number of publications in the field at the national level.

vii.   Relative Impact Index

RII is defined as the citations per publication for an institution in a field divided by aggregate citations per publication at the national level in that field. A value above unity indicates the relative citation strength of an institution in that field. The indices will provide information on the relative strength of an organisation in specific S&T and its relative impact as compared to that of the national level. RII is defined as follows:

$$RII_{it} = (\frac{C_{it}}{Pub_{it}})/(\frac{\sum_t C_{it}}{\sum_t Pub_{it}}) \,,$$

where the above formula indicates the ratio of the citations of an institution *i* in a particular field *t*, divided by the total number of publications at the national level in this field, and the number of citations of an institution under study in the whole field, divided by the total number of publications in the field at the national level.

2.4   Fieldwork and Interview

In order to complement the quantitative analysis of publication and patent data, a series of in-depth interviews was conducted with various entities in the national research system, namely public and private universities, PRIs and companies. Interviews are particularly useful for understanding the reasons behind the observed development of publication and patenting activities obtained through publication and patent data. Also, in-depth insights into the subject matters can be pursued based on the vast experiences of the interviewees.

A total of 27 in-person interview sessions with institutions, individual researchers and innovators were conducted during the four month period of June – September 2015. The selection of interviewees is based on their high achievement in publication and patenting activities, as identified through the publication and patent databases. Also, the interview process encompassed the various stakeholders of the research community in the country in order to generate a comprehensive account of the research system. These interview sessions involved the participation of a total of 65 interviewees and informants – individually or collectively as a focus group – from various universities, PRIs, companies, as well as researchers and industry practitioners who are productive in indexed journal publication and patenting activities. An interview session was also conducted with MyIPO in order to obtain detailed insights into several issues raised by the various institutions and researchers.

All interviewees were ensured confidentiality and anonymity of identity. Figure 2.3 illustrates the selection of interviewees for this purpose while Table 2.1 details the background of the interviewees and informants in general.

Figure 2.3   Selection of Interviewees
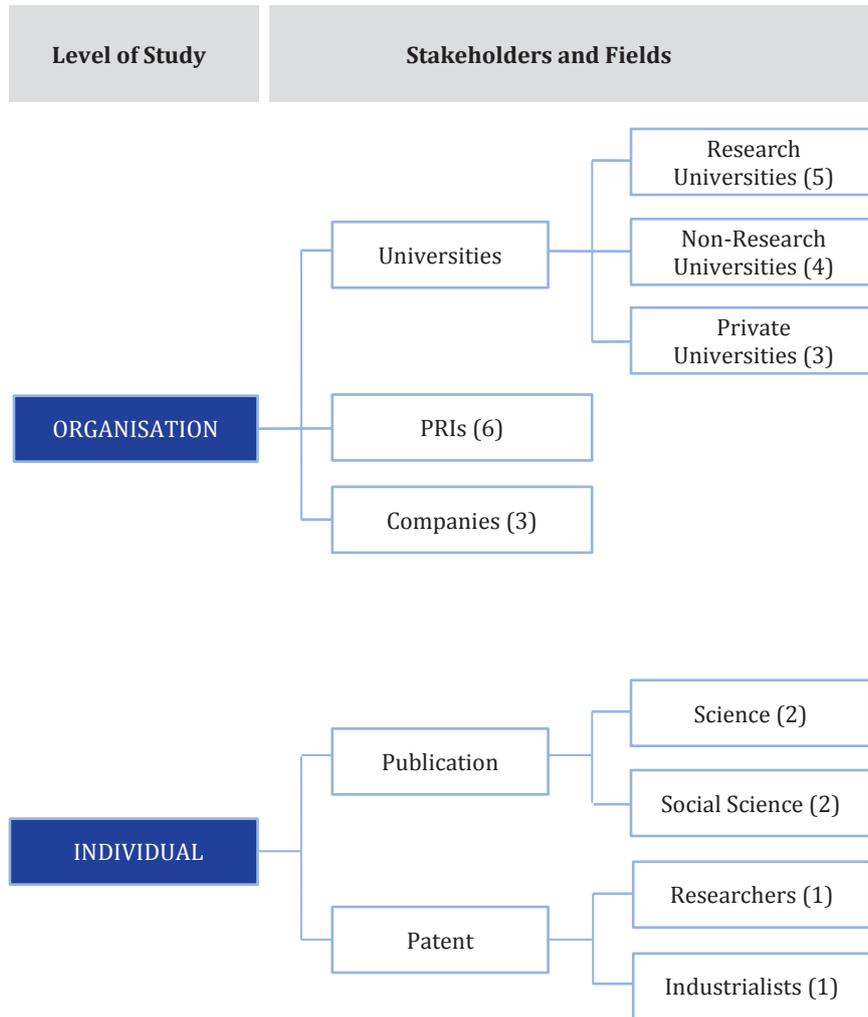
Note : Figures in parentheses indicate the number of organisations and individuals interviewed

Table 2.1   Background of Interviewees and Informants

Types of Institutions / Researchers / Innovators	Background
Universities	These include the RUs, non-RUs and private universities. Our interviewees consist of – among others – the university's Deputy Vice Chancellor of Research and Innovation, Directors of the Research Management Centres of various universities, the Director of the Technology Transfer Office, and senior officers in charge of publication, commercialisation and IP protection activities in the universities.
PRIs	These include both fully- and semi-governmental bodies. Our interviewees – among others – consist of Directors, the Deputy Director General of R&D, Heads of IP, Senior Directors of Corporate Strategy Division, and Research Officers in the PRIs. The PRIs selected for interview were from various sectors, namely primary resource and agriculture-based, electronics and machinery, and medical.
Companies	These include the Manager and Assistant Manager of Group Legal and Secretarial Division, and the Manager of R&D and Sales Division.
Researchers & Innovators	These include productive researchers in both science and social science from universities, PRIs, industrialists as well as individual innovators.

The following aspects and issues were explored throughout the interview sessions:

    i.   Recent trends and developments in publication and patenting activities;

    ii.   Main drivers contributing to publication and patenting activities;

    iii.   Binding constraints in publication and patenting activities;

    iv.   Strategies in overcoming the binding constraints; and

    v.   Policy directions for strengthening publication and patenting activities.

These aspects are essential in order to highlight some of the unresolved issues in research systems that policymakers should address in the near future. Listed below are the interview questions that served as a guideline during the interview sessions. These interview questions – which were structured into three parts – corresponded to the framework of inquiry of this study.

i. Publication and Patent Evolution

- How has your organisation evolved in knowledge and scientific production (in terms of publications and patenting activities)?

- In which of the areas/fields has your organisation established strengths at the moment?

- How was this achieved? What are the main drivers? (e.g. policy, instruments, people, collaboration etc.)

- What are the main challenges or constraints for your organisation in publication and patent production? How would you prioritise, from the most constraining to the least?

ii. Organisational Strategies

- In the case of your organisation, what immediate strategies are required to ensure that returns on publications and patenting can be maximised?

- What are your organisation's future plans (in the next five years) to improve citations or utilisations for both publications and patents?

iii. Public Policy Prescription

- What is in the national regulatory environment – policies, rules and regulations – that promotes/hinders publication and patent production in Malaysia?

- How can the root causes of hindering be eliminated and the constraints removed?

- As a whole, how should Malaysia position itself in publication and patent production? How should we improve in the future? What is needed?

2.5   Scope of Coverage and Data Collection

This study uses Thomson Reuter's WoS, namely SCIE, SSCI and ESI databases. While SCIE and SSCI provide a historical series of publication data and h-index from January 2001 to December 2014, ESI provides a historical series of publication citations. The following publication fields as categorised by WoS are reviewed in this study:

- 22 main categories used in ESI;
- 224 categories for publication subfields; and
- 59 categories used in ESI.

In addition, 77[2] Malaysian journal titles indexed by Elsevier's SCOPUS are included in this study. SciVal is used to cross check the SCOPUS publication counts and citations for Malaysian journals.

For patenting analysis, databases from MyIPO and World Intellectual Property Organisation (WIPO) are used in this study[3]. These databases provide a historical series of patent data from January 2001 to December 2014. MyIPO database provides data on Malaysia's patents granted to both local and foreign residents. Patent application and granting produced in Malaysia is shown in Appendix A. The WIPO database provides data on Malaysian patents filed at WIPO; it indicates the interest of Malaysian inventors in patenting their inventions in the international market. The 35 patenting fields as categorised by International Patent Classification (IPC) are explored in this study. The publications of 22 main scientific fields classified under ESI analytical database and the patents of 35 main technological fields (Table 2.2) under the IPC are studied in detail. Citation analysis is inclusive of self-citations.

In order to assess the organisational h-index of S&T activities, this study utilised the organisational citations data from WoS and MyIPO databases from year 2001 to 2014. The data is structured within four-year citation windows (2001–2004, 2005–2008, 2009–2011 and 2012–2014) to highlight the relative broad impact of organisational publications and patents for different periods of time. This also allows us to benchmark the broad impact of publications and patents among Malaysia's S&T organisations for different periods of time.

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2   76 Malaysian journals recorded in 2012. In 2014, there were 77 Malaysian journals but only 63 journals have up-to-date records of articles via the SCOPUS database. The data for the remaining journals were tracked using SCIMAGO.

3   Patents granted from MyIPO is able to assess both the quantity and impact of local patents that shape and affect the local technological market, while patents filed in PCT allows the assessment of the patenting efforts of Malaysia's inventors and firms at the international level.

Table 2.2   Scientific Fields and Patent Classifications

ESI's Scientific Fields	IPC's Patent Classifications
Agricultural Sciences	Electrical Machinery, Apparatus, Energy
Biology & Biochemistry	Audio-visual Technology
Chemistry	Telecommunications
Clinical Medicine	Digital Communication
Computer Science	Basic Communication Processes
Economics & Business	Computer Technology
Engineering	It Methods for Management
Environment/Ecology	Semiconductors
Geosciences	Optics
Immunology	Measurement
Materials Science	Analysis of Biological Materials
Mathematics	Control
Microbiology	Medical Technology
Molecular Biology & Genetics	Organic Fine Chemistry
Multidisciplinary	Biotechnology
Neuroscience & Behaviour	Pharmaceuticals
Pharmacology & Toxicology	Macromolecular Chemistry, Polymers
Physics	Food Chemistry
Plant & Animal Science	Basic Materials Chemistry
Psychiatry/Psychology	Materials, Metallurgy
Social Sciences, General	Surface Technology, Coating
Space Science	Micro-Structural and Nanotechnology
	Chemical Engineering
	Environmental Technology
	Handling
	Machine Tools
	Engines, Pumps, Turbines
	Textile and Paper Machines
	Other Special Machines
	Thermal Processes and Apparatus
	Mechanical Elements
	Transport
	Furniture, Games
	Other Consumer Goods
	Civil Engineering

Source :   WoS – ESI and IPC Technology Concordance Table.

For patents, this study used two patent search engines (PatSnap and LexisNexis) to mine the patenting data. The search engines allowed us to obtain the citation details of Malaysian-owned patents in MyIPO and WIPO. The PCT patents covers useful information of patents filed under WIPO (Wong and Salmin, 2015). It indicates the interest of the research enterprises in commercialising their inventions in international markets. The use of PCT patents data helps us to prevent the home bias effect that is observed at many national patent offices. The reasons for using the selected databases are their availability, completeness for analysis, and comparability across different countries. The process and roadmap of this study is presented in Figure 2.4.

VantagePoint software is used in this study for visualising scientific and technological networks of Malaysia. In addition, this study used PatSnap's 3-D landscaping add-on tool to highlight the technological competencies of Malaysia. This allows us to identify both the core and niche technological areas that would develop Malaysia's technological market.

Figure 2.4   The Process and Roadmap of the Analysis
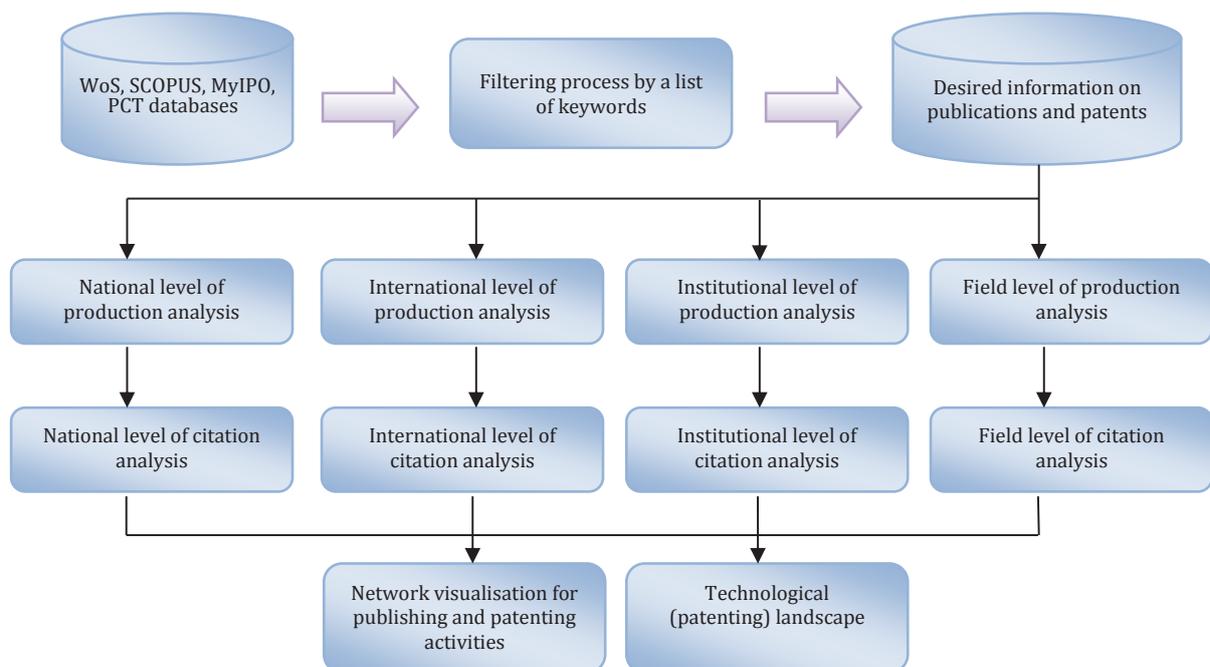
2.6 Study Caveats

The interpretation of the bibliometric studies should also be made cautiously, given some limitations of its use; amongst these are:

    i.   Publications and patents are not the sole output of scientific activity. There are a variety of knowledge transfer activities conducted by researchers, such as other protection of IP or commercial confidentiality of scientific activity outputs that have potential for commercialisation.

    ii.   Not all publications appear in bibliometric databases. Presentations at conferences and other media are not accounted for in the evaluation of research results. Book chapters published by Malaysian institutions are only reported in Appendix G.

    iii.   Citations of articles and patents is an indirect indication of quality and impact, and not a direct measure.

    iv.   Analysis on patents filed in Malaysia is constrained by the data availability. MyIPO patent database only captures data on the number of patents granted in Malaysia. Nevertheless, Malaysian patent performance at the international level uses patents filed, which is available through the PCT database.

    v.   Similar to Bibliometric Study 2012, Malaysian journals published in Malaysia (those not listed in either WoS or SCOPUS) – which are now under the purview of the Malaysian Citation Centre (MCC) – are not included in this study.

2.7 Summary

This chapter describes the framework and methodology of the study, giving the terminology of S&T and operational definition of the indicators as well as methods that will be used for analysis. Data coverage and study caveats are further explained.
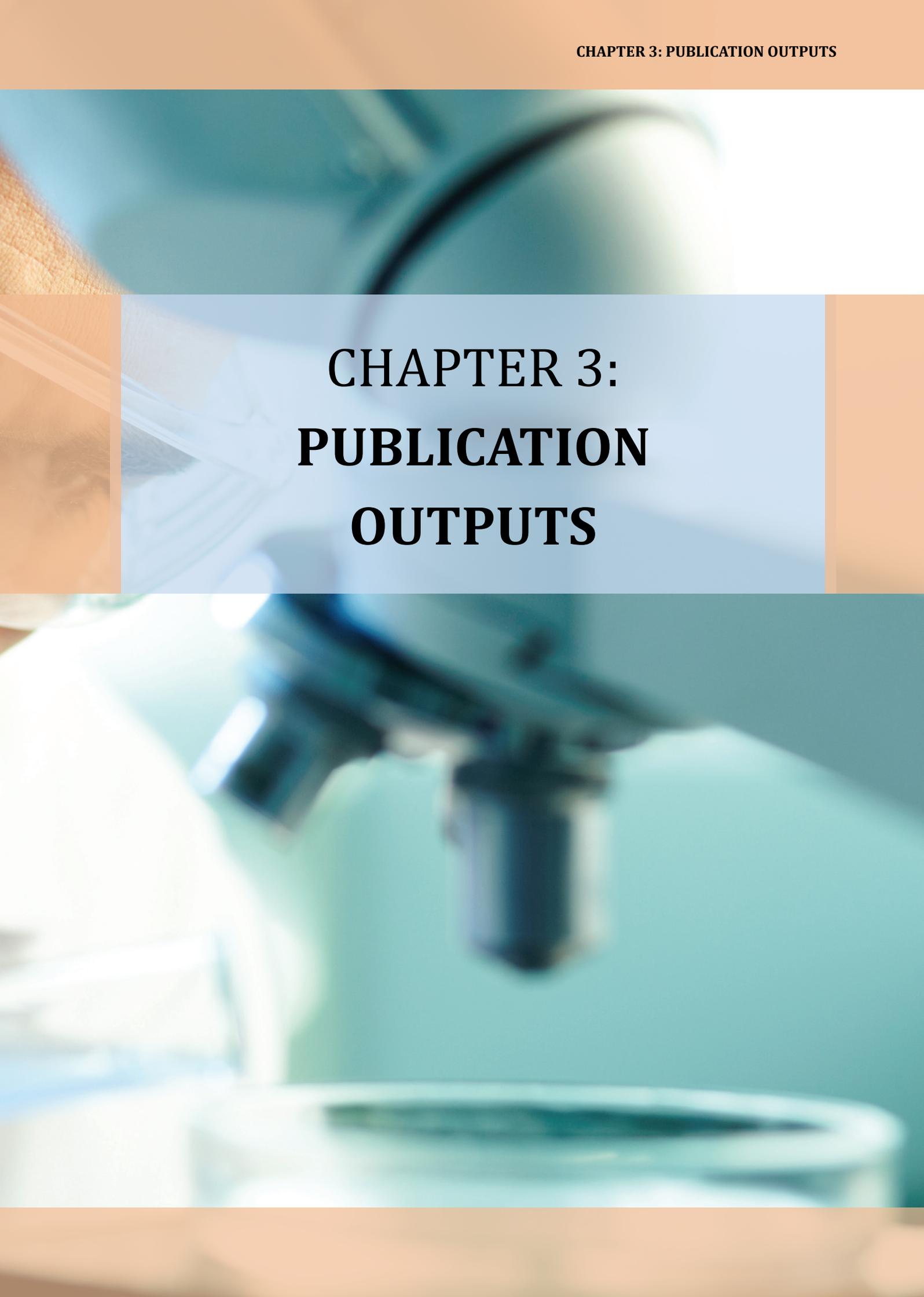
CHAPTER 3:
PUBLICATION OUTPUTS

CHAPTER 3:   PUBLICATION OUTPUTS

3.1   Introduction

This chapter reports the findings on publication outputs for the years 2001 to 2014. Publications – in the form of articles and proceedings published internationally in WoS databases (i.e. SCIE and SSCI) and Malaysian journal publications in SCOPUS database – are analysed in this study.

3.2   International Publications: Summary of Findings

From a total 90,128 publications in the period of 2001 to 2014, a total of 59,131 international articles which comprise 224 subject categories were recorded by Thomson Reuters. These articles were produced by 118,357 authors across Malaysia, of which nearly 83% were affiliated with the five RUs. The publication output has grown exponentially since 2008, and has surpassed that of Singapore and Finland, for example. This exponential growth in publications is a direct consequence of the objectives set under the Ninth Malaysia Plan (9MP), the increase in national R&D funding as well as the establishment of RUs in promoting excellence in teaching and R,D&I.

Focusing only on publication of journal articles, the field of Materials Science produced the highest number of articles (4,266 articles) followed by Crystallography (4,153 articles), which jointly contributed nearly 14% of all publications produced to date. In terms of collaboration, while England, the United States of America, India, Japan and Australia remain the top collaborating countries, there is a notable increase in collaborations with Middle Eastern countries, particularly Iran and Saudi Arabia. Within Malaysia, there is a healthy collaboration effort among the RUs, especially between Universiti Malaya, Universiti Putra Malaysia and Universiti Kebangsaan 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.

In terms of proceedings publications, researchers in the field of Electrical & Electronic Engineering (9,158 proceedings) are clearly the most active, with a number of publications that is almost double that of the second most productive field of Materials Science (4,541 proceedings). The detailed analysis of the international publications is presented in the next sections.

3.2.1 Total Articles and Proceedings Output and Growth

A total of 90,128 international articles and proceedings from Malaysia were recorded during the years 2001 to 2014.

Malaysia's total international publications output increased exponentially in number from 2001 (1,029 publications) to 2014 (15,915 publications). In terms of growth rate, there is a general upwards trend of growth rate during the period of 2003 to 2008 (see Figure 3.1) with clear spikes of growth in the years 2004 (57.25%) and 2008 (51.19%). However, the publication growth rate of articles and proceedings decreased during the period 2011 (34.62%) to 2014 (5.98%). Articles and proceedings output and growth data is provided in Appendix B.

Figure 3.1   Yearly Publication Output and Growth Rate

Data coverage :   WoS – SCIE and SSCI, 2001-2014.

3.2.2 Total Articles and Proceedings by Malaysia Plans

Figure 3.2 shows the performance of publication of articles and proceedings according to the Malaysia Plans. Under the Eighth Malaysia Plan (8MP) (2001-2005) a total of 7,749 articles and proceedings were published. The number of publications increased to 27,291 during the period of the 9MP (2006-2010), which translates to a 252.19% growth rate. Currently, under the Tenth Malaysia Plan (10MP) (2011-2015), the total output stands at 55,088 published articles and proceedings as of end of 2014. Data on total articles and proceedings according to Malaysia Plan is provided in Appendix C.

Figure 3.2   Total Articles and Proceedings by Malaysia Plans
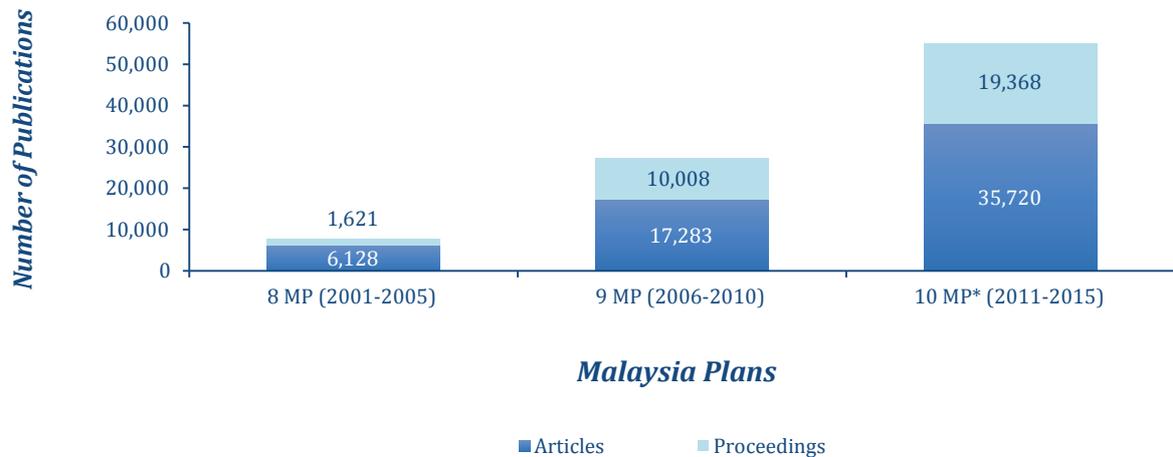
Data coverage :   WoS – SCIE and SSCI, 2001-2014.

Note   :   The scope of the study is from 2001 to 2014, while the 10MP covers the period 2011 to 2015. The recorded numbers are until end of 2014 (excludes 2015).

3.3   Articles Output and Growth

Malaysia's international publication of articles increased from 2001 to 2014. A total of 59,131 international articles from Malaysia by 118,357 authors were recorded during this period of study.

From Figure 3.3, it can be seen that during the period 2001 to 2007, the publication outputs grew at a slower pace with an increment rate of less than 20%. The publications growth intensified during the period 2008 to 2011, with a spike of 48.92% increase in the number of international publications in the year 2009. The 2012 study showed the same trend and attributed the spike to the increase in national R&D expenditures in 2008. The publication growth, however, had a slower pace during the period 2012 to 2014. Nevertheless, Malaysia had achieved the mark of more than 5,000 international publications a year since 2010.

Figure 3.3   Yearly Articles Output and Growth Rate
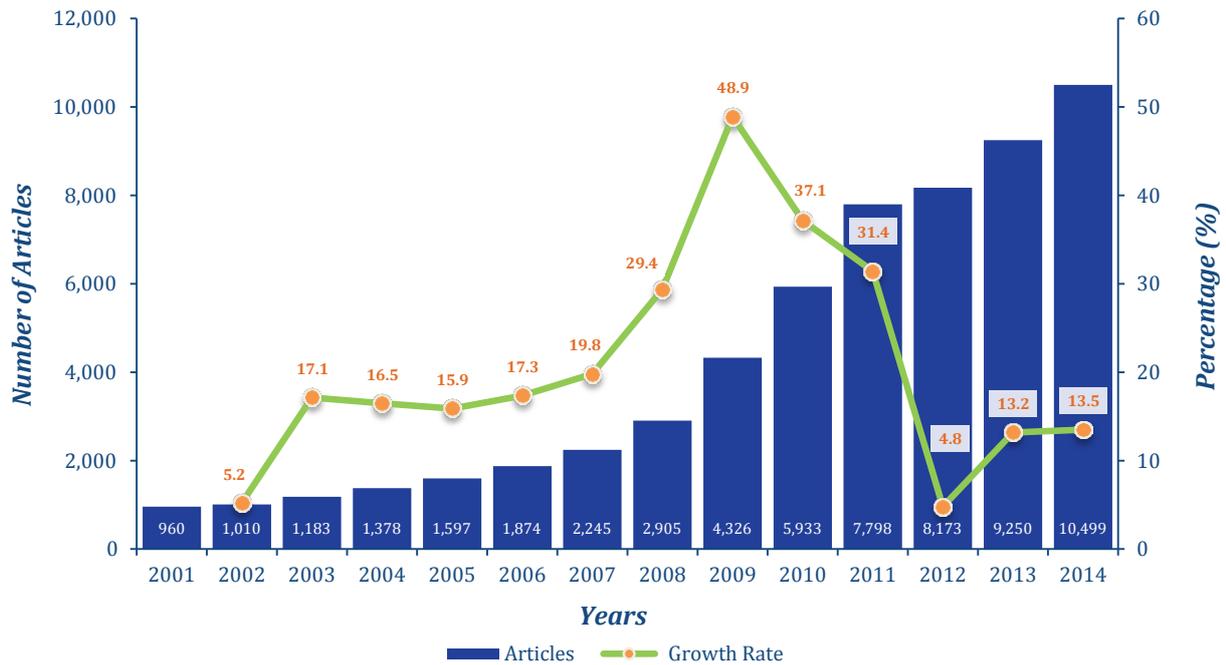
Data coverage :   WoS – SCIE and SSCI, 2001-2014.

3.3.1   Top Fields of Research: SCIE and SSCI

Assuming that the number of publication outputs may be indicative of the areas of strengths and weaknesses of Malaysia's knowledge output, the articles are grouped according to the subject categories defined by Thomson Reuters. For the sciences, Figure 3.4 shows that the field of Materials Science produced the highest number of articles (4,266 articles) followed by Crystallography (4,153). Together with the areas of Electrical & Electronic Engineering (3,346), Chemical Engineering (2,763) and Multidisciplinary Sciences (2,761), these made up the top five contributing areas in article publication in Malaysia. In comparison to the 2012 study, the top four areas of strength remained the same, with Materials Science showing a huge improvement in the number of published articles to rank as the topmost contributing area in this study.

From Figure 3.5, the top 5 contributing areas of research for publications in the social sciences are Economics (574 articles), Management (510), Public, Environmental & Occupational Health (446), Business (419) and Education & Educational Research (379).

Figure 3.4   Top 15 Fields of Research of Malaysia by Articles Counts: SCIE
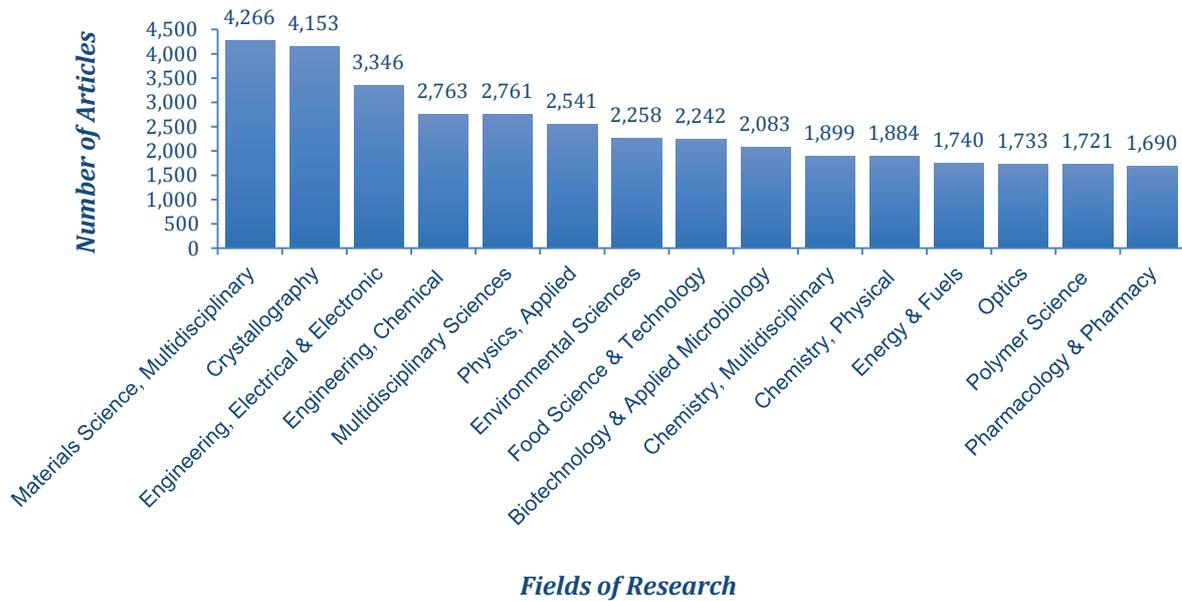
Fields of Research

Data coverage : WoS – SCIE, 2001-2014.

Figure 3.5   Top 15 Fields of Research of Malaysia by Articles Counts: SSCI
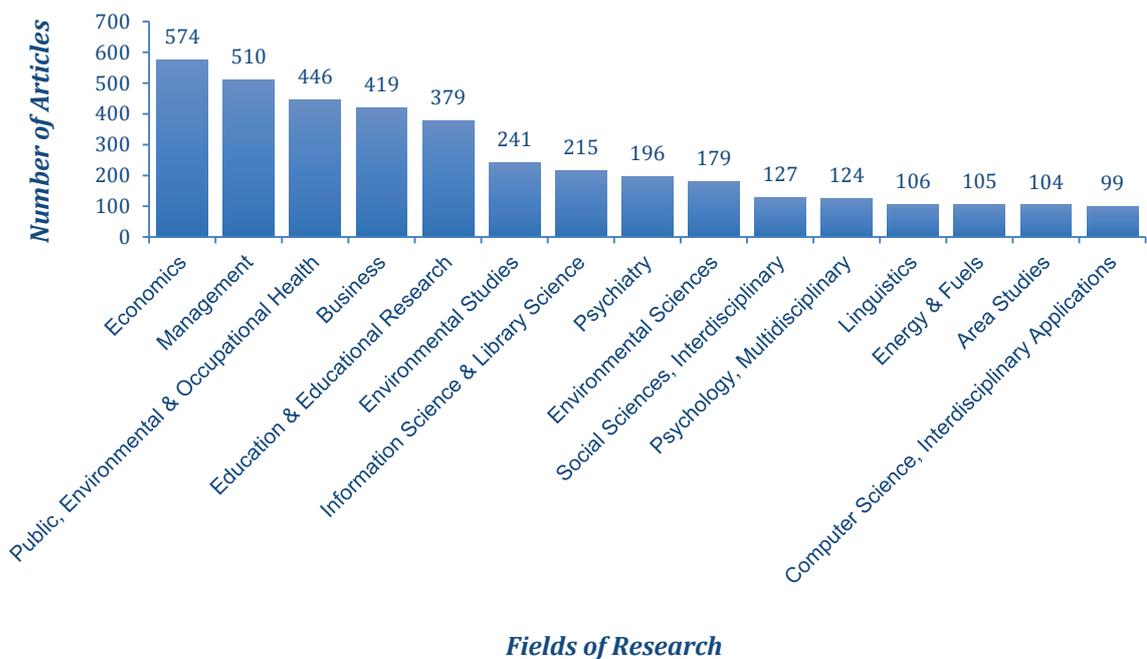
Fields of Research

Data coverage : WoS – SSCI, 2001-2014.

Figure 3.6 shows the research fields where Malaysia recorded a limited number of published articles. It may indicate that Malaysia is relatively underdeveloped in these areas of research. The areas of Ocean Engineering, History of Social Sciences, Mining & Mineral Processing, Neuroimaging and Transplantation had 1 published article each in the period of 2001 to 2014. Some other areas with only 2 publications in the same period of time include Ethnic Studies, Limnology and Medical Ethics. The shortfall could be attributed to the small critical mass of researchers engaging in these fields. Fields with few numbers of articles in SCIE and SSCI are listed in Appendix E and Appendix F respectively.

Figure 3.6   Top 15 Fields of Research with Limited Articles
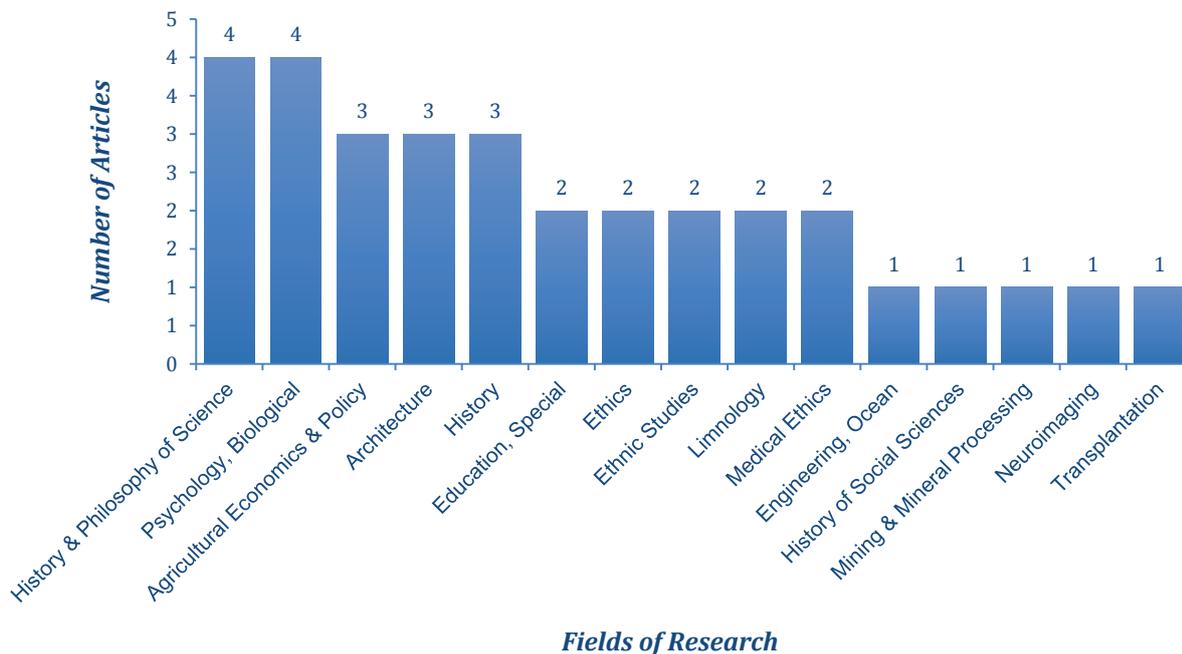
Data coverage :   WoS – SCIE and SSCI, 2001-2014.

3.3.2   Institutions by Number of Articles

Scientists' affiliations reflect the support and contributions made by the institutions to research through the affiliated scientists. From Figure 3.7, based on the data from SCIE and SSCI databases it is evident that the RUs contributed the most to the total number of published articles in the period 2001 to 2014. Universiti Malaya (UM: 14,920 articles), Universiti Sains Malaysia (USM: 11,568), Universiti Putra Malaysia (UPM: 9,870), Universiti Kebangsaan Malaysia (UKM: 7,486) and Universiti Teknologi Malaysia (UTM: 4,893) contributed almost 83% of the total number of published articles in the period 2001 to 2014. In comparison to the 2012 study, Universiti Malaysia Perlis has shown big improvement to be listed for the first time among the top 15 institutions; this is a four-fold increase in publications from the 2012 study (260 articles) to this study (UNIMAP: 1,067). Information on the top 15 PRIs ranked by number of articles is provided in Appendix D.

Figure 3.7   Top 15 Institutions by Number of Articles
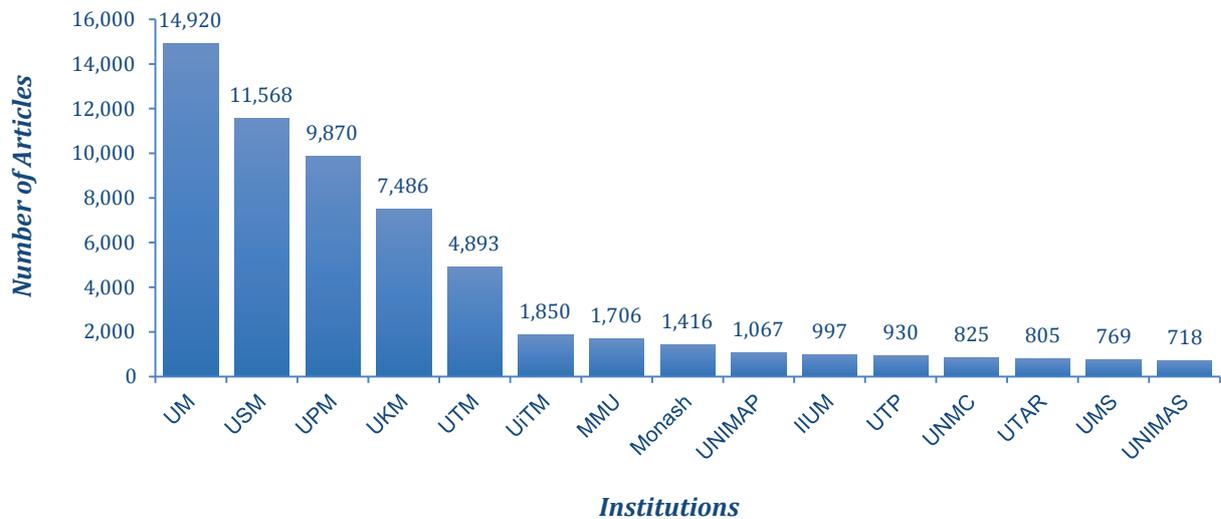
Data coverage :   WoS – SCIE and SSCI, 2001-2014.

3.3.3 Institutions by Top Two Fields of Research

This section analyses the strength of fields of research within the universities. Identifying the strengths of research areas of higher learning institutions in Malaysia is crucial. Figure 3.8 and Figure 3.9 display the top two areas of strength in terms of the number of article publications. For the sciences, both Universiti Malaya (UM) and Universiti Sains Malaysia (USM) have the highest publications in the areas of Crystallography (2,122 and 1,764 articles, respectively) and Materials Science (835 and 1,017, respectively). Universiti Putra Malaysia's (UPM) top two fields of research are Food Science & Technology (1,064) and Biotechnology & Applied Microbiology (747), while Universiti Kebangsaan Malaysia (UKM) is seen to be productive in the areas of Multidisciplinary Sciences (891) and Materials Science (519). The area of Materials Science (603) is also one of the top fields of research for Universiti Teknologi Malaysia (UTM), followed by Electrical & Electronic Engineering (563).

For the social sciences, Universiti Malaya (UM) and Universiti Sains Malaysia (USM) have publication strength in the area of Public, Environmental & Occupational Health (160 and 90 articles, respectively) while Universiti Putra Malaysia (UPM) has strength in Economics (122).

Figure 3.8   Top Two Fields of Research by Institutions: SCIE

Institution and Top 2 Fields of Research	Number of Articles
UNIMAS - Infectious Diseases	41
UNIMAS - Zoology	73
UMS - Ecology	60
UMS - Zoology	69
UTAR - Engineering, Electrical & Electronic	63
UTAR - Chemistry, Multidisciplinary	67
UNMC - Engineering, Electrical & Electronic	70
UNMC - Engineering, Chemical	157
IIUM - Biotechnology & Applied Microbiology	76
IIUM - Materials Science, Multidisciplinary	107
UTP - Energy & Fuels	114
UTP - Engineering, Chemical	203
UNIMAP - Engineering, Electrical & Electronic	205
UNIMAP - Materials Science, Multidisciplinary	270
Monash - Economics	75
Monash - Engineering, Chemical	106
MMU - Physics, Applied	226
MMU - Engineering, Electrical & Electronic	549
UiTM - Pharmacology & Pharmacy	137
UiTM - Materials Science, Multidisciplinary	244
UTM - Engineering, Electrical & Electronic	563
UTM - Materials Science, Multidisciplinary	603
UKM - Materials Science, Multidisciplinary	519
UKM - Multidisciplinary Sciences	891
UPM - Biotechnology & Applied Microbiology	747
UPM - Food Science & Technology	1,064
USM - Materials Science, Multidisciplinary	1,017
USM - Crystallography	1,764
UM - Materials Science, Multidisciplinary	835
UM - Crystallography	2,122

Data coverage :   WoS – SCIE, 2001-2014.

Figure 3.9   Top Two Fields of Research by Institutions: SSCI
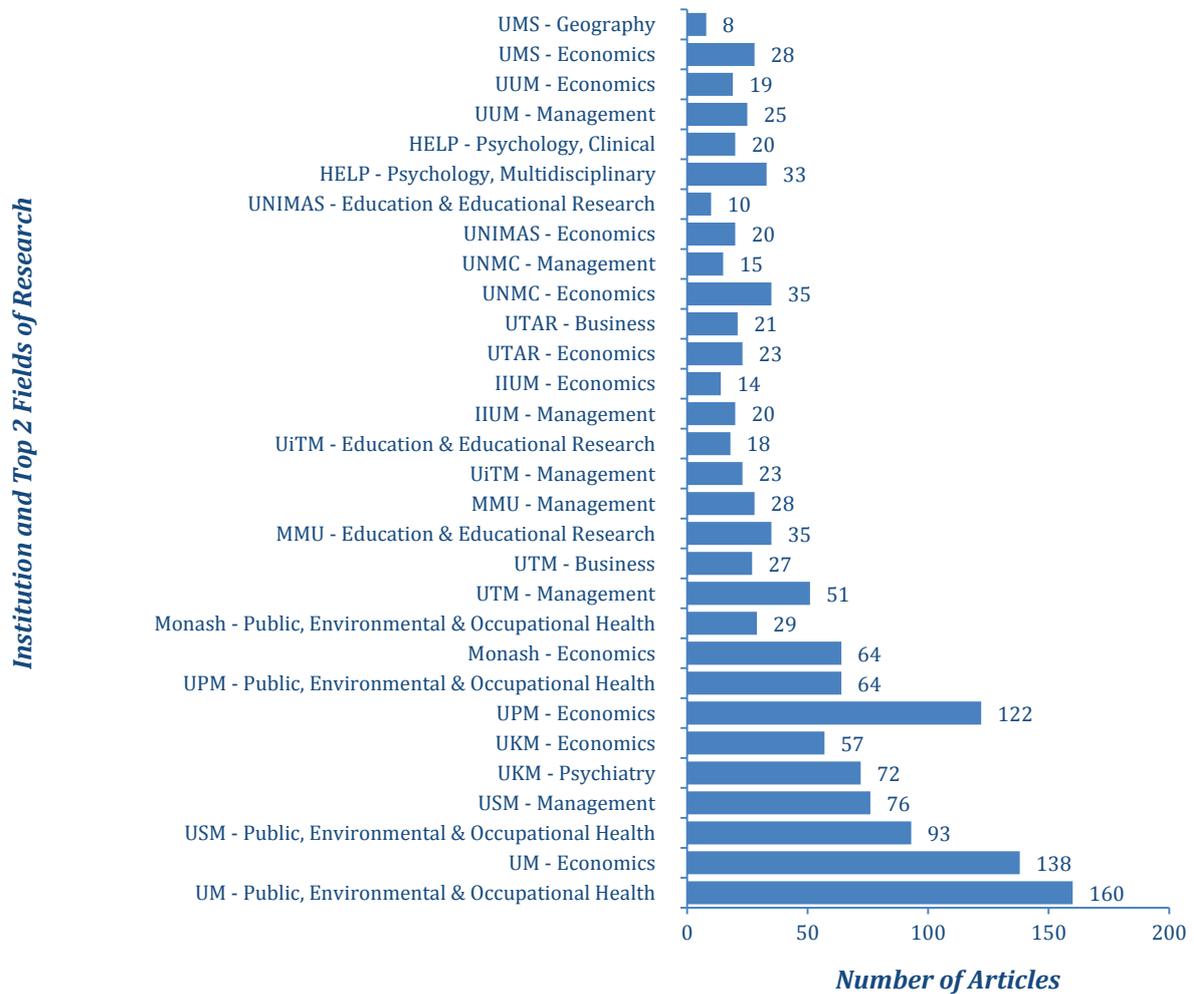
Data coverage :   WoS – SSCI, 2001-2014.

3.3.4   Institutional International Collaboration

Collaboration between researchers across borders is much encouraged as it leads to new ideas and produces publications of high quality. Figure 3.10 and Figure 3.11 show that Universiti Malaya (UM) and Universiti Sains Malaysia (USM) are most active in collaborations with international institutions. For research in the sciences, Universiti Sains Malaysia (USM) has the highest number of joint publications (449 articles) with Prince of Songkla University, followed by Mangalore University (264) and Nanjing University (179). Universiti Malaya (UM) has produced joint publications with King Abdulaziz University (325), National University of Singapore (274), Monash University (258), University of London (230), Ohio State University (197) and Imperial College London (195) among others. Universiti Putra Malaysia (UPM) has many collaboration with Islamic Azad University (245) while Universiti Kebangsaan Malaysia (UKM) collaborated productively with Babeş-Bolyai University (160). For research in the social sciences, Universiti Malaya (UM) has collaborations with Monash University (25), University of London (24), Yale University (22) and National University of Singapore (19). Universiti Sains Malaysia (USM) has joint efforts with University of Waterloo (19), Cancer Council Victoria (17) and Mahidol University (17).

It can be seen that Universiti Malaya (UM) has a wider network of collaborations with institutions across different continents in the world (Figure 3.10 and Figure 3.11), including some of the world's top universities such as University of Oxford (187 articles), Imperial College London (195), Yale University (22) and University of Sydney (11).

Figure 3.10   Top 15 International Collaborating Institutions: SCIE
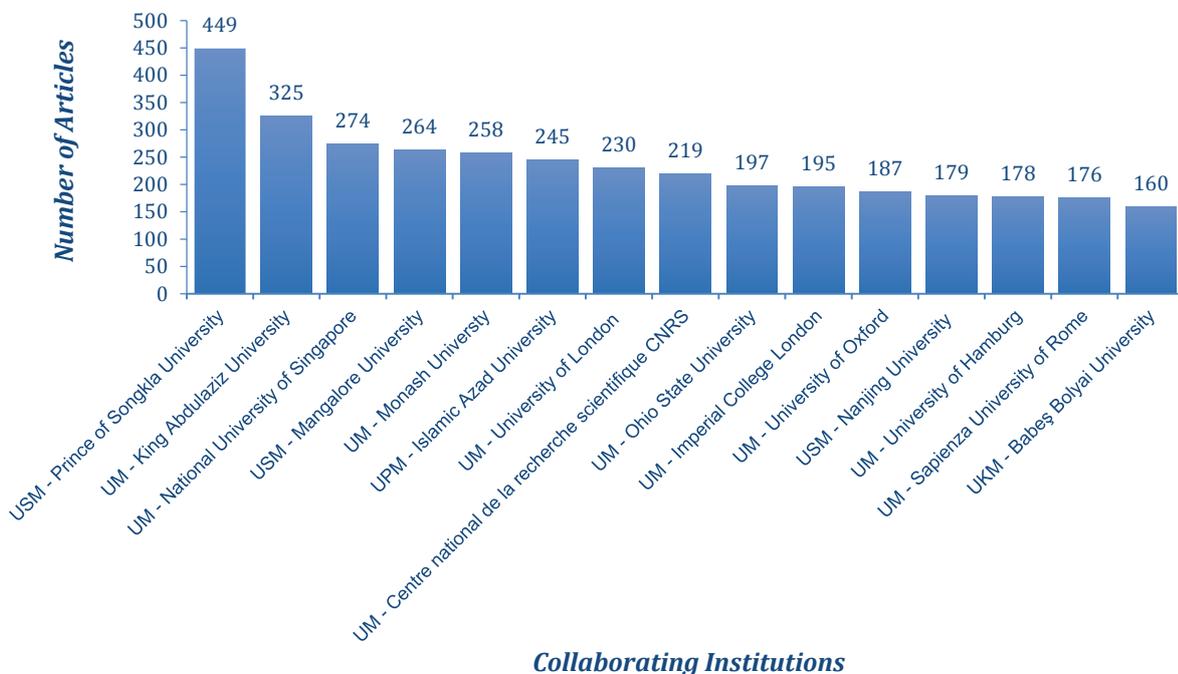
Data coverage : WoS SCIE, 2001–2014.

Figure 3.11   Top 15 International Collaborating Institutions: SSCI

Collaborating Institutions
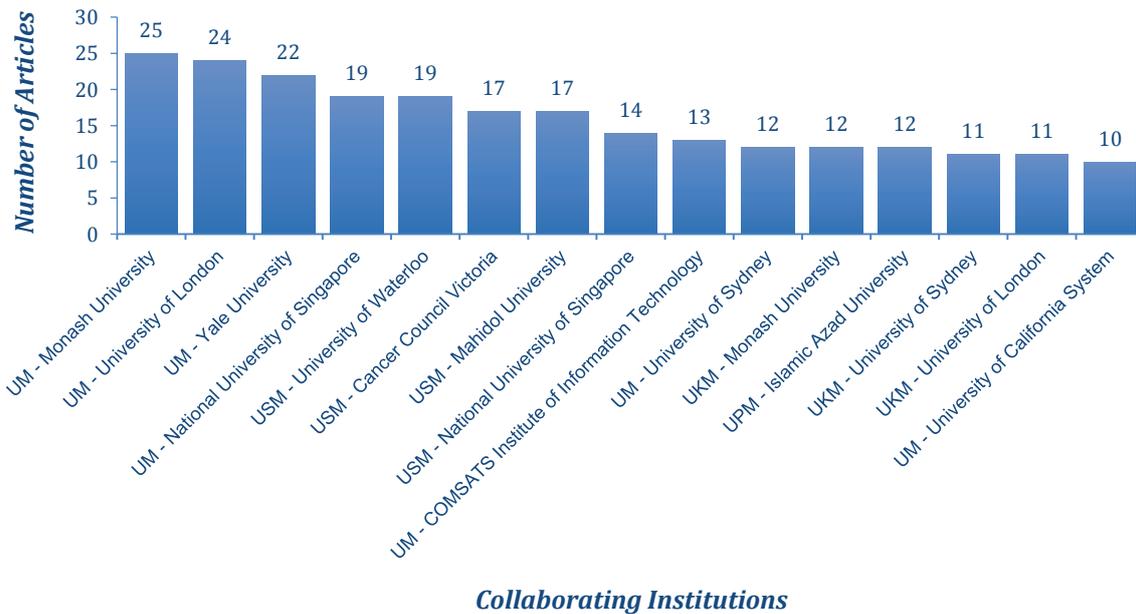
Data coverage   :   WoS – SSCI, 2001-2014.

3.3.5   Institutional National Collaboration

At the national level, Universiti Putra Malaysia, Universiti Kebangsaan Malaysia and Universiti Malaya closely collaborated with each other; the collaboration between Universiti Putra Malaysia and Universiti Kebangsaan Malaysia produced the highest number of collaborative articles in the sciences (UPM-UKM: 697 articles) as seen from Figure 3.12, while collaboration between Universiti Malaya and Universiti Kebangsaan Malaysia produced the highest number of collaborative articles in the social sciences (UM-UKM: 52) as seen in Figure 3.13. These three universities are located relatively close to each other compared to the other universities, and the proximity between these universities might have promoted more productive collaborations between them. Collaborations between these three universities with the other institutions are less productive – for example the collaborations between Universiti Malaya and Universiti Teknologi MARA in the sciences produced only about half of the total number of articles (UM-UiTM: 355 articles, Figure 3.12) as that of the collaboration between Universiti Putra Malaysia and Universiti Kebangsaan Malaysia.

In the sciences (Figure 3.12), partnering between Universiti Malaya-Universiti Sains Malaysia (UM-USM) yielded 349 articles, while that between Universiti Putra Malaysia-Universiti Sains Malaysia (USM-UPM) yielded 263 articles. In the social sciences (Figure 3.13), collaboration between Universiti Malaya-Universiti Sains Malaysia (UM-USM) produced 32 articles, and Universiti Sains Malaysia-Universiti Kebangsaan Malaysia (USM-UKM) produced 24 articles.

Figure 3.12   Top 15 National Collaborating Institutions: SCIE
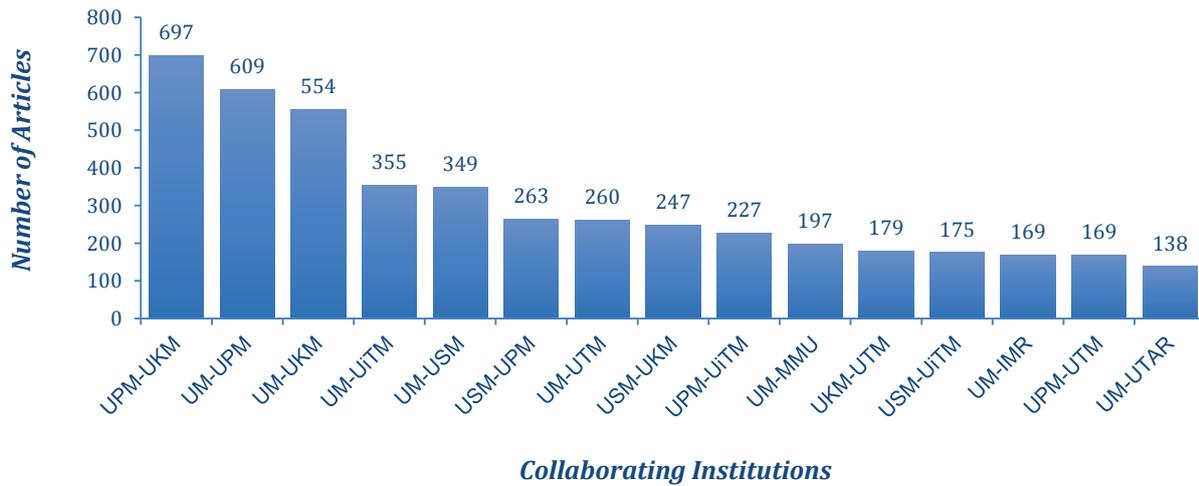
Data coverage :   WoS – SCIE, 2001-2014.

Figure 3.13   Top 15 National Collaborating Institutions: SSCI
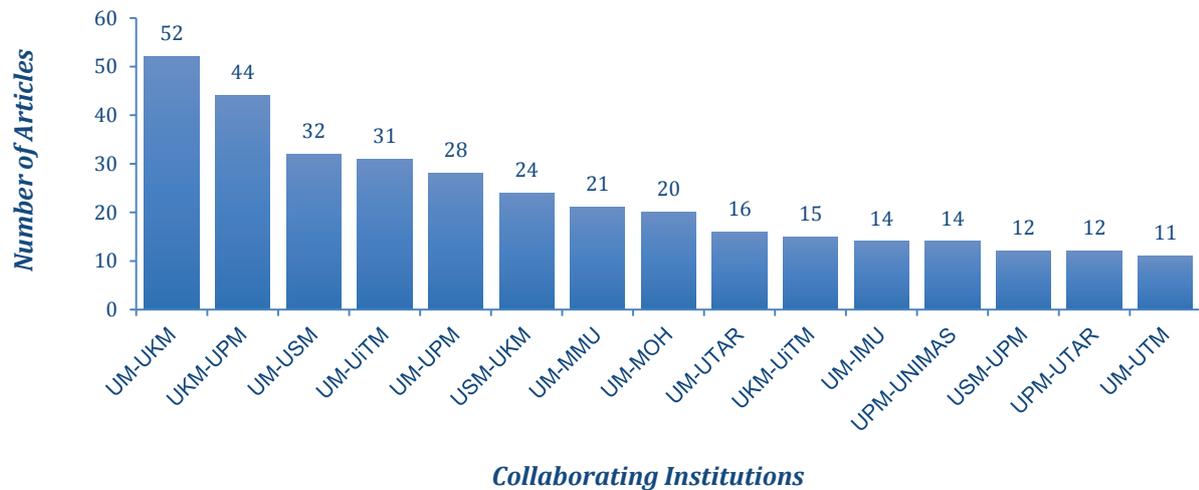
Data coverage :   WoS – SSCI, 2001-2014.

3.3.6   Countries Ranked by Number of Articles

From the period 2001 to 2014, researchers from Malaysia collaborated most productively with researchers from England (3,602 articles) and the United States of America (3,299). India, Japan, Australia, Iran and China are also among the top collaborating countries with Malaysia (Figure 3.14). While England and the United States of America continue to remain the top countries collaborating with Malaysia, there is a notable increase in collaborations with researchers from Iran (820 articles in 2012 to 2,523 articles in this study – 8th rank in 2012 to 6th rank in this study) and Saudi Arabia (343 to 1,370 – 15th rank to 8th rank). However, collaborations with China has dropped slightly (3rd rank in 2012 to 7th rank in this study) over the recent years.

Figure 3.14   Top 15 Countries Collaborating with Malaysia
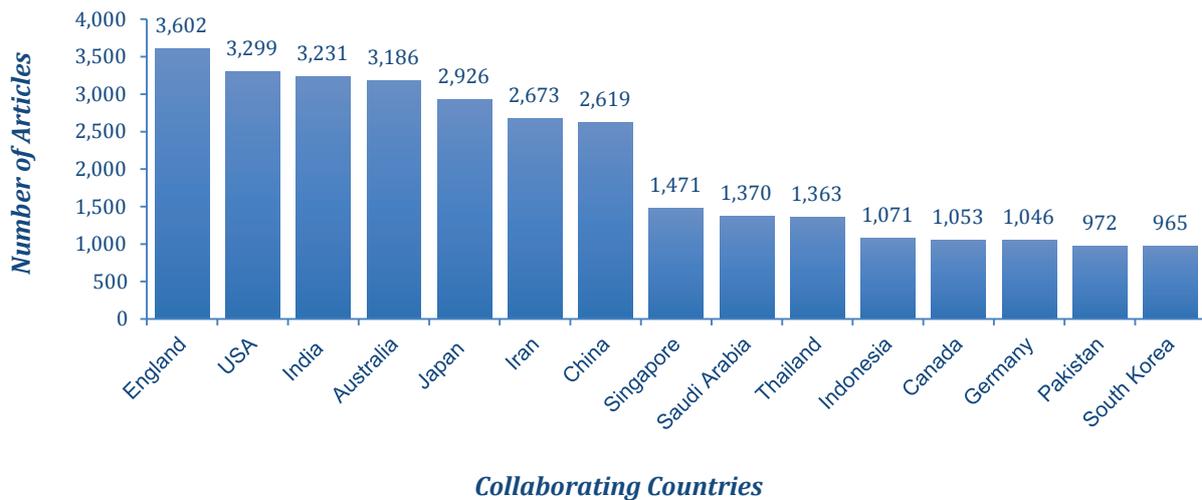
Data coverage : WoS – SCIE and SSCI, 2001-2014.

3.3.7   Scientists and Researchers Ranked by Number of Articles

The top two scientists with the most number of articles are Ng Seik Weng (Universiti Malaya) and Fun Hoong Kun (Universiti Sains Malaysia), who produced 1,929 and 1,922 articles (Figure 3.15), respectively. They were also the top two scientists cited in the 2008 and 2012 studies. Both scientists work in the area of Crystallography, the second most productive area in terms of publications. Harith Ahmad is ranked third (543 articles), followed by Suchada Chantrapromma (480), Sulaiman Wadi Harun (469) and Edward Richard Tom Tiekink (448). These six researchers have been the top six researchers since the 2012 study.

The top two most productive researchers in the social sciences are Viren Swami (HELP University) and Ooi Keng Boon (UCSI University), who produced 78 and 44 articles, respectively (Figure 3.16).

Figure 3.15   Top 15 Scientists Ranked by Number of Articles: SCIE
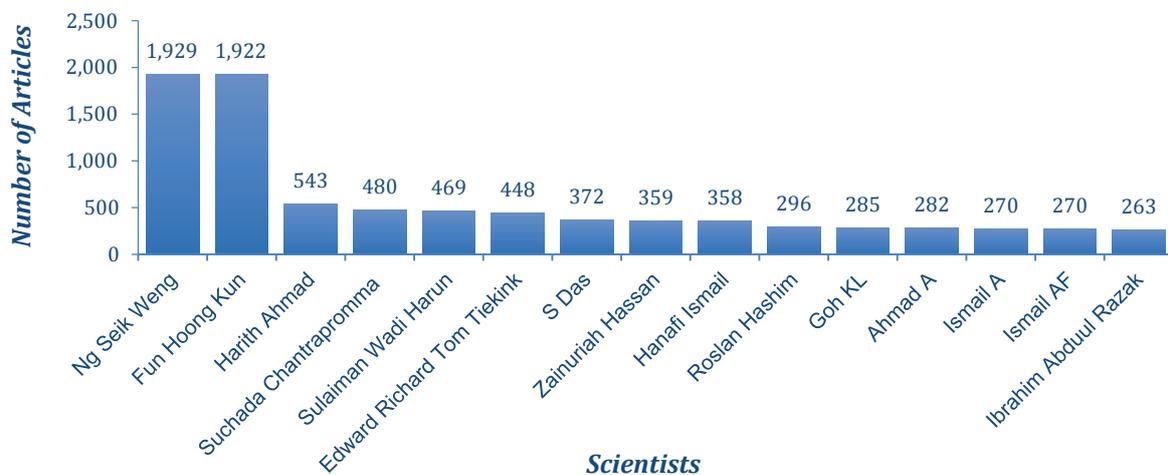
Data coverage : WoS – SCIE, 2001-2014.

Figure 3.16 Top 15 Researchers Ranked by Number of Articles: SSCI
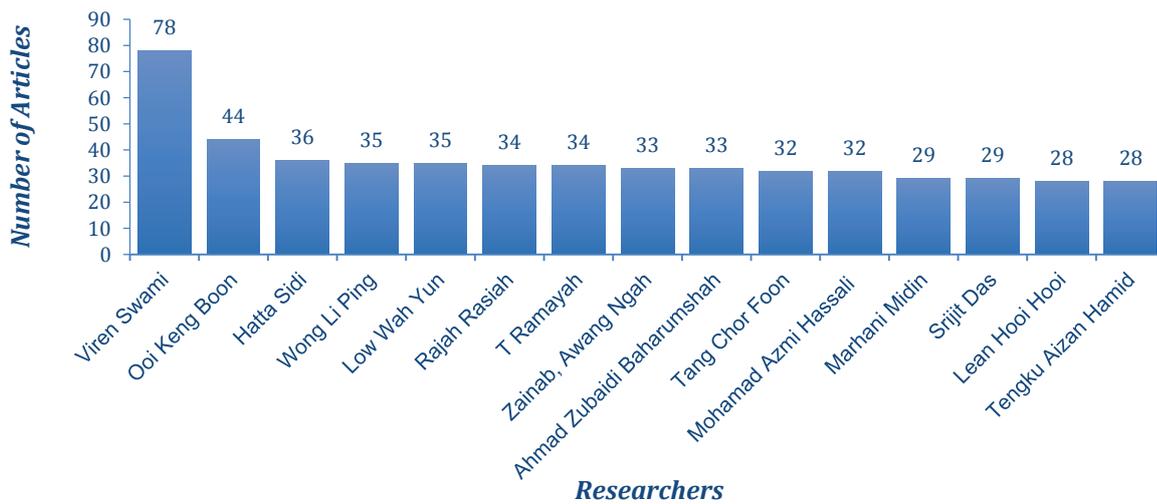
Data coverage : WoS – SSCI, 2001-2014.

3.3.8 International Journals Ranked by Number of Malaysian Articles

From SCIE database (Figure 3.17), the highest number of publications recorded for the period 2001-2014 is produced from Acta Crystallographica (3,642 articles). This is followed by Sains Malaysiana (1,152 articles) which published less than half the total of Acta Crystallographica, and PLOS ONE which published 524 articles from Malaysia. Each of the other journals published less than 500 articles from Malaysia; these include The Scientific World Journal (437 articles), African Journal of Biotechnology (327), Tropical Biomedicine (301), Molecules (299), Asian Pacific Journal of Cancer Prevention (298), Journal of Applied Polymer Science (272) and Food Chemistry (258).

From SSCI database (Figure 3.18), African Journal of Business Management produced most of Malaysia's articles (220 articles) in the social sciences. The journals Energy Policy (62), Malaysian Journal of Library & Information Science (61) and Asia-Pacific Journal of Public Health (61) are among the top international journals that publish social science articles from Malaysian institutions.

Figure 3.17   International Journals Ranked by Number of Malaysian Articles: SCIE
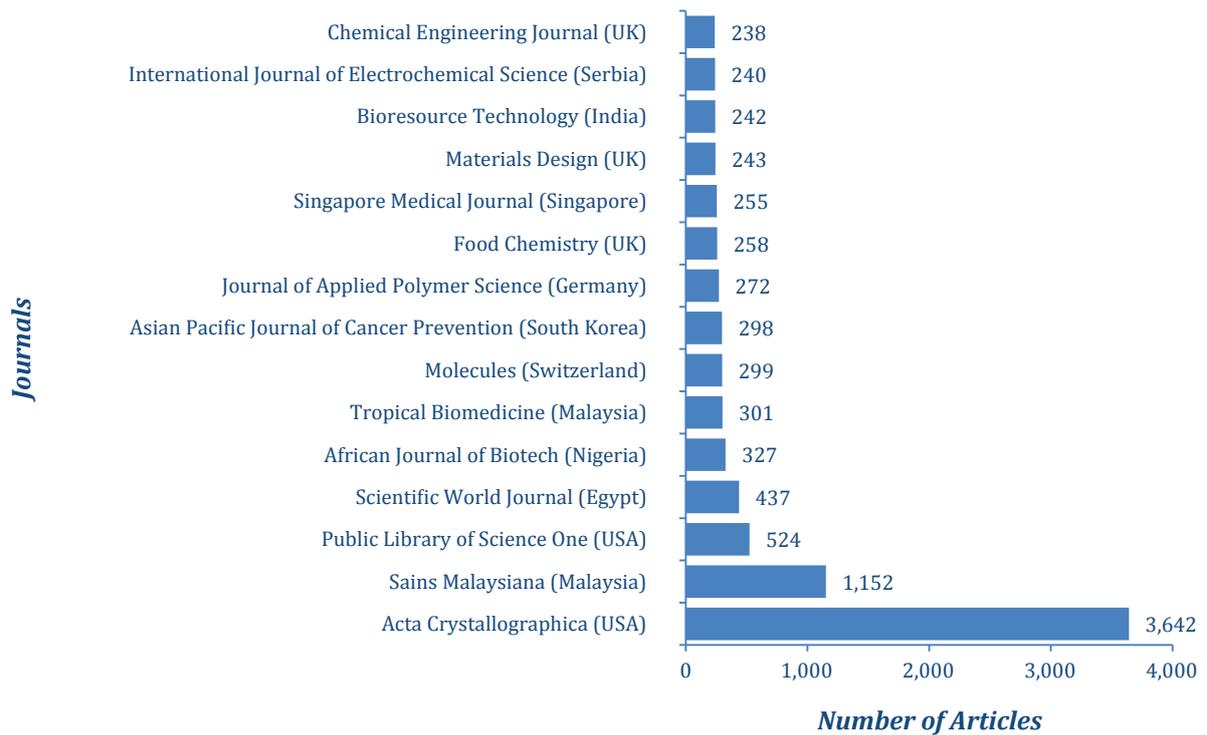
Data coverage :   WoS – SCIE, 2001-2014.

Figure 3.18   International Journals Ranked by Number of Malaysian Articles: SSCI
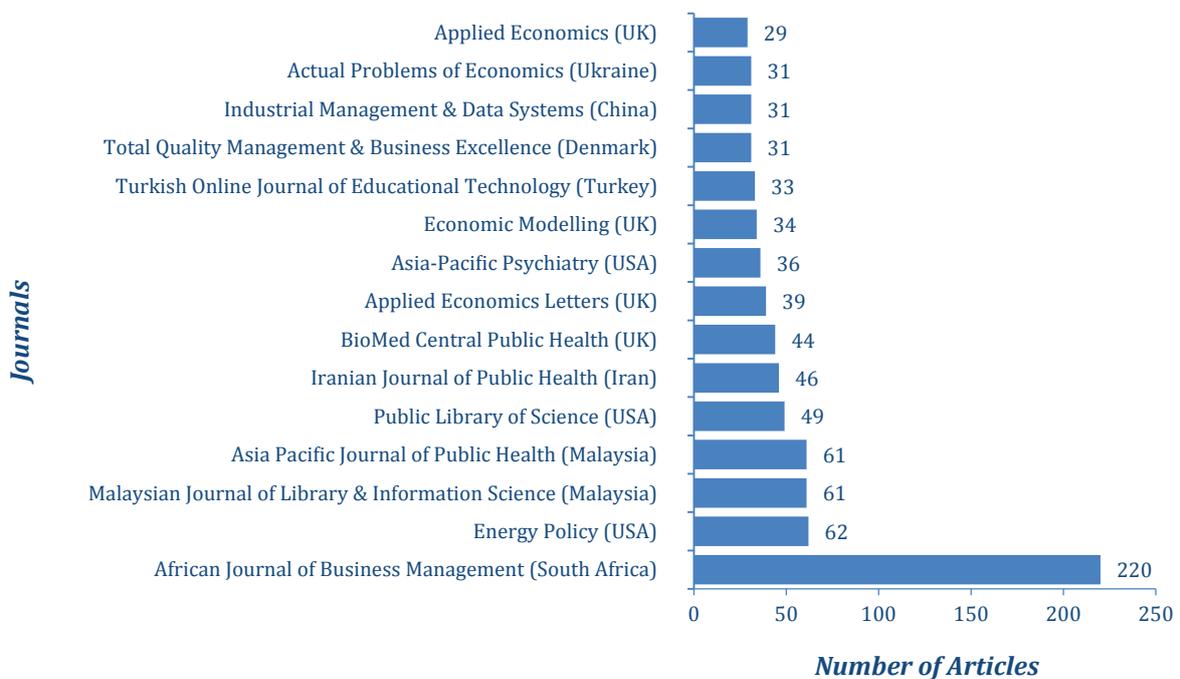
Data coverage :   WoS – SSCI, 2001-2014.

3.4   Proceedings Output and Growth

There are 30,997 proceedings published during the period 2001 to 2014. From Figure 3.19, it can be seen that there is a clear spike in growth rate from year 2003 (21.51%) to 2004 (484.07%). However, unlike the number of articles published, there is no obvious trend in the number of proceedings published over the years. The number of proceedings generally increases from year to year, except from year 2009 to year 2010 that saw a 30.58% decrease as well as from year 2013 to year 2014 with a 6.09% decrease.

Figure 3.19   Yearly Proceedings Output and Growth Rate
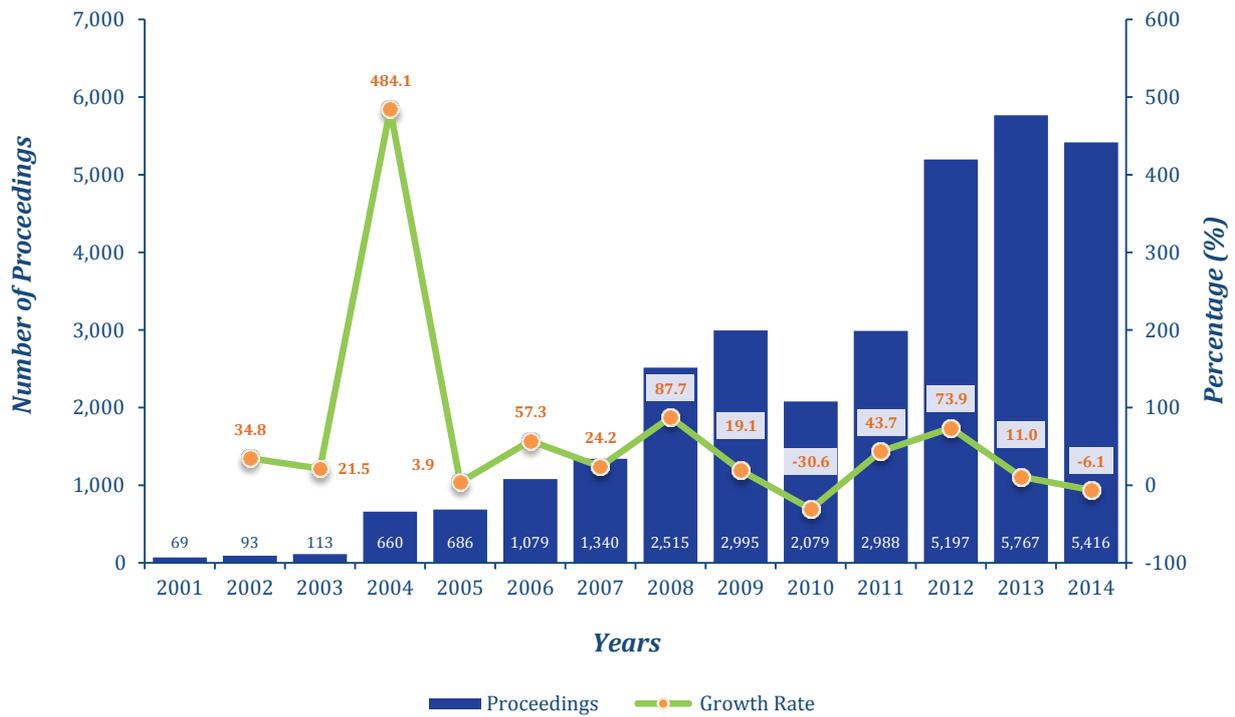
Data coverage : WoS – SCIE and SSCI, 2001-2014.

3.4.1   Top Fields of Research: Proceedings

For the proceedings, the field of Electrical & Electronic Engineering produced the highest volume (9,158 proceedings), double that of the next largest volume from Materials Science (4,541). This is a striking difference from the observed number of articles published, where Materials Science is the most productive field while Electrical & Electronic Engineering is the third most productive field (Figure 3.4). This difference is largely due to the nature of the fields and practice of the researchers in the corresponding fields.

Figure 3.20   Top 15 Fields of Research of Malaysia by Proceedings Counts
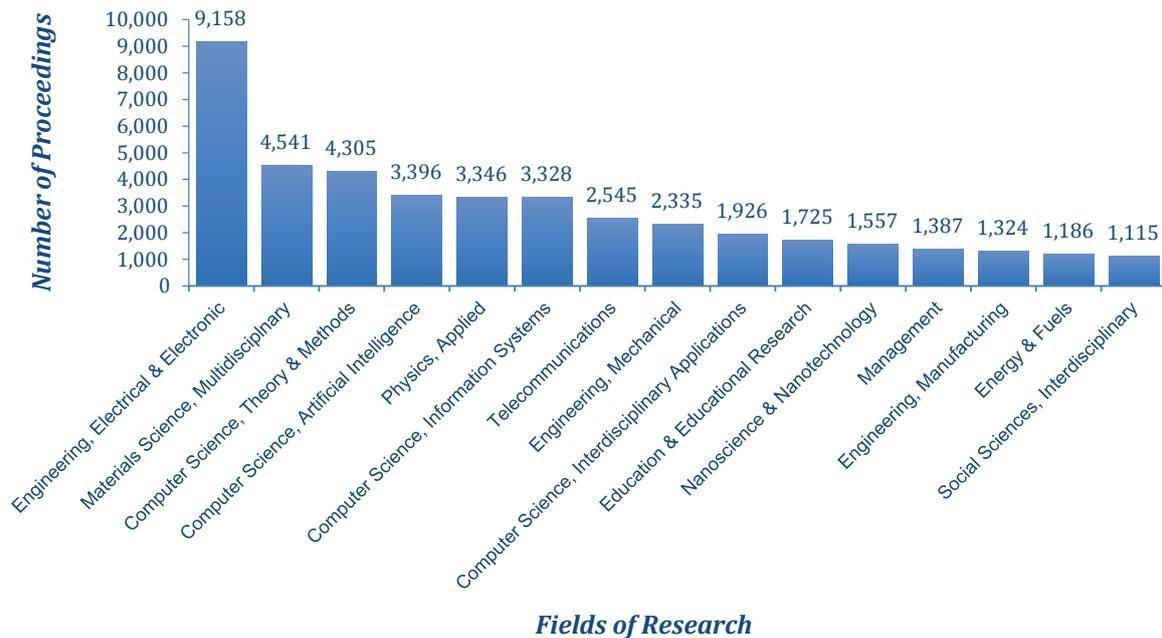
Data coverage :   WoS – SCIE and SSCI, 2001-2014.

3.4.2   Institutions by Number of Proceedings

In contrast to the observation from Figure 3.7, Figure 3.21 shows that Universiti Teknologi Malaysia (UTM: 3,829 proceedings) produced the highest number of proceedings while Universiti Malaya – the most productive institution in terms of article publications – placed fifth (UM: 2,212 proceedings). This is not surprising since Universiti Teknologi Malaysia's research strength is in the areas of Materials Science and Electrical & Electronic Engineering (Figure 3.8), which are the top two fields in terms of number of proceedings published (Figure 3.20). Universiti Kebangsaan Malaysia (UKM) published 3,542 proceedings followed by Universiti Teknologi MARA (UiTM: 3,434) and Universiti Sains Malaysia (USM: 2,472).

Figure 3.21   Top 15 Institutions by Number of Proceedings

Data coverage :   WoS – SCIE and SSCI, 2001-2014.

3.5   Malaysian Journal Publications

The following findings are based on the search results from SCOPUS database for the period of 2001 to 2014, which covers Malaysian journal publications.

3.5.1   Articles Outputs and Growth

A total of 17,896 articles were published in Malaysian journals during the years 2001 to 2014.

It is evident from Figure 3.22 that the number of articles published in Malaysian journals increased over the years 2001 to 2013. In the year 2008, there was a 55.88% increase in the number of published articles (689 articles to 1,074 articles) compared to the year 2007. The year 2008 was also the first year that saw the number of published articles breaking the mark of 1,000 published articles. The average growth rate of number of articles in Malaysian Journals between 2001 and 2013 was 22.27%. It overtook the world average growth rate (6%) of number of articles reported in SCIMAGO[4]. However, there was a drop in the number of articles in the year 2014. This is most likely due to the shift towards publishing in international and ISI journals which increased exponentially over the years, leading to a 17.63% decrease from 2013 (Figure 3.22). The pattern appears to be consistent with that of the world average growth rate (-4%) reported in SCIMAGO. The number of Malaysian journals also increased from just 7 journals in year 2001 to 76 journals in year 2012 (Figure 3.23). The top three Malaysian journals over the period 2001 to 2014 are the Medical Journal of Malaysia (2,084 articles), Jurnal Teknologi (Sciences and Engineering) (1,377 articles) and International Food Research Journal (1,371 articles).

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4   SCIMAGO is a portal that ranks journals and countries using the SCOPUS database.

Figure 3.22   Number of Articles in Malaysian Journals
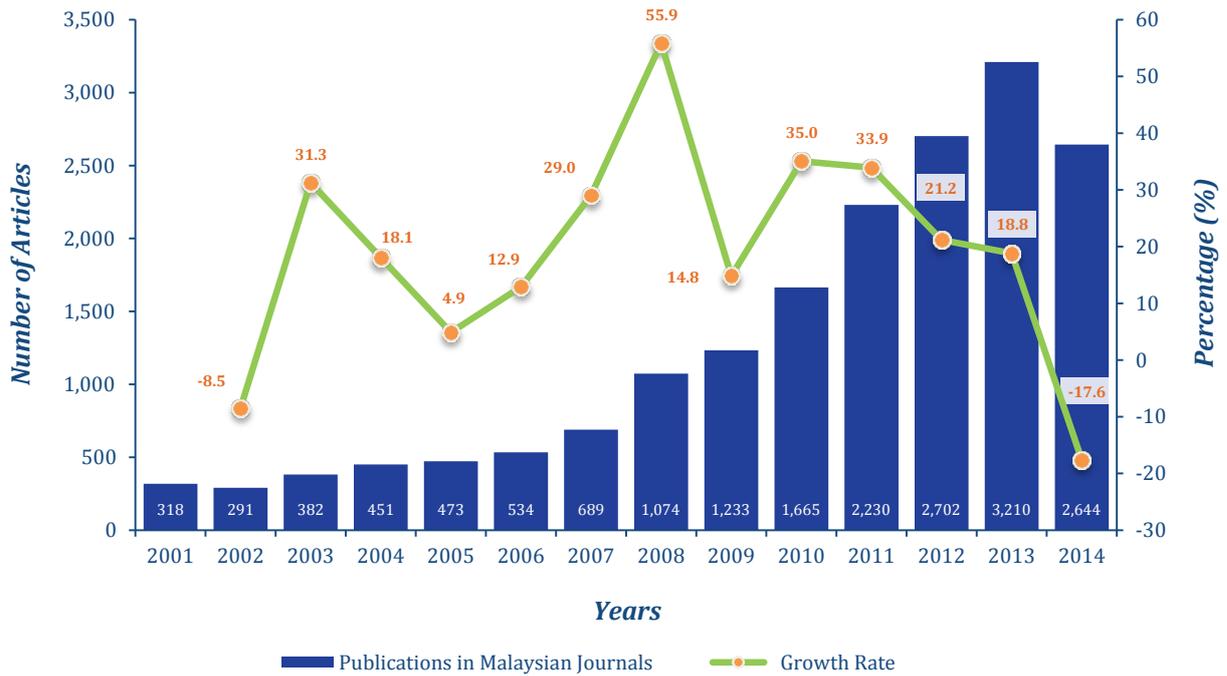
Data coverage :   SCOPUS, 2001-2014.

Figure 3.23   Number of Malaysian Journals
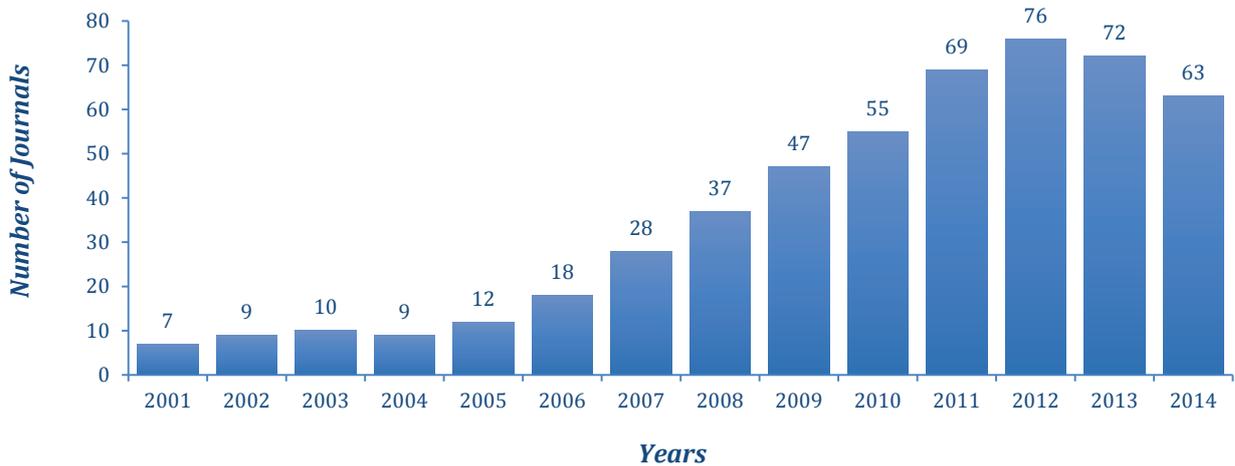
Data coverage :   SCOPUS, 2001-2014.

Note   :   In 2014, there are 77 Malaysian journals but only 63 journals have up-to-date records of articles by SCOPUS database. The data for the remaining journals were tracked using SCIMAGO.

From the 8MP through to the 10MP (Figure 3.24), the number of published articles in Malaysian journals increased by more than 2.5 fold, from 1,915 articles under the 8MP to 5,195 articles under the 9MP. For 2011 to 2014, the figure stands at 10,786 articles, breaking the mark of 10,000 published articles.

Figure 3.24   Article Outputs in Malaysian Journals by Malaysia Plans
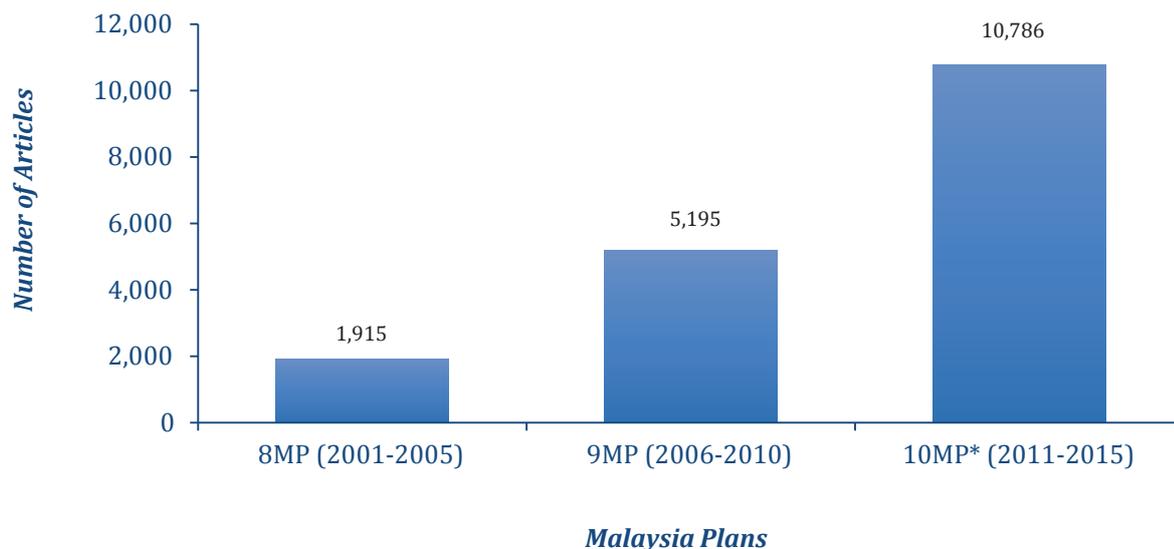
Data coverage : SCOPUS, 2001-2014.

Note : The scope of the study is from 2001 to 2014, while the 10MP covers the period 2011 to 2015. The recorded numbers are until end of 2014 (excludes 2015).

3.6   Relative Specialisation Index (RSI)

The publication data for institutions is now used to calculate relative advantages among the institutions in science, as it is equally important to compare on a relative term to that of an absolute basis. The RSI here is the ratio of the number of publications of an institution in a particular field, divided by the total number of publications at the national level in this field, and the number of publications of an institution under study in the whole field, divided by the total number of publications in the field at the national level. A value above one indicates relative strength over the national average and a value below one indicates relative weakness over the national average.

Figure 3.25 reveals the relative strength of selected institutions in scientific fields. Those institutions that have attained the level of – or outperformed – the national average are revealed. There are nine institutions that have attained RSI value above one for specific scientific fields. While the 5 RUs outperformed the national average for more than one field, Multimedia University, University of Nottingham Malaysia Campus, Universiti Teknologi PETRONAS and Malaysian Palm Oil Board each specialised in only one field. Universiti Malaya stands out as the institution that has gained comparative advantages in 7 fields. Universiti Putra Malaysia and Malaysia Palm Oil Board stand out as the two institutions specialising in

agricultural sciences. Many institutions (Universiti Malaya, Universiti Kebangsaan Malaysia, Universiti Teknologi Malaysia, Multimedia University, University of Nottingham Malaysia Campus and Universiti Teknologi PETRONAS) targeted engineering as their specialisation field. Universiti Malaya stands out as specialising in more than two fields, including Chemistry, Engineering, Clinical Medicine, Material Science, Environment/Ecology, Plant & Animal Science and General Social Sciences. Universiti Sains Malaysia attained specialisation in Chemistry and Materials Science, Universiti Putra Malaysia in Agricultural Sciences and Plant & Animal Science, Universiti Kebangsaan Malaysia in Engineering and Clinical Medicine, and Universiti Teknologi Malaysia in Environment/Ecology and Engineering.

Figure 3.25   RSI by Selected Institutions

Data coverage :   WoS – ESI, 2001-2014.

3.7   Summary

From a total 90,128 publications in the period of 2001 to 2014, a total of 59,131 international articles which comprise 224 subject categories were recorded by Thomson Reuters. These articles were produced by 118,357 authors across Malaysia. The number of publications increased from 6,128 articles under the 8MP to 17,283 articles under the 9MP. The increasing trend continues under the current 10MP with 35,720 published articles as of end of 2014.

In the sciences, the field of Materials Science produced the highest number of articles (4,266 articles) followed by Crystallography (4,153). In the social sciences, the fields of Economics (574) and Management (510) are found to be the top two contributing areas of research for publications. The field of Electrical & Electronic Engineering (9,158 proceedings) has the most proceedings publications, followed by Materials Science (4,541).

As a whole, the five RUs contributed almost 83% of the total number of published articles. In terms of collaboration, while England, the United States of America, India, Japan and Australia remain the top collaborating countries, there is a notable increase in collaborations with Middle Eastern countries, particularly Iran and Saudi Arabia. Within Malaysia, there is a healthy collaboration effort among the RUs, especially between Universiti Malaya, Universiti Putra Malaysia and Universiti Kebangsaan Malaysia.

The number of articles published in Malaysian journals has grown over the years 2001 (318 articles) to 2013 (3,210 articles). The number of Malaysian journals has also increase from 7 journals in 2001 to 76 journals in 2012.

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INLET DUCT

CHAPTER 4:
PUBLICATION CITATIONS
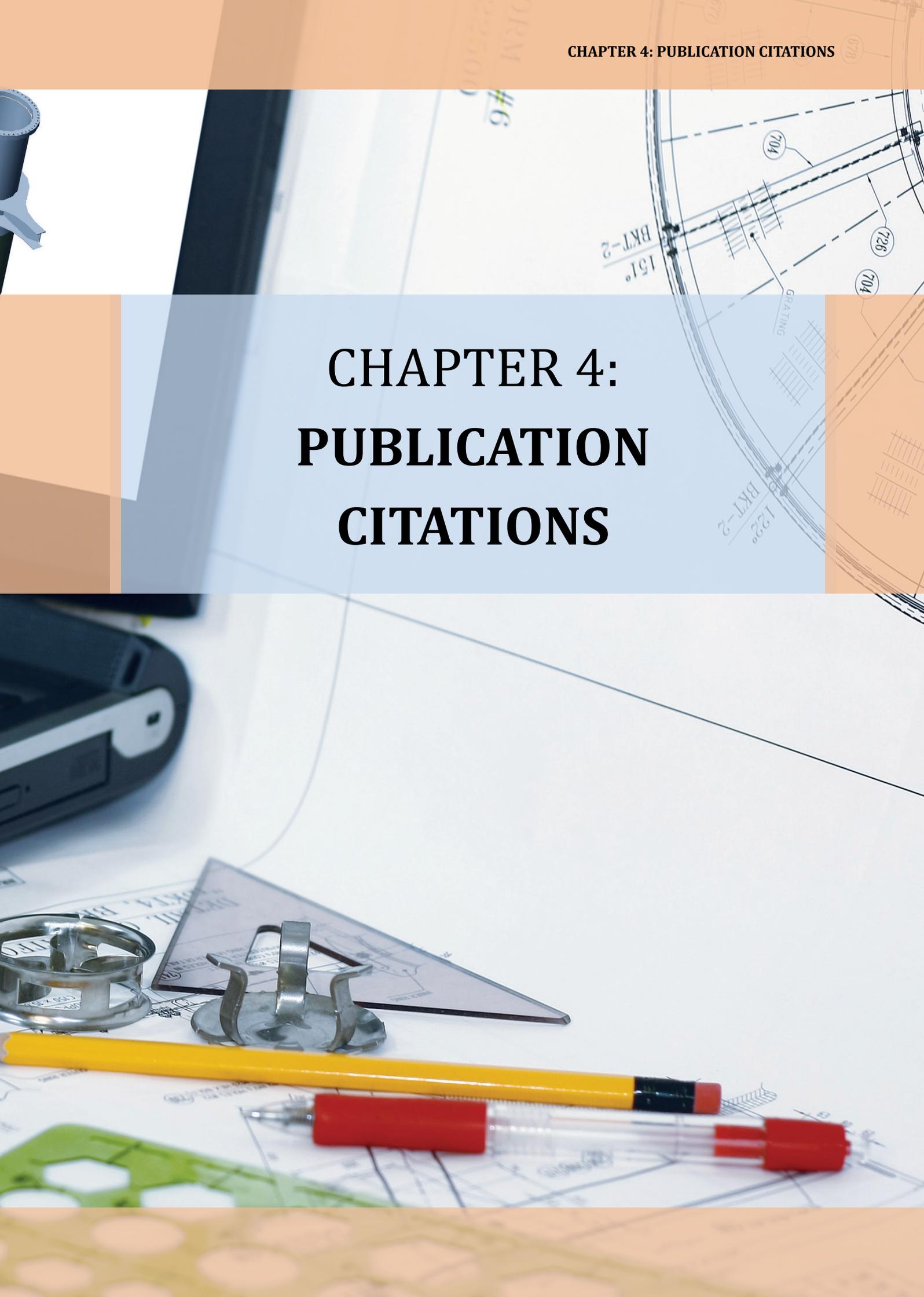
CHAPTER 4:   PUBLICATION CITATIONS

4.1   Introduction

This chapter reports the findings on article citations for the years 2001 to 2014. Publication citations are considered as a quality measurement of a researcher's work. It also indicates the impact of the particular articles.

4.2   Citations: Summary of Findings

A total of 394,353 article citations are recorded for the period of 2001 to 2014. Figure 4.1 indicates that the highest citation count of 46,275 was recorded in 2011, followed by 45,939 and 41,447 citations in 2010 and 2009 respectively. In general, the number of citations shows an increasing trend, in tandem with an increasing trend of article publications. However, the number of citation counts has decreased since 2012, even though the number of articles published has grown exponentially over the years up to 2014 (see Chapter 3). Thus, citations per article – measured as the ratio of citation counts to the total number of articles produced – displays a decreasing trend over the period under study, as expected.

Figure 4.1   Yearly Articles and Citations Counts with Citations per Article
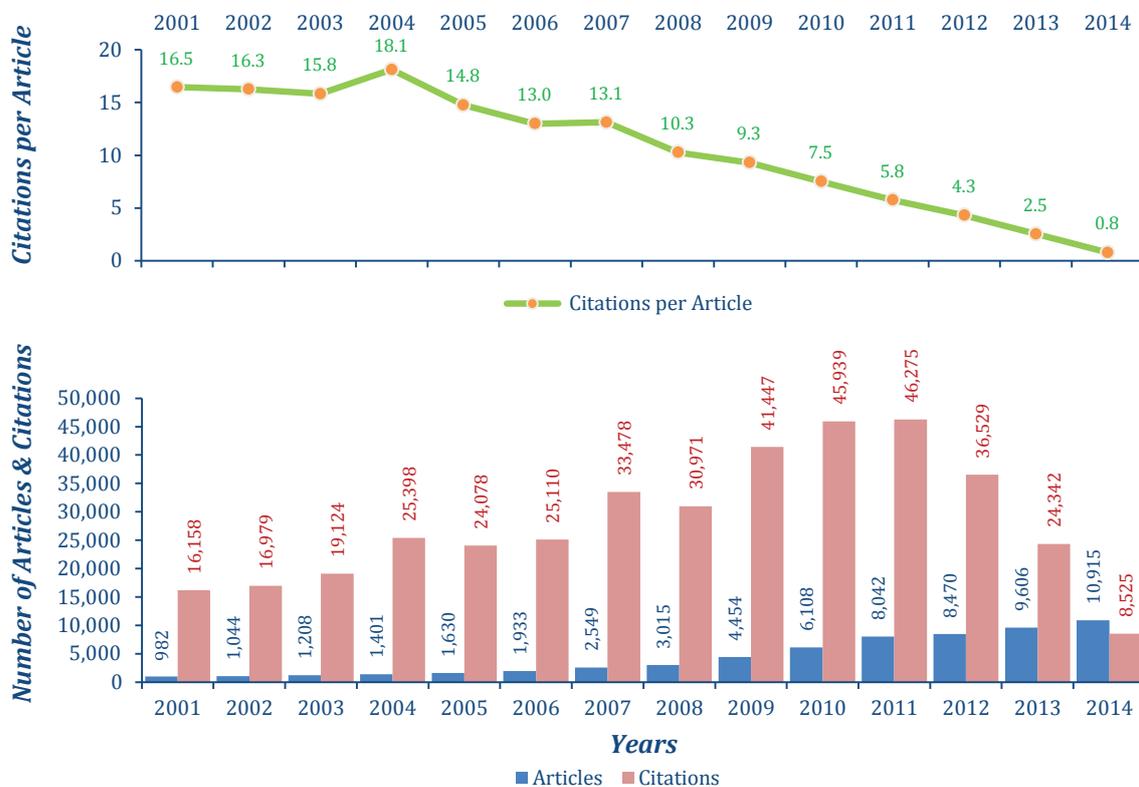
Data coverage :   WoS – SCIE and SSCI, 2001-2014.

4.3 Comparison of Articles and Citations in Selected Countries

Table 4.1 displays a summary of citations and articles produced by 64 countries for the period of 2001-2014. In comparison to other countries, Malaysia's ratio of citations per article is 5.37. The ranking has improved from 136 in 2012 to 62 in 2015. Nevertheless, Malaysia's citations per article, is still far behind many developing countries such as Philippines (30th), Thailand (36th), Indonesia (37th), China (45th) and Vietnam (49th). Iceland records the highest citations per article with a ratio of 19.48. Although having the most number of articles (3,652,510 articles), USA ranked 6th in terms of citations per article (17.40) – behind Switzerland (19.35), Scotland (18.12), the Netherlands (18.05) and Denmark (17.72). Regionally, Singapore (13.51), Thailand (9.53), the Philippines (11.14), Indonesia (8.99) and Vietnam (7.34) have higher citations per article than Malaysia. These comparisons are based on the ESI due to the availability of data for global comparison of articles and citations.

Table 4.1   Number of Articles, Citations and Citations per Article by Country

No.	Country	WoS Articles	Citations	Citations per Article (C/A)	Rank by C/A
1	USA	3,652,510	63,537,290	17.40	6
2	China	1,496,549	11,962,020	7.99	45
3	Germany	950,932	14,573,151	15.33	10
4	England	852,945	14,502,634	17.00	7
5	Japan	842,873	9,835,789	11.67	27
6	France	673,460	9,732,498	14.45	17
7	Canada	575,899	8,754,572	15.20	12
8	Italy	553,773	7,625,504	13.77	20
9	Spain	466,916	5,792,507	12.41	25
10	India	429,760	3,138,659	7.30	50
11	Australia	425,004	5,821,629	13.70	21
12	South Korea	417,597	3,607,771	8.64	40
13	Netherlands	328,008	5,920,452	18.05	4
14	Brazil	318,813	2,328,220	7.30	51
15	Russia	297,770	1,707,661	5.73	55
16	Taiwan	246,831	2,179,052	8.83	38
17	Switzerland	236,443	4,575,219	19.35	2
18	Turkey	221,558	1,429,125	6.45	52
19	Sweden	219,516	3,627,388	16.52	8
20	Poland	206,617	1,599,609	7.74	47
21	Belgium	180,153	2,911,238	16.16	9
22	Iran	163,688	904,017	5.52	58

Table continued on next page

No.	Country	WoS Articles	Citations	Citations per Article (C/A)	Rank by C/A
23	Scotland	132,176	2,394,554	18.12	3
24	Denmark	130,038	2,304,081	17.72	5
25	Israel	128,908	1,869,213	14.50	15
26	Austria	122,686	1,859,794	15.16	13
27	Finland	108,892	1,645,728	15.11	14
28	Greece	106,835	1,215,302	11.38	29
29	Mexico	101,391	847,354	8.36	41
30	Norway	99,241	1,438,442	14.49	16
31	Portugal	97,861	1,086,445	11.10	31
32	Singapore	94,832	1,281,462	13.51	22
33	Czech Republic	93,448	920,763	9.85	33
34	South Africa	80,542	808,600	10.04	32
35	New Zealand	75,608	978,997	12.95	23
36	Argentina	75,215	738,384	9.82	34
37	Ireland	65,000	932,156	14.34	18
38	Hungary	61,262	713,108	11.64	28
39	Romania	59,827	322,372	5.39	61
40	Egypt	57,317	358,546	6.26	54
41	Malaysia	56,571	304,068	5.37	62
42	Thailand	51,635	492,058	9.53	36
43	Chile	50,696	494,165	9.75	35
44	Ukraine	50,617	262,045	5.18	63
45	Saudi Arabia	46,509	253,527	5.45	59
46	Wales	45,170	689,563	15.27	11
47	Pakistan	41,760	232,384	5.56	57
48	Serbia	33,550	164,615	4.91	64
49	Slovenia	33,211	292,274	8.80	39
50	Croatia	31,134	229,688	7.38	48
51	Slovakia	30,201	245,366	8.12	44
52	Tunisia	24,577	138,085	5.62	56
53	Colombia	24,300	192,395	7.92	46
54	Bulgaria	23,029	189,131	8.21	43
55	Northern Ireland	22,139	311,095	14.05	19
56	Lithuania	18,186	115,875	6.37	53

No.	Country	WoS Articles	Citations	Citations per Article (C/A)	Rank by C/A
57	Nigeria	17,676	95,457	5.40	60
58	Vietnam	13,480	99,006	7.34	49
59	Estonia	13,297	161,886	12.17	26
60	Venezuela	12,313	102,017	8.29	42
61	Kenya	10,981	138,480	12.61	24
62	Indonesia	10,855	97,634	8.99	37
63	Philippines	8,381	93,353	11.14	30
64	Iceland	7,625	148,551	19.48	1

Data coverage : WoS – ESI, 2001-2014.

4.4   Citations According to Fields of Research Compared to Top Countries

The field of Immunology has the highest citations per article (10.86) for Malaysian articles, followed by Environment/Ecology (8.72), Space Science (8.60) and Biology & Biochemistry (8.03) as shown in Table 4.2. The country that is productive in these areas is USA with a citation per article ratio of 26.31 for Immunology, 16.95 for Environment/Ecology, 23.08 for Space Science and 21.46 for Biology & Biochemistry. The USA has high citations per article of 62.99 for the Multidisciplinary research field, while Malaysia only achieved 5.44. Malaysia has lower citations per article for the fields of Economics & Business (2.61), Computer Science (2.43) and Mathematics (2.40). Nevertheless, compared against the USA, the citations per article for these fields (Economics & Business, Computer Science and Mathematics) are 11.07, 8.07 and 5.50 respectively. Lower citations per article for these areas of research are also influenced by the nature of the disciplines of research.

Table 4.2   Number of Articles, Citations and Citations per Article by Fields of Research

No.	Field of Research	Malaysia			Top Country			
		WoS Articles	Citations	C/A	Top Country	WoS Articles	Citations	C/A
1	Immunology	542	5,885	10.86	USA	91,764	2,413,886	26.31
2	Environment / Ecology	2,586	22,553	8.72	USA	107,091	1,815,319	16.95
3	Space Science	52	447	8.60	USA	65,768	1,517,866	23.08
4	Biology & Biochemistry	2,101	16,878	8.03	USA	325,136	6,978,525	21.46
5	Microbiology	867	6,250	7.21	USA	56,913	1,265,234	22.23
6	Neuroscience & Behaviour	474	3,307	6.98	USA	184,962	4,445,512	24.03

No.	Field of Research	Malaysia			Top Country			
		WoS Articles	Citations	C/A	Top Country	WoS Articles	Citations	C/A
7	Molecular Biology & Genetics	853	5,758	6.75	USA	166,748	5,906,484	35.42
8	Clinical Medicine	6,095	37,233	6.11	USA	776,866	14,362,509	18.49
9	Agricultural Sciences	2,964	17,489	5.90	USA	65,776	701,289	10.66
10	Multidisciplinary	226	1,230	5.44	USA	11,396	717,875	62.99
11	Pharmacology & Toxicology	1,949	10,599	5.44	USA	92,875	1,583,802	17.05
12	Engineering	8,364	44,548	5.33	USA	209,866	1,610,435	7.67
13	Chemistry	10,801	56,673	5.25	USA	250,294	5,137,017	20.52
14	Psychiatry / Psychology	489	2,518	5.15	USA	159,540	2,395,099	15.01
15	Geosciences	914	4,512	4.94	USA	114,779	1,901,712	16.57
16	Physics	3,271	15,425	4.72	USA	259,613	4,462,051	17.19
17	Materials Science	5,038	23,220	4.61	USA	94,174	1,578,956	16.77
18	Plant & Animal Science	2,876	13,016	4.53	USA	168,587	1,974,340	11.71
19	Social Sciences, General	2,291	7,127	3.11	USA	295,871	2,435,330	8.23
20	Economics & Business	818	2,137	2.61	USA	87,388	967,566	11.07
21	Computer Science	1,837	4,472	2.43	USA	86,941	701,645	8.07
22	Mathematics	1,163	2,791	2.40	USA	87,253	480,157	5.50
23	All Fields	56,571	304,068	5.37	-	362,510	63,537,290	17.40

Data coverage : WoS – ESI, 2001-2014.

4.5 Number of Articles and Citations by Institutions

As shown in Figure 4.2, Universiti Malaya has garnered 91,646 citations from 15,428 articles. This is the highest number of citations, followed by Universiti Sains Malaysia (USM) and Universiti Putra Malaysia (UPM) with 83,002 and 58,678 citations respectively. The five RUs have a combined total of 304,703 citations from a total of 50,067 articles, resulting in 77.27% of all citations produced. In addition, there is a combined total of 71,006 citations (18.01%) from 11,449 articles produced by the ten non-RUs (see Figure 4.2).

Figure 4.2   Top 15 Institutions by Number of Articles and Citations
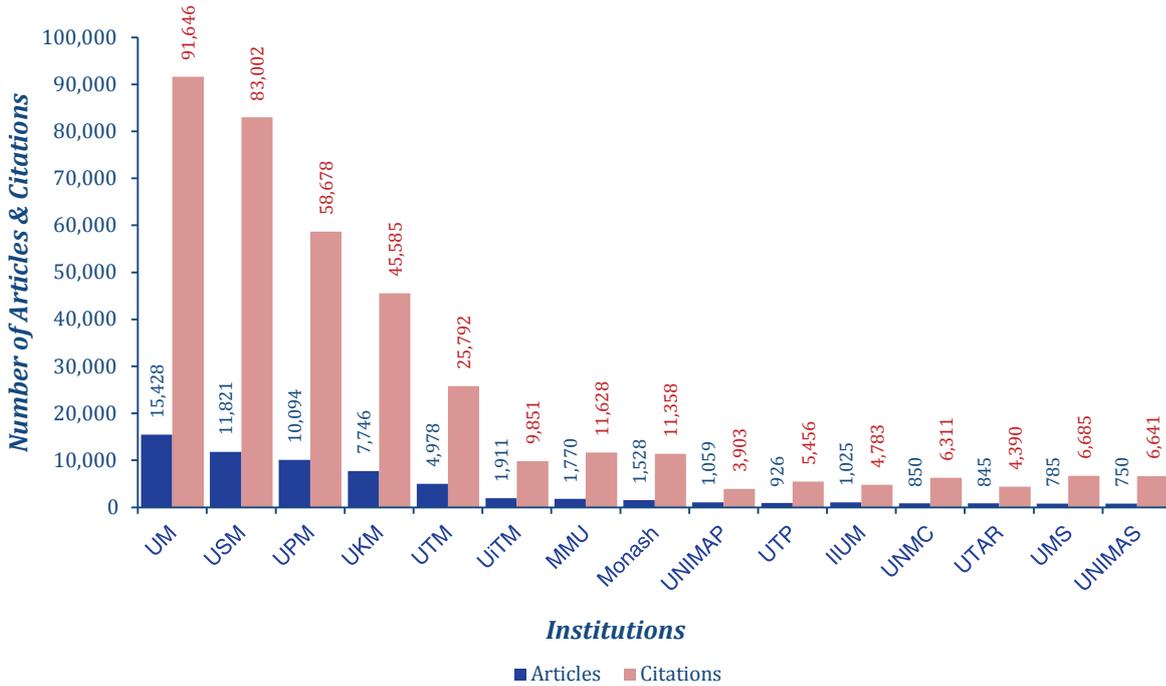
Data coverage :   WoS – SCIE and SSCI, 2001-2014.

4.6   Institutions by Citations per Article

Figure 4.3 displays the citations per article produced by fifteen universities in Malaysia. It is interesting to note that the top four institutions with highest citations per article are Universiti Malaysia Sarawak (UNIMAS: 8.85), Universiti Malaysia Sabah (UMS: 8.52), Monash University Malaysia (Monash: 7.43) and University of Nottingham Malaysia Campus (UNMC: 7.42). Among Malaysian RUs, Universiti Sains Malaysia (USM) recorded the highest citations per article of 7.02, followed by Universiti Malaya (UM) at 5.94.

Figure 4.3   Top 15 Institutions by Citations per Article

Data coverage :   WoS – SCIE and SSCI, 2001-2014.

4.7 Institutions by h-Index

The h-index has been used as a measure of research performance for individual researchers as well as institutions. It has the advantage of accounting for both number of articles and number of citations, which are indicators of quantity and quality of research.

4.7.1 Malaysian Institutions by h-Index

In Malaysia, Universiti Malaya tops the list with the highest h-index of 35 for the duration 2012 to 2014, followed by Universiti Sains Malaysia with a h-index of 30 (Table 4.3). As expected, the five RUs ranked higher than the other institutions in terms of h-index from the years 2001 to 2014. For the duration 2012 to 2014, the non-RUs with the highest h-index are Monash University Malaysia (17), University of Nottingham Malaysia Campus (17), followed by Universiti Teknologi MARA (16) and Universiti Malaysia Perlis (15). Interestingly, both Monash University Malaysia and University of Nottingham Malaysia Campus do not rank high in terms of number of published articles (Figure 3.5); this is indicative that most of their articles are of a certain quality and are mostly cited by other researchers.

Table 4.3   Top 15 Malaysian Institutions by h-Index

University	2001–2004	2005–2008	2009–2011	2012–2014
Universiti Malaya	59	57	51	35
Universiti Sains Malaysia	58	62	48	30
Universiti Putra Malaysia	53	46	40	28
Universiti Teknologi Malaysia	33	35	34	28
Universiti Kebangsaan Malaysia	42	42	39	26
Monash University Malaysia	19	25	32	17
University of Nottingham Malaysia Campus	-	25	28	17
Universiti Teknologi MARA	20	27	26	16
Universiti Malaysia Perlis	-	11	17	15
Universiti Teknologi PETRONAS	12	19	27	14
Multimedia University	25	29	21	12
Universiti Malaysia Sarawak	23	24	20	12
Universiti Tunku Abdul Rahman	7	17	22	11
Universiti Malaysia Sabah	21	27	21	11
International Islamic University Malaysia	15	20	19	10

Data coverage :   WoS – SCIE and SSCI, 2001-2014.

4.7.2 Malaysian Institutions Compared to International Institutions by h-Index

To gauge the research performance of Malaysian institutions internationally, the h-index of Malaysian institutions are compared against the h-index of selected international collaborating institutions as identified in Section 3.3.4. Only those institutions with less than 10,000 articles within the period of 2012 to 2014 are considered, due to the limitation of the WoS interface in producing results for citations. It is clear that most international collaborating institutions have higher h-index than the Malaysian institutions. From Table 4.4, the top two highest ranking collaborating institutions – University of Bristol and University of Southampton – have h-index of 72 and 67 respectively, while the highest ranking Malaysian institution – Universiti Malaya – has an h-index of 35. Universiti Malaya ranked higher than Chulalongkorn University (31), followed by Universiti Sains Malaysia (30) and Curtin University of Technology (29).

Table 4.4   Malaysian and International Collaborating Institutions by h-Index

Collaborating Institution	h-Index	Articles	Citations	Citations per Article
University of Bristol	72	8,955	60,179	6.72
University of Southampton	67	8,760	50,494	5.76
University of Glasgow	65	7,269	50,333	6.92
University of Western Australia	65	9,316	49,221	5.28
University of Hong Kong	56	8,807	43,602	4.95
University of Hamburg	56	4,940	34,521	6.99
University of Adelaide	53	7,284	43,160	5.93
University of Auckland	51	6,613	36,282	5.49
Chinese University of Hong Kong	50	7,588	33,896	4.47
University of Belgrade	48	9,046	31,228	3.45
King Abdulaziz University	46	7,545	31,773	4.21
King Saud University	36	8,029	22,932	2.86
Mahidol University	35	3,652	13,229	3.62
Universiti Malaya	35	8,413	22,292	2.65
Chulalongkorn University	31	3,650	13,701	3.75
Universiti Sains Malaysia	30	5,076	12,380	2.44
Curtin University of Technology	29	1,921	9,764	5.08
Universiti Putra Malaysia	28	5,170	10,957	2.12

Collaborating Institution	h-Index	Articles	Citations	Citations per Article
Universiti Teknologi Malaysia	28	3,445	9,085	2.64
Universiti Kebangsaan Malaysia	26	4,203	8,197	1.95
Monash University Malaysia	17	935	2,735	2.93
University of Nottingham Malaysia Campus	17	520	1,612	3.10
Universiti Teknologi MARA	16	1,082	2,055	1.90
Universiti Malaysia Perlis	15	841	2,003	2.38
Universiti Teknologi PETRONAS	14	589	1,180	2.00
Sapienza University of Rome	13	221	1,116	5.05
Multimedia University	12	386	738	1.91
Universiti Malaysia Sarawak	12	370	524	1.42
Universiti Malaysia Sabah	11	336	771	2.29
Universiti Tunku Abdul Rahman	11	445	885	1.99
International Islamic University Malaysia	10	436	657	1.51

Data coverage : WoS – SCIE and SSCI, 2012–2014.

4.8 Scientists and Researchers Ranked by Number of Citations

The top two scientists with the most number of citations are Fun Hoong Kun (Universiti Sains Malaysia) and Bassim H. Hameed (Universiti Sains Malaysia) with 8,612 and 7,386 citations (Figure 4.4), respectively. Despite being the scientist with the most number of articles, Ng Seik Weng (Universiti Malaya) came third for citations with 6,834. In terms of number of citations, Ahmad Abdul Latif ranked fourth (5,500 citations), followed by Ismail, Hanafi (4,076) and Ismail, Ahmad Fauzi (3,862). All these scientists have accumulated more than 3,500 citations each.

The top two researchers in the social sciences in terms of number of citations are Saidur, Rahman (Universiti Malaya) and Viren Swami (HELP University) with 564 and 563 citations, respectively (Figure 4.5). Ooi Keng Boon (UCSI University) ranked third with 509 citations.These are the three researchers with more than 500 citations each among the social scientists in Malaysia.

Figure 4.4   Top 15 Scientists Ranked by Number of Citations: SCIE
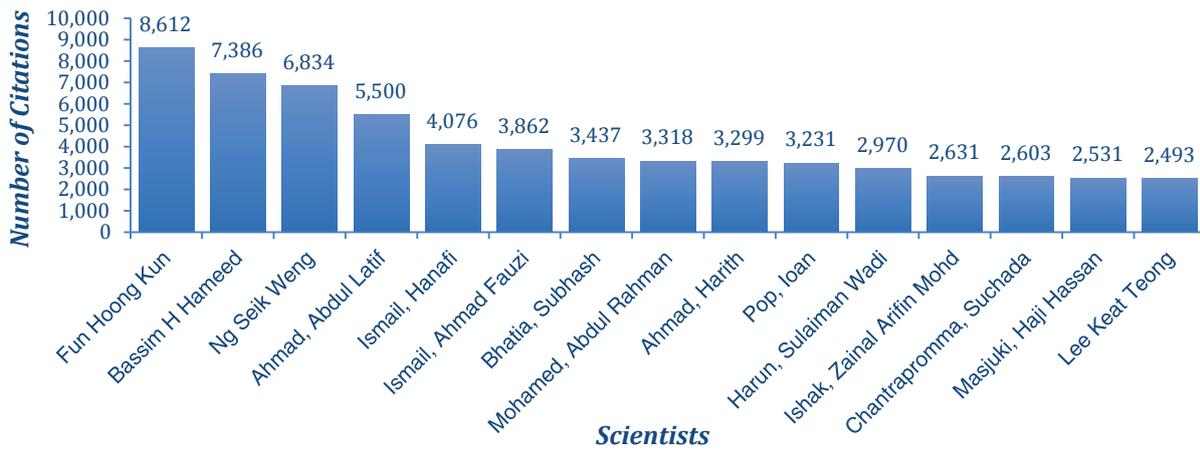
Data coverage :   WoS – SCIE, 2001-2014.

Note   :   The top 15 researchers in citation counts are sorted based on the data extraction of the first top 100 researchers by article counts.

Figure 4.5   Top 15 Researchers Ranked by Number of Citations: SSCI
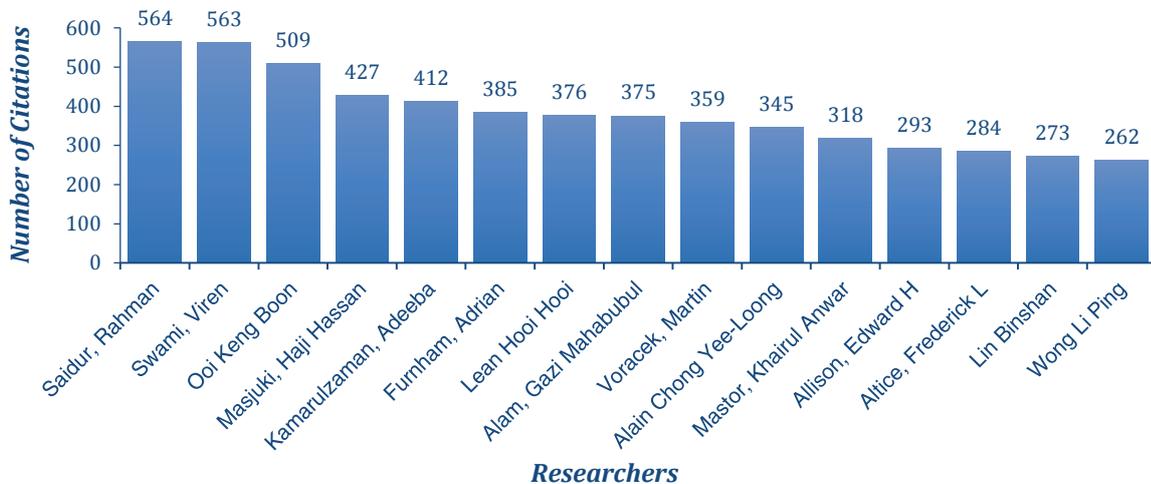
Data coverage : WoS – SSCI, 2001-2014.

Note   :   The top 15 researchers in citation counts are sorted based on the data extraction of the first top 100 researchers by article counts.

4.9   Relative Impact Index (RII)

RII is defined as the citations per article for an institution in a field divided by aggregate citations per article at the national level in that field. A value above unity indicates the relative citation strength of an institution in that field. Figure 4.6 reveals the institutions that have attained the level of – or outperformed – the national average. Universiti Sains Malaysia emerged to have attained citation strength for a few research areas (Figure 4.6). While Universiti Malaya and Universiti Putra Malaysia attained relative strength for two research

areas each, Universiti Kebangsaan Malaysia, Universiti Teknologi Malaysia, University of Nottingham Malaysia Campus and Universiti Teknologi PETRONAS gained relative strength for one area each. Universiti Malaya achieved relative strength above the national average in Clinical Medicine and Environment/Ecology, Universiti Sains Malaysia in Chemistry, Engineering, Material Science, Environment/Ecology, Agricultural Sciences, and General Social Science. Universiti Putra Malaysia performed in Chemistry and Material Science, Universiti Teknologi Malaysia in Environment/Ecology, and both University of Nottingham Malaysia Campus and Universiti Teknologi PETRONAS in Engineering.

Figure 4.6   RII of Selected Institutions
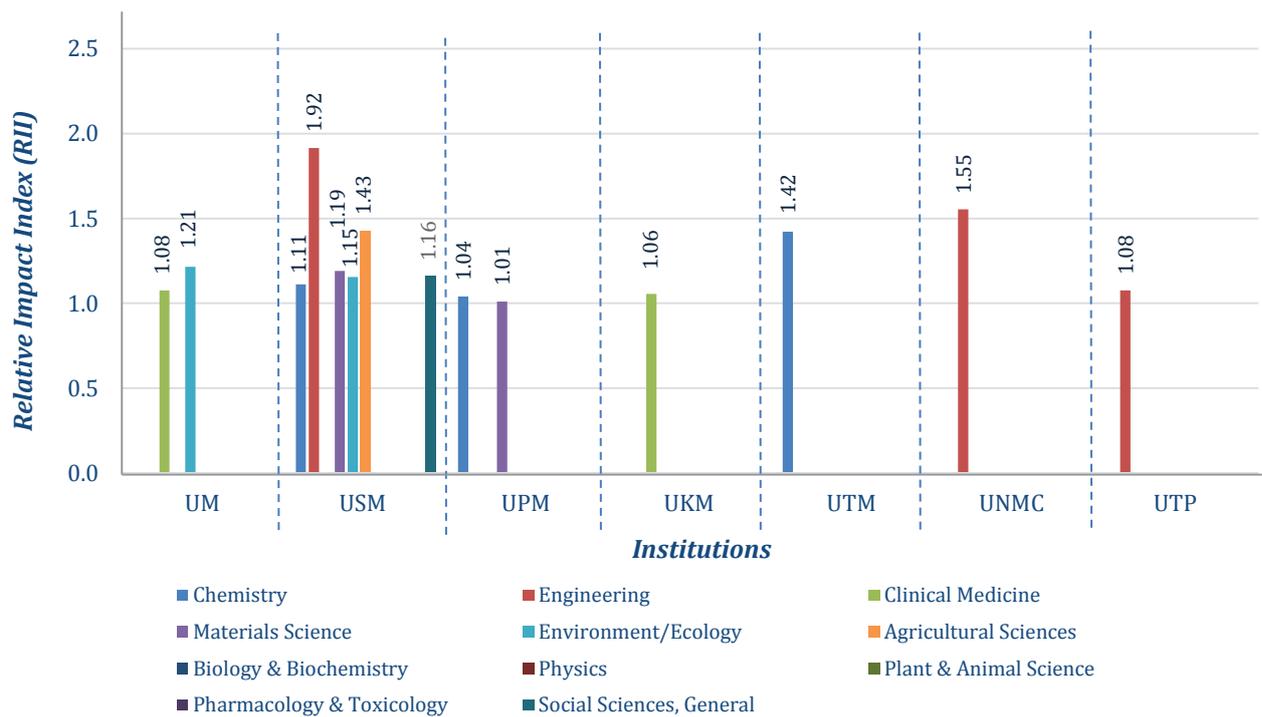
Data coverage : WoS – ESI, 2001-2014.

4.10   Publication Network

Figure 4.7 and Figure 4.8 show the co-publication network structure for sciences and social sciences respectively. The two networks are constructed based on the co-authorship between the 30 most productive organisations from 2012 to 2014. It implies that there are a few strong foreign partners who are collaborating closely with the Malaysian universities in publications. Imperial College, University of Oxford, Melbourne University, National University of Singapore, University of Queensland and King Abdulaziz University emerged to be the top universities working closely with universities in Malaysia. University of Queensland, Queensland University of Technology, Yale University, Melbourne University, University of Western Australia, Mahidol University and National University of Singapore are among the top foreign universities that work closely with universities in Malaysia in the areas of social sciences publication. Interestingly, Australian universities have attained a dominant footprint in Malaysia's co-publication network for both sciences and social sciences publications.

Figure 4.7   Malaysia's Science Co-Publication Network, 2012–2014
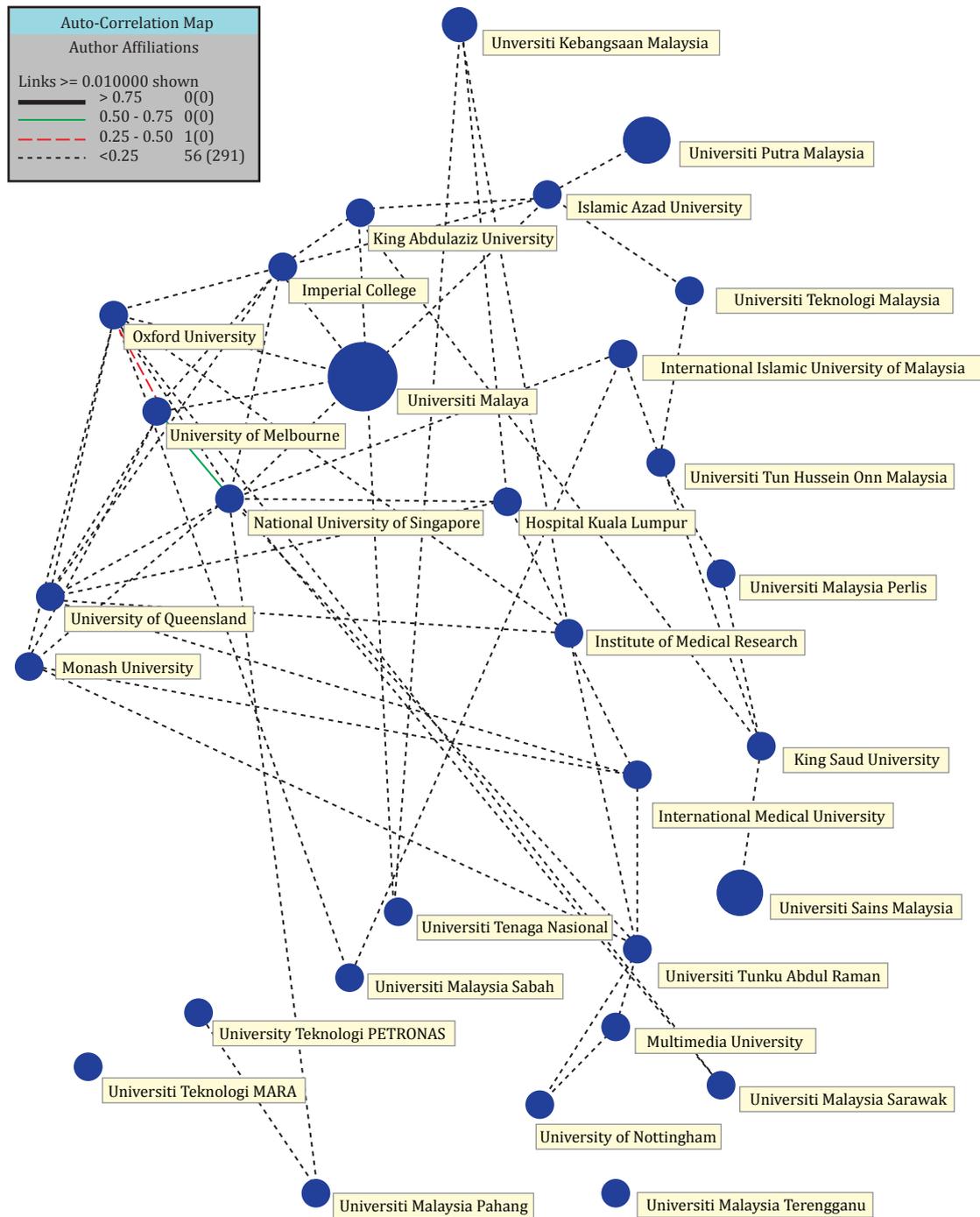
Data coverage : WoS – SCIE, 2012-2014.

Note   : Similarity index denotes the degree of similarity in proportion to the number of co-authored articles. (Similarity index of 1 would mean that the co-authors appear on every publication in both sets together. Likewise, similarity index of 0.25 signifies that there is 25% of co-author articles shared with both sets). Threshold for links is set at 0.01 similarity index. There are 291 hidden links in this map.

Figure 4.8   Malaysia's Social Science Co-Publication Network, 2012–2014
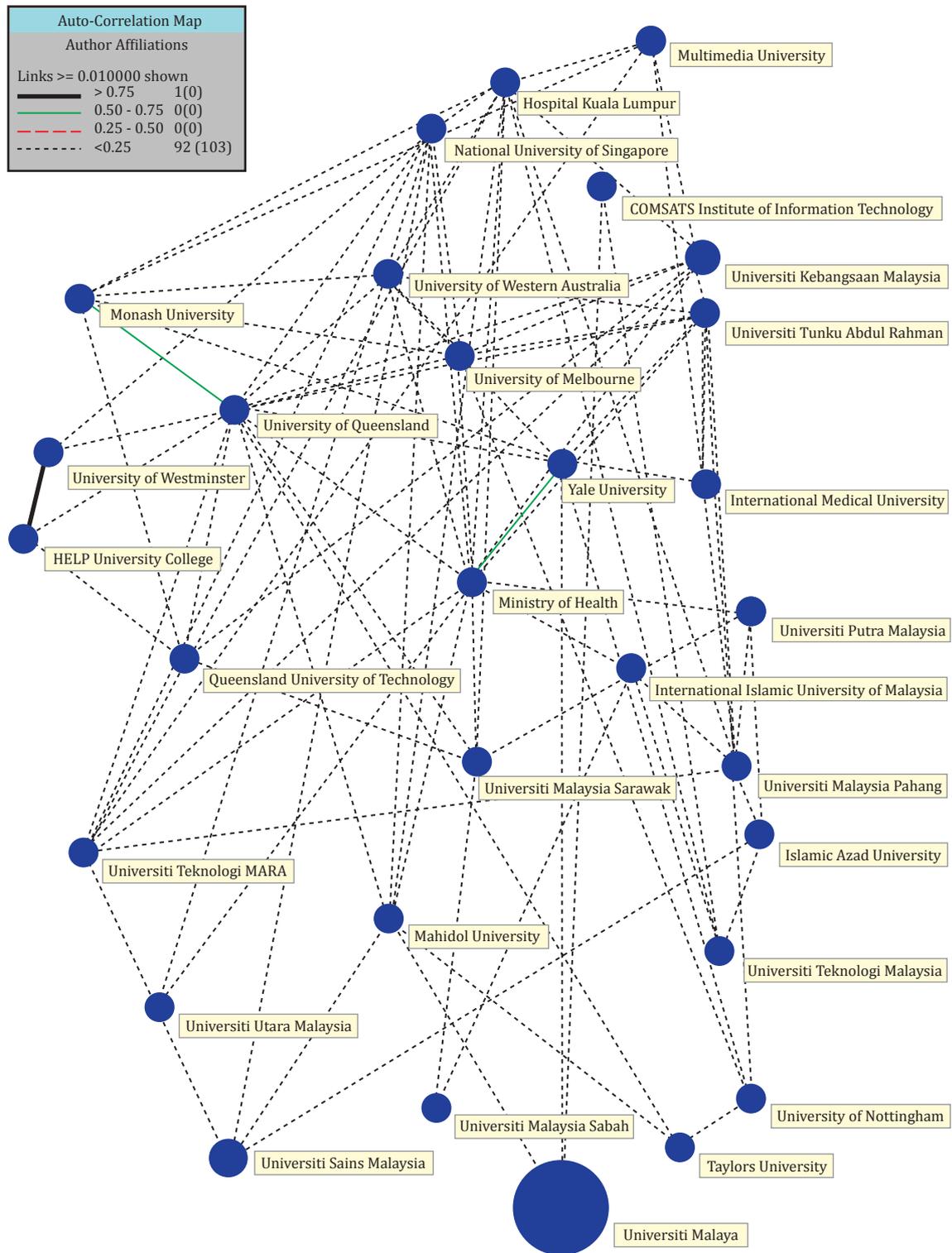
Data coverage : WoS – SSCI, 2012-2014.

Note : Threshold for links is set at 0.01 similarity index. There are 103 hidden links in this map.

4.11 Summary

A total of 394,353 citations were generated for the period of 2001 to 2014. The highest citation count of 46,275 was recorded in 2011, followed by 45,939 and 41,447 citations in 2010 and 2009, respectively. In general, the number of citations shows an increasing trend, in tandem with increasing trend of publications. Nevertheless, citations per article display a decreasing trend over the period under study.

Among 64 collaborating countries, Malaysia has citations per article ratio of 5.37 compared to Iceland with the highest citations per article ratio of 19.48. The field of research garnering the highest citations per article for Malaysian articles is the field of Immunology (10.86), followed by Environment/Ecology (8.72).

The five RUs collectively contributed to 77.27% of all citations produced in Malaysia over the period of 2001 to 2014.
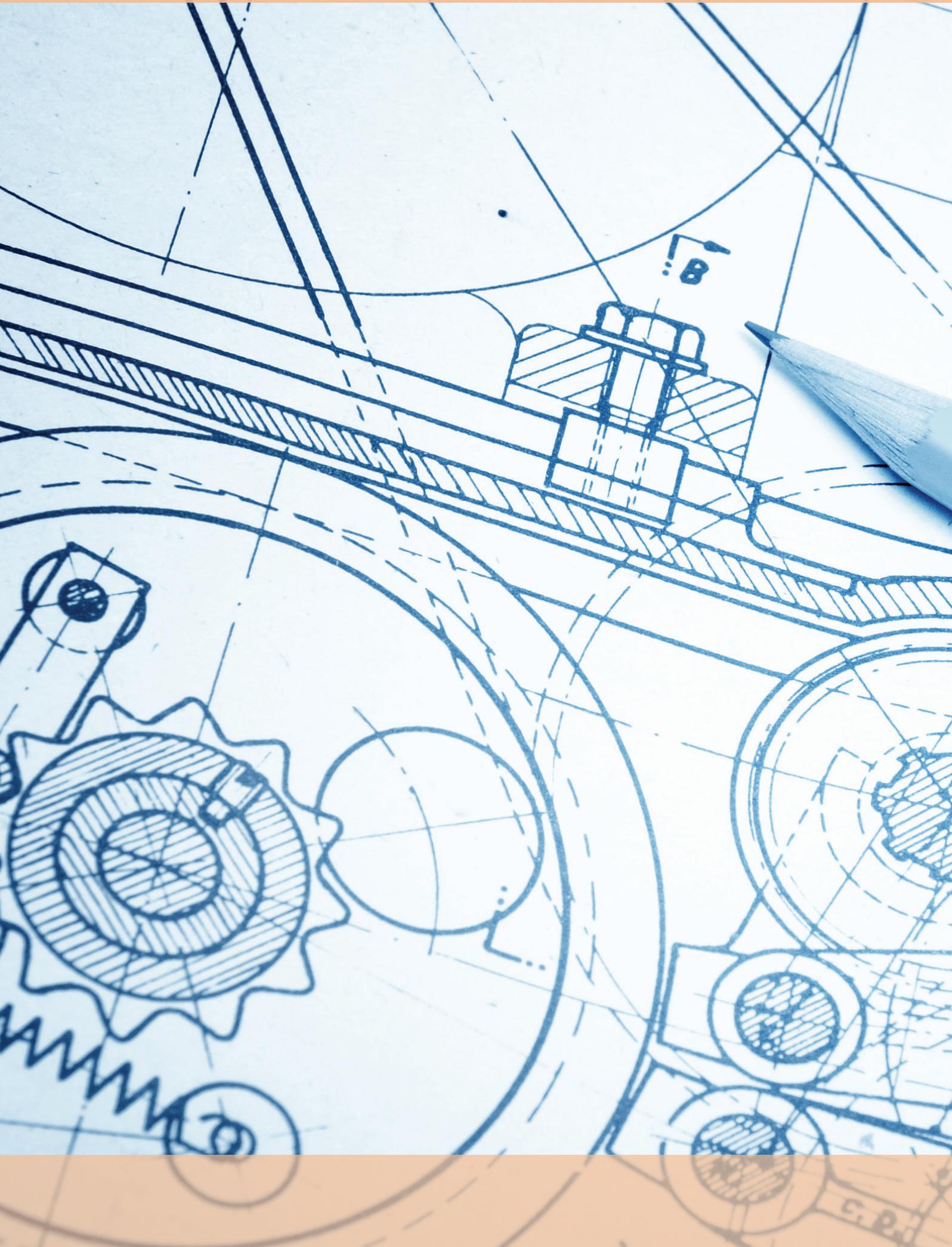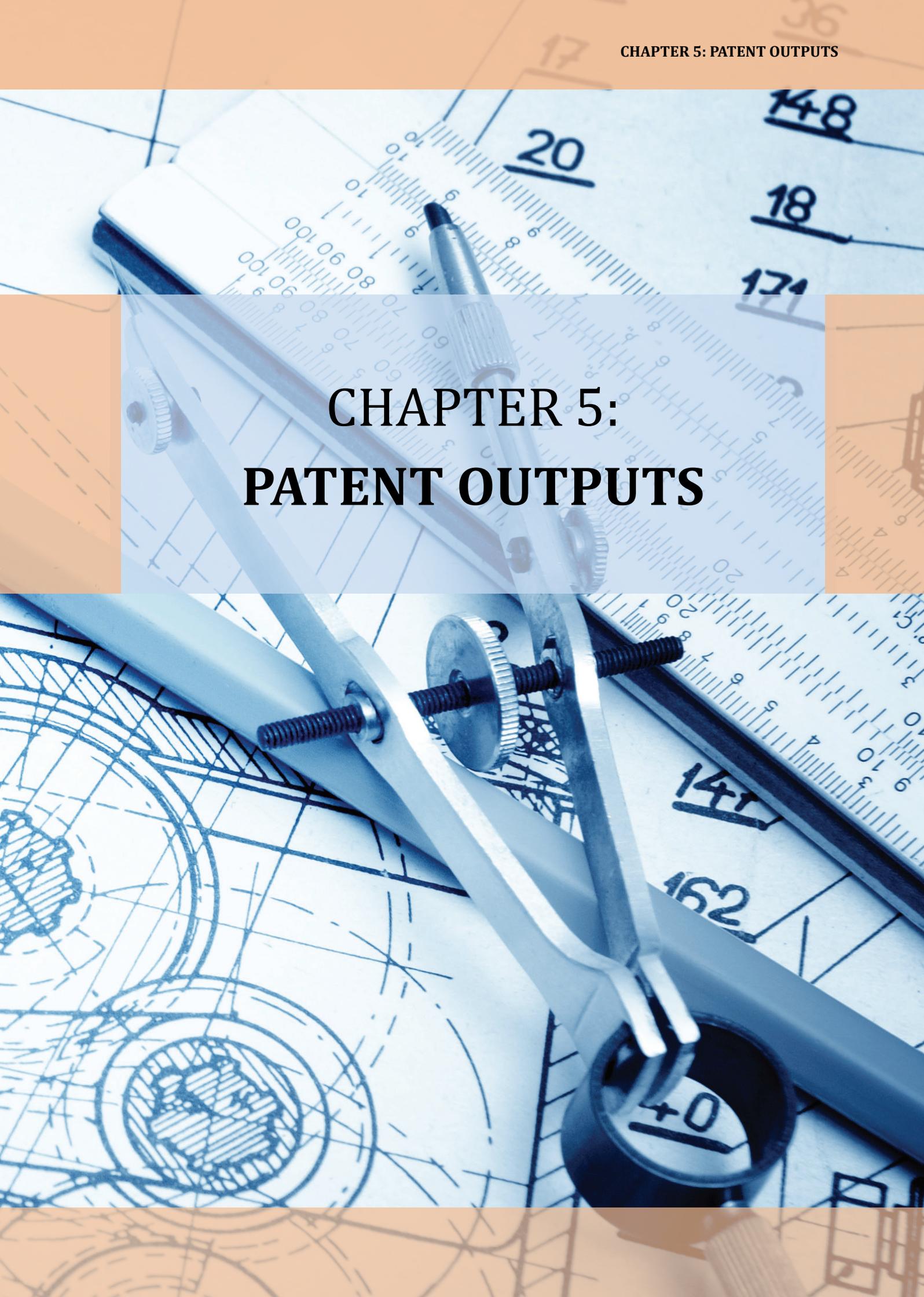
CHAPTER 5:
PATENT OUTPUTS

CHAPTER 5:   PATENT OUTPUTS

5.1   Introduction

This chapter reports the findings on patent outputs for the years 2001 to 2014. Patents considered in this study are retrieved from the PCT and MyIPO databases.

5.2   Malaysia's PCT and MyIPO Patents

For the period of 2001 to 2014, a total of 3,611 patents from Malaysia were filed under the PCT. The field of Computer Technology has the highest number of patents (400 patents) followed by Digital Communication (317). MIMOS Berhad (788) is very productive in terms of patents output, having about 7 times more patents than the second most productive institution, namely Universiti Putra Malaysia (133). Successful collaborations are seen between academic institutions and industry.

MyIPO granted a total of 2,461 patents for Malaysia during the years 2001 to 2014. Based on the data from MyIPO, the fields of Civil Engineering (163 patents) and Chemical Engineering (98) are the leading fields with most patents granted. MIMOS Berhad (184) has the most patents granted, followed closely by Universiti Teknologi Malaysia (181).

The detailed analysis of the patent outputs is presented in the following sections.

5.2.1   Patent Outputs, 2001 to 2014

A total of 3,611 patents from Malaysia were filed under the PCT during the years 2001 to 2014. On the other hand, MyIPO granted 2,461 patents in the same period of time.

5.2.2   Patent Growth, 2001 to 2014

Malaysia's patent outputs filed under the PCT showed a sharp growth (89.1%) from the year 2008 to 2009. However, the patent outputs have not shown much growth since 2010 (Figure 5.1). In terms of number of patent outputs, the year 2008 to 2009 showed an increase of over 212 patents. The highest number of patent outputs is seen in year 2011 with 500 patents. The number of outputs however dropped to 445 patents in the year 2013. Nevertheless, from the MyIPO database (Figure 5.2), there is a general upwards trend in the number of patents granted over the years 2003 (23 patents) to 2014 (378 patents). Appendix H provides PCT and MyIPO patent output during the period of 2001-2014.

Figure 5.1   Yearly Patent Output and Growth Rate: PCT

Data coverage :   PCT, 2001-2014.

Figure 5.2   Yearly Patent Output and Growth Rate: MyIPO

Data coverage :   MyIPO, 2001-2014.

5.2.3   Patent Output According to Malaysia Plans

Figure 5.3 shows the performance of patent outputs according to the 8MP–10MP. According to the PCT database, a total of 241 patents were filed during the 8MP (2001-2005).This number soared to 1,493 patents under the 9MP (2006-2010). It is expected that the number of patents filed will increase under the 10MP (2011-2015), if this trend continues. The number of patents to date for 2010-2014 stands at 1,877 patents. On the other hand, in Figure 5.4, MyIPO database shows that the number of patents granted grew from 88 patents to 1,061 patents under the under the 8MP and 9MP, respectively. The number of patents granted continued to grow to 1,312 patents up to 2014. Appendix I provides data on patent output according to Malaysian Plan during the period of 2001-2014.

Figure 5.3   Patent Output by Malaysia Plans: PCT
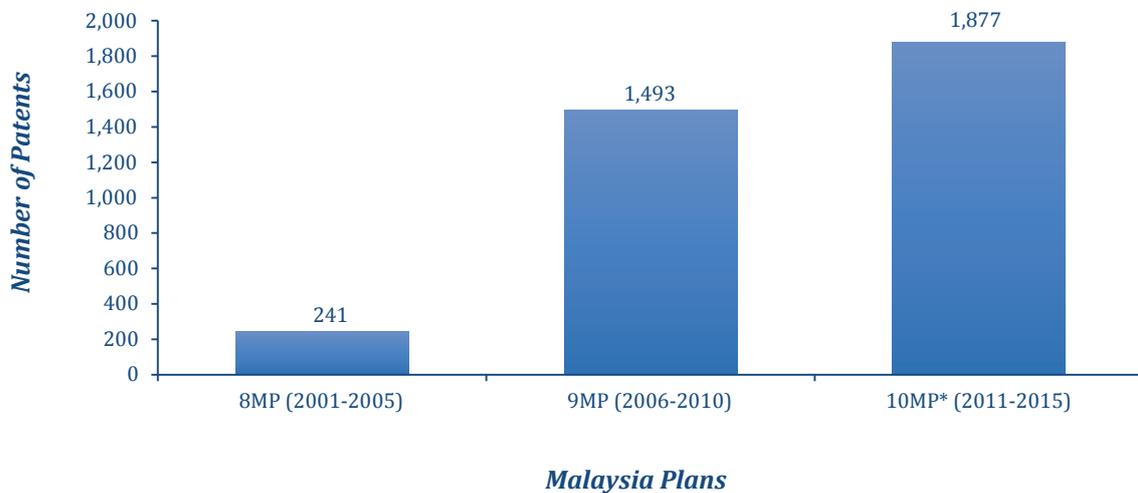
Data coverage : PCT, 2001-2014.

Note   : The scope of the study is from 2001 to 2014, while the 10MP covers the period 2011 to 2015. The recorded numbers are until end of 2014 (excludes 2015).

Figure 5.4   Patent Output by Malaysia Plans: MyIPO
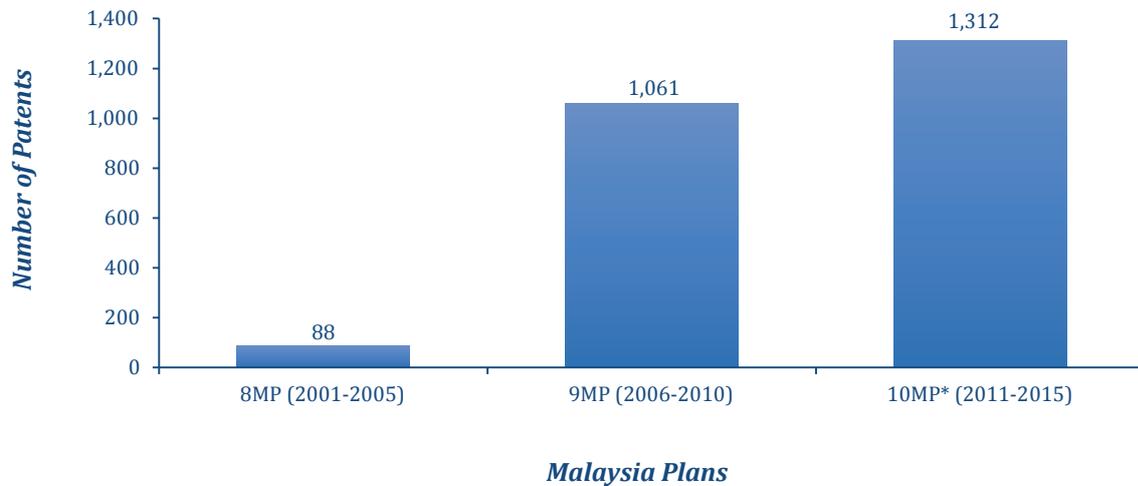
Malaysia Plans

Data coverage : MyIPO, 2001-2014.

Note   : The scope of the study is from 2001 to 2014, while the 10MP covers the period 2011 to 2015. The recorded numbers
                   are until end of 2014 (excludes 2015).

5.2.4   Fields of Research: Areas of Strengths and Weaknesses

Figure 5.5 shows that the field of Computer Technology has the highest number of patents (400 patents) filed, followed by Digital Communication (317), according to the PCT database. The areas of Measurement (217), Semiconductors (216) and Telecommunications (175) are among the top five areas with the highest number of patents filed. On the other hand, the MyIPO database shows that two fields of engineering – namely Civil Engineering (163) and Chemical Engineering (98) – are the leading fields with most patents granted (Figure 5.6). It is also seen in Figure 5.6 that there is a large number of patents granted (772 patents) which did not specify their technology specialisation field.

Figure 5.5   Top 15 Fields of Research of Malaysia by Patent Counts: PCT

IPC Technology Specialisations
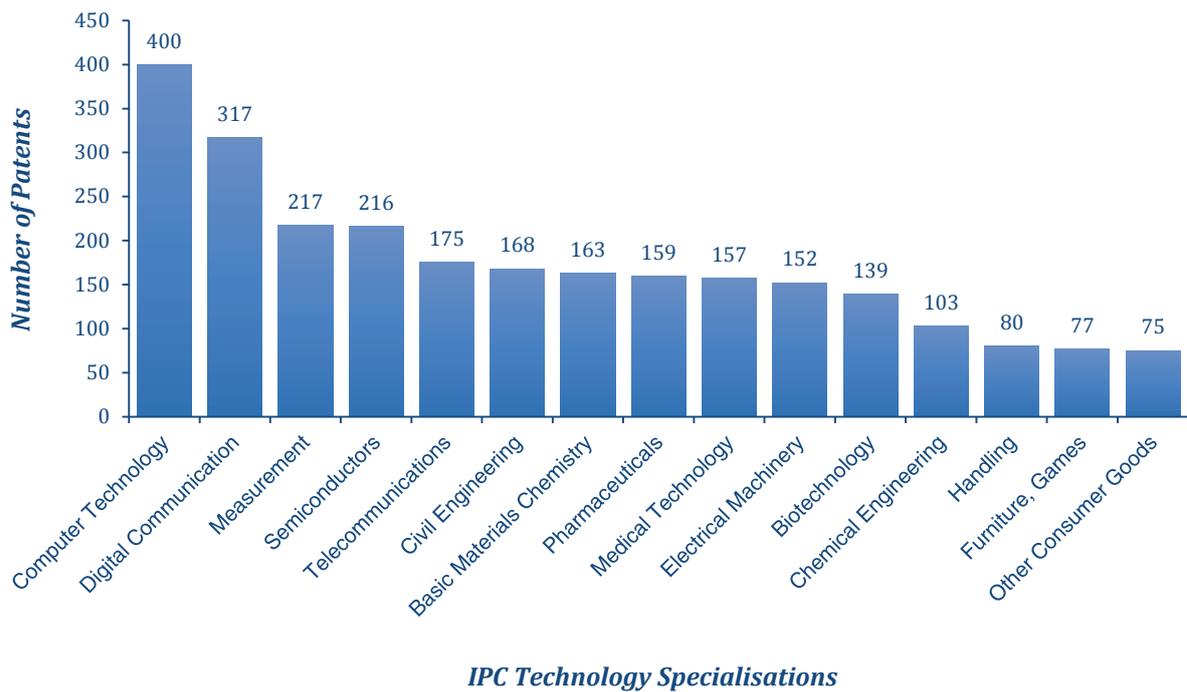
Data coverage : PCT, 2001-2014.

Figure 5.6   Top 15 Fields of Research of Malaysia by Patent Counts: MyIPO

IPC Technology Specialisations
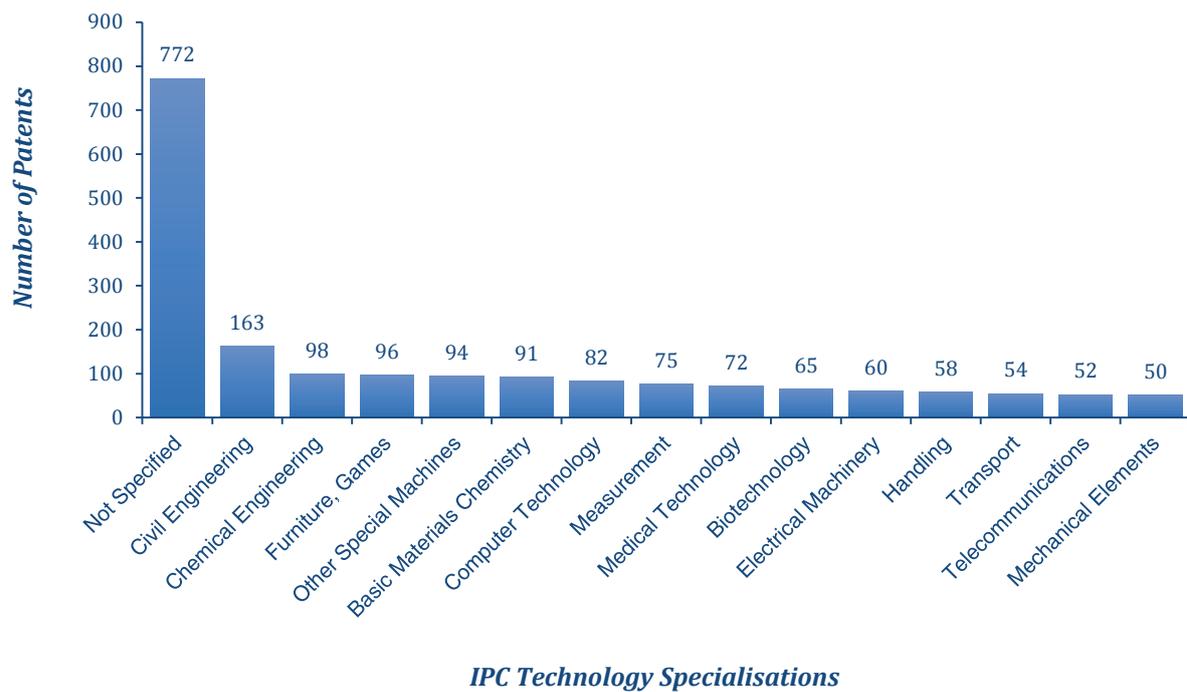
Data coverage : MyIPO, 2001-2014.

5.2.5   Institutions by Number of Patents

It is evident from Figure 5.7 that MIMOS Berhad is by far more active in producing patents compared to other institutions, having filed 788 patents under PCT. Among the academic institutions, Universiti Putra Malaysia produced the most patents (UPM: 133 patents) followed by Universiti Sains Malaysia (USM: 94), right after Intel Corporation (Intel: 117). In terms of patents granted according to the MyIPO database (Figure 5.8), MIMOS Berhad (MIMOS: 185 patents) has the most patents granted followed closely by Universiti Teknologi Malaysia (UTM: 181). Appendix J provides data on the number of PCT patents filed by PRIs during the period of 2001-2014.

Figure 5.7   Top 15 Institutions Ranked by Patent Counts: PCT
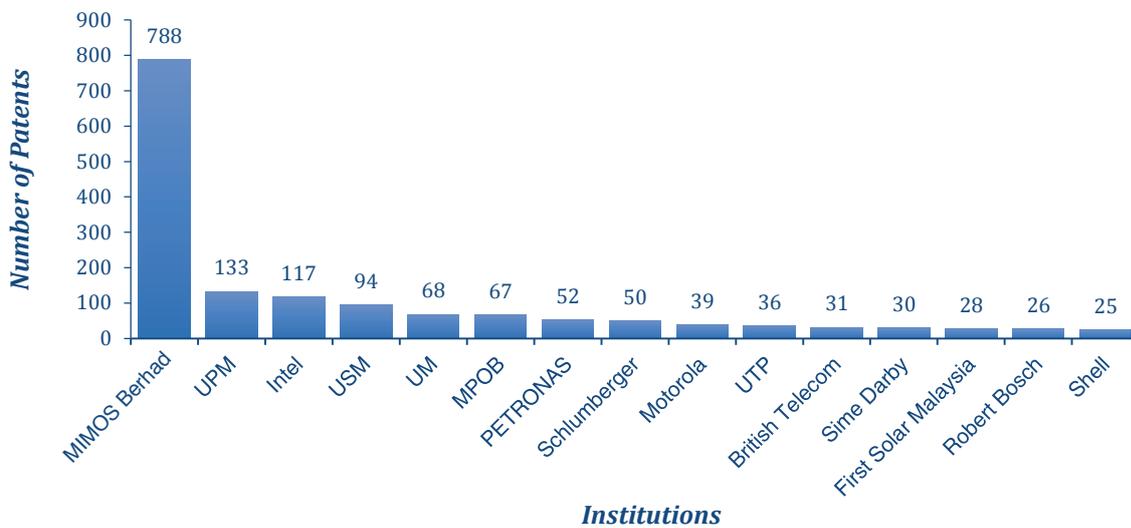
Data coverage :   PCT, 2001-2014.

Figure 5.8   Top 15 Institutions Ranked by Patent Counts: MyIPO
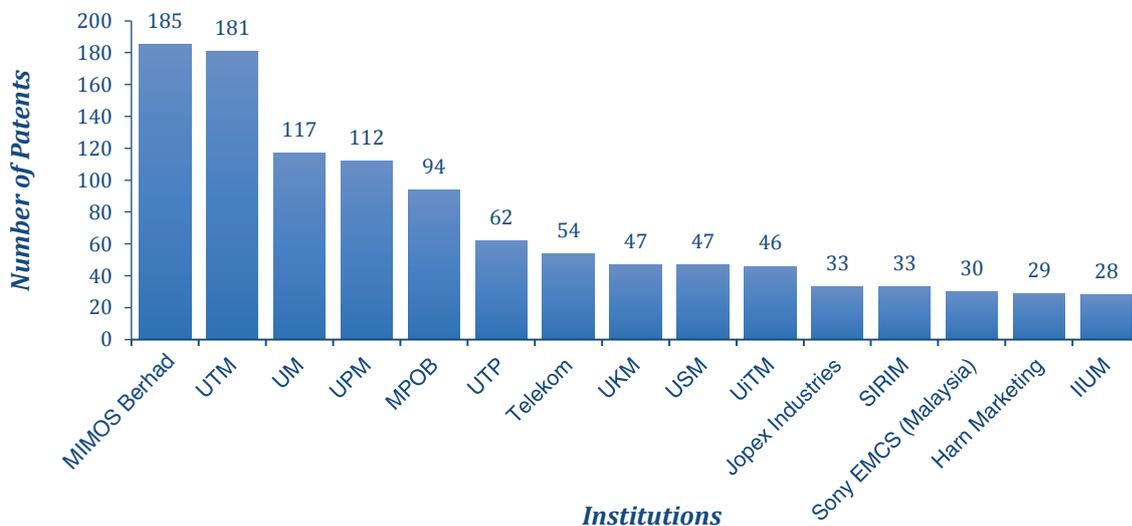
Data coverage :   MyIPO, 2001-2014.

5.2.6 Institutions and Fields of Research

From PCT database, Figure 5.9 shows that most of the patents produced by MIMOS Berhad are in the field of Digital Communication (200 patents), followed by Computer Technology (193), making these two the fields with the highest patents production in Malaysia. Within the institution itself, Intel Corporation has the highest patents production in the area of Computer Technology (Intel: 82). Among the higher learning institutions, Universiti Putra Malaysia and Universiti Sains Malaysia both produced more patents in the field of Biotechnology (UPM: 29; USM: 22). Figure 5.10 shows the corresponding top two fields of patents granted for the top 15 institutions by patents counts according to MyIPO database.

Figure 5.9   Institutions and Top Two Fields with High Patents Output: PCT
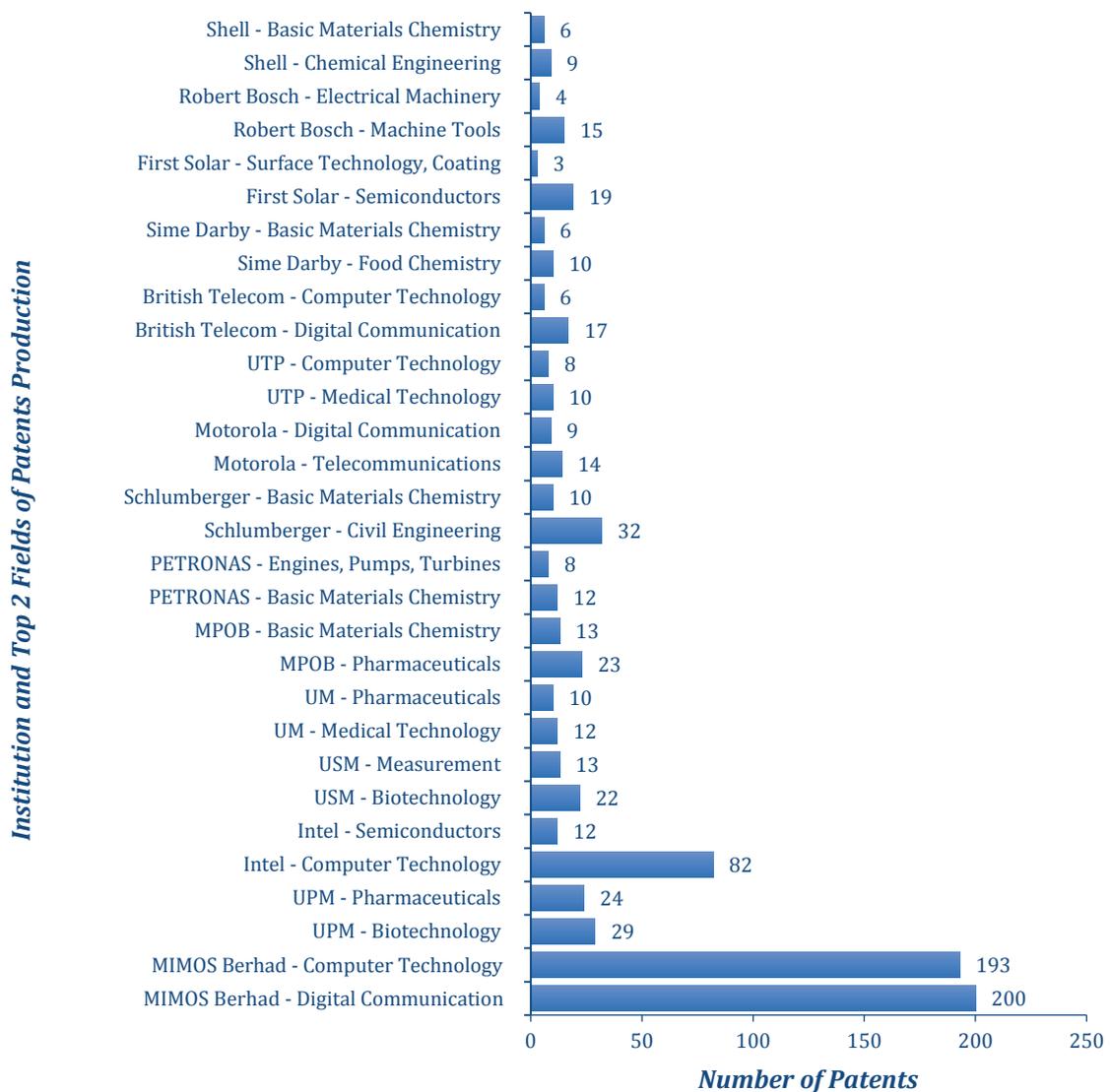
Data coverage : PCT, 2001-2014.

Figure 5.10   Institutions and Top Two Fields with High Patents Output: MyIPO
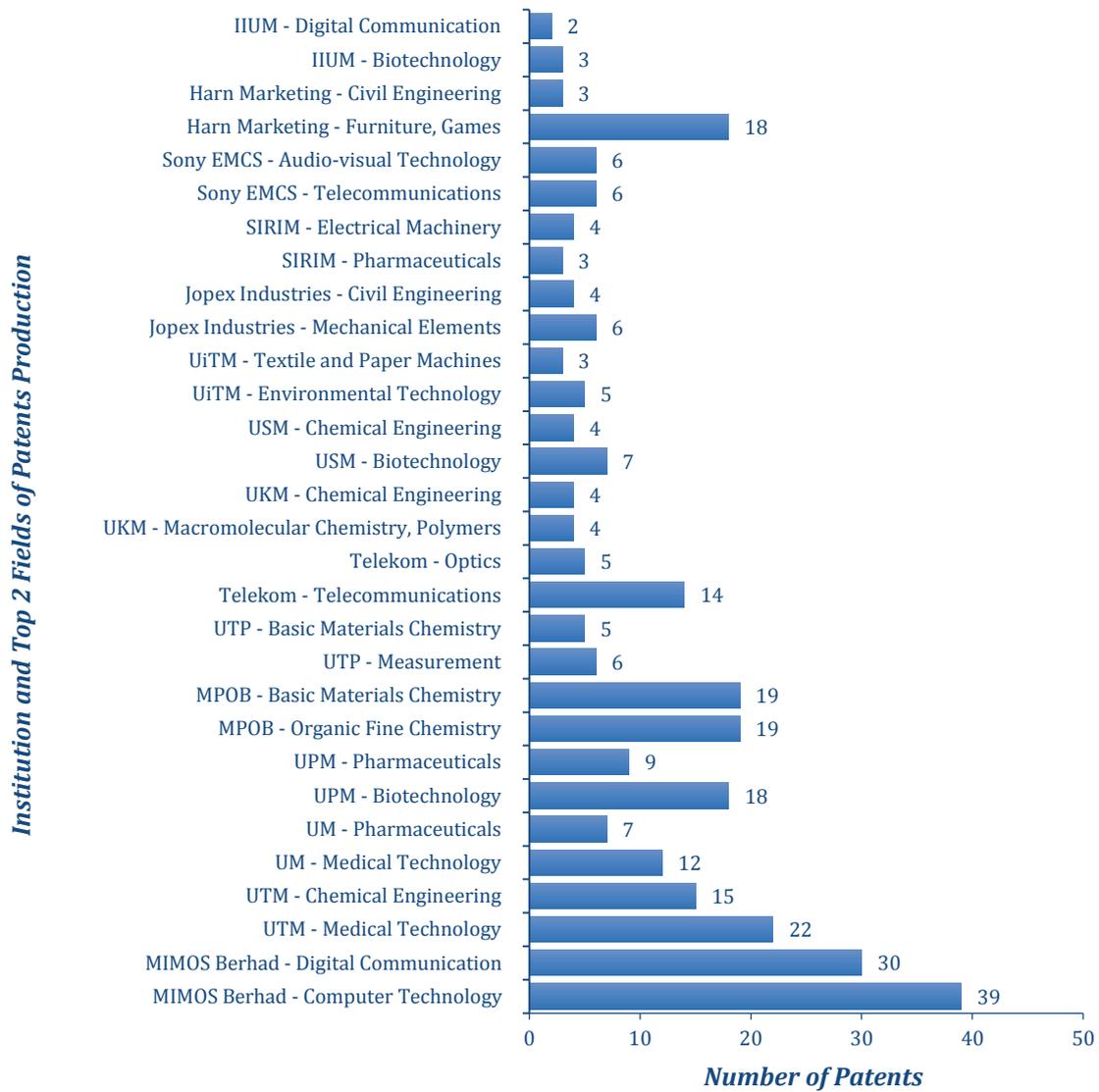
Data coverage :   MyIPO, 2001-2014.

5.2.7 Institutional Collaboration

Successful collaborations are seen to be forged between academic institutions and industries. Collaborations between Universiti Putra Malaysia-Malaysian Palm Oil Board (MPOB) as well as between Universiti Putra Malaysia-MIMOS Berhad has resulted in four patents in each case (Figure 5.11). Also, collaborations between Universiti Kebangsaan Malaysia-Sime Darby, Universiti Malaya-SIRIM Berhad as well as between Universiti Malaya-Jadi Imaging Technologies yielded three patents each. Under MyIPO, the highest number of collaborative patents granted is achieved between SIRIM Berhad-MOSTI (5 patents).

Figure 5.11   Top 12 Collaborating Institutions Ranked by Patent Counts: PCT
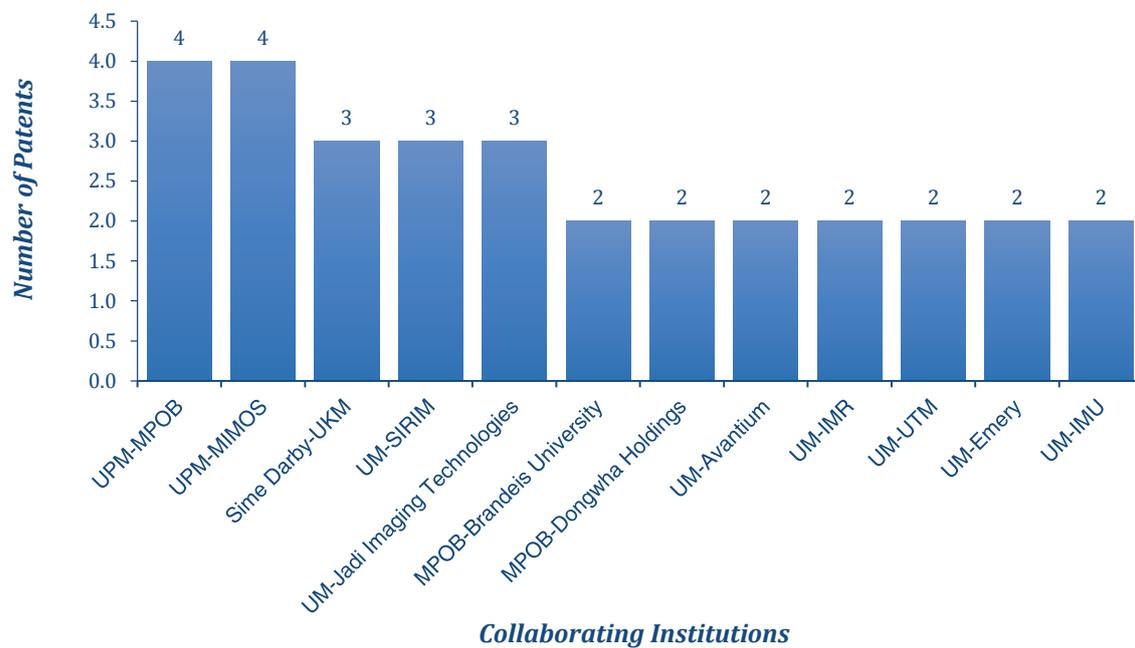
Data coverage : PCT, 2001-2014.

Note   : Data displayed has a cut-off point for collaborating institutions with 2 or more collaborations. A large number of those with one collaboration is not reported in the figure.

Figure 5.12   Top 8 Collaborating Institutions Ranked by Patent Counts: MyIPO
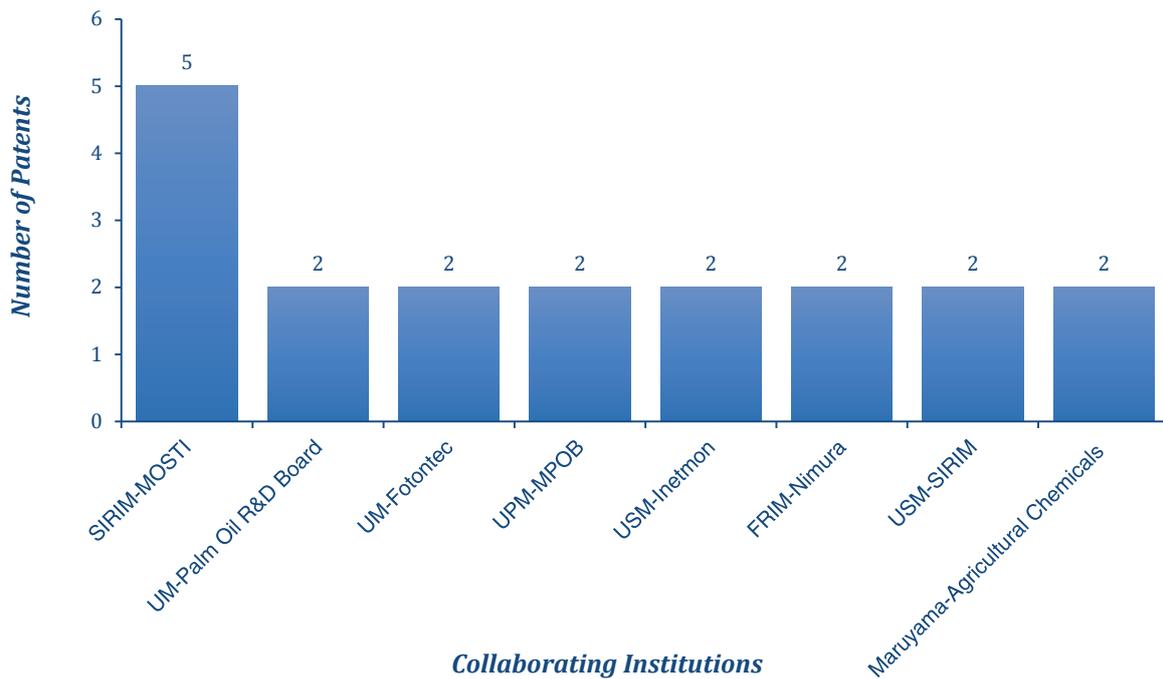
Data coverage : MyIPO, 2001-2014.

Note : Data displayed has a cut-off point for collaborating institutions with 2 or more collaborations. A large number of those with one collaboration is not reported in the figure.

5.2.8   Countries Ranked by Number of Patents

In comparison with selected countries around the world, it is seen from Table 5.1 and Table 5.2 that the number of patents from Malaysia filed or granted is still lacking. Patent granted in MyIPO is dominated by USA and Japan, each with nearly fourfold the patents granted for Malaysia.

Table 5.1   Countries by Number of Patents Filed: PCT

Countries	Total Patents	Countries	Total Patents
USA	1,049,994	Australia	32,861
Germany	446,982	India	28,946
Japan	399,343	Denmark	23,712
France	138,794	Singapore	13,781
UK	134,748	Malaysia	3,611
China	129,401	Thailand	811
South Korea	123,172	Indonesia	501
Netherlands	89,562	Philippines	414
Switzerland	65,335	Vietnam	304
Canada	39,232		

Data coverage : PCT, 2001-2014.

Note   : Total patent counts for 2001 to 2014. The keyword "US" was omitted for searches related to Indonesia (ID), India (IN), Canada (CA) and Germany (DE) due to clashing country codes with US state codes.

Table 5.2   Countries by Number of Patents Granted: MyIPO

Countries	Total Patents	Countries	Total Patents
USA	8,687	Australia	511
Japan	8,111	Singapore	351
Malaysia	2,461	Denmark	120
Germany	2,353	India	119
UK	1,537	Andorra	1
China	590		

Data coverage : MyIPO, 2001-2014.

5.2.9   Individual Inventors Ranked by Number of Patents

Under the PCT, the top two inventors with the most number of patents are Hon Hock Woon and Ahmad Mohd Rais, who filed 31 and 28 patents (Figure 5.13), respectively. Under the MyIPO, Law Harn Yan (24 patents) and Dr. Nazri bin Kamsah (10) are the two most successful individuals in terms of number of patents granted (Figure 5.14).

Figure 5.13   Top 15 Inventors Ranked by Number of Patents: PCT
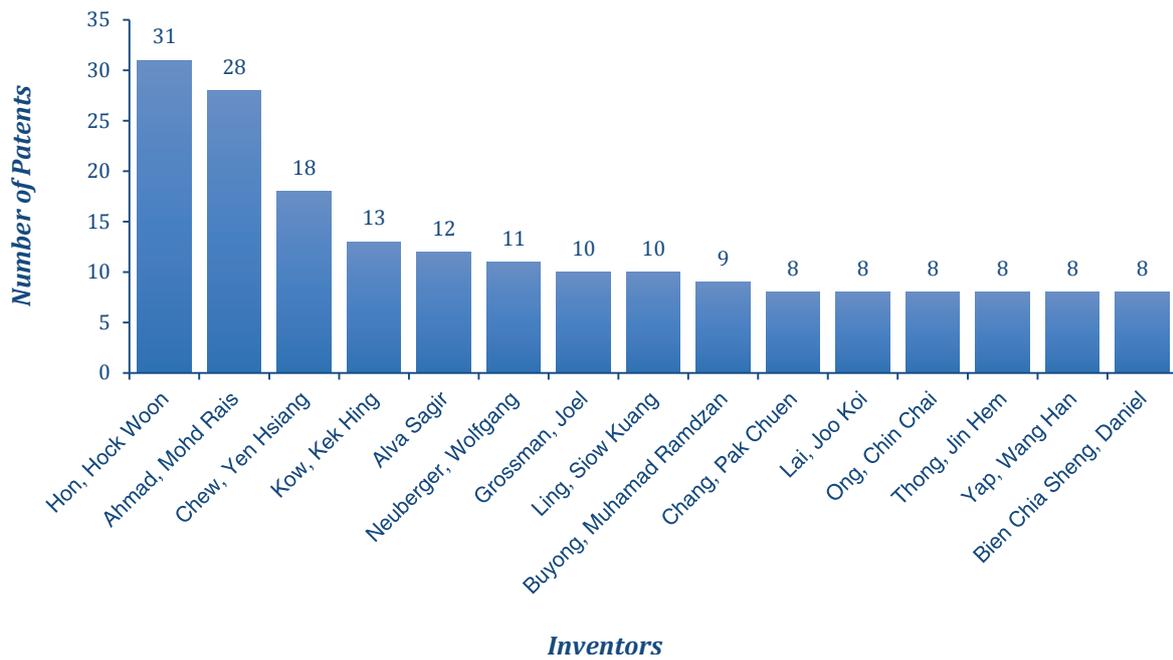
Inventors

Data coverage :   PCT, 2001-2014.

Figure 5.14   Top 15 Inventors Ranked by Number of Patents: MyIPO

Inventors
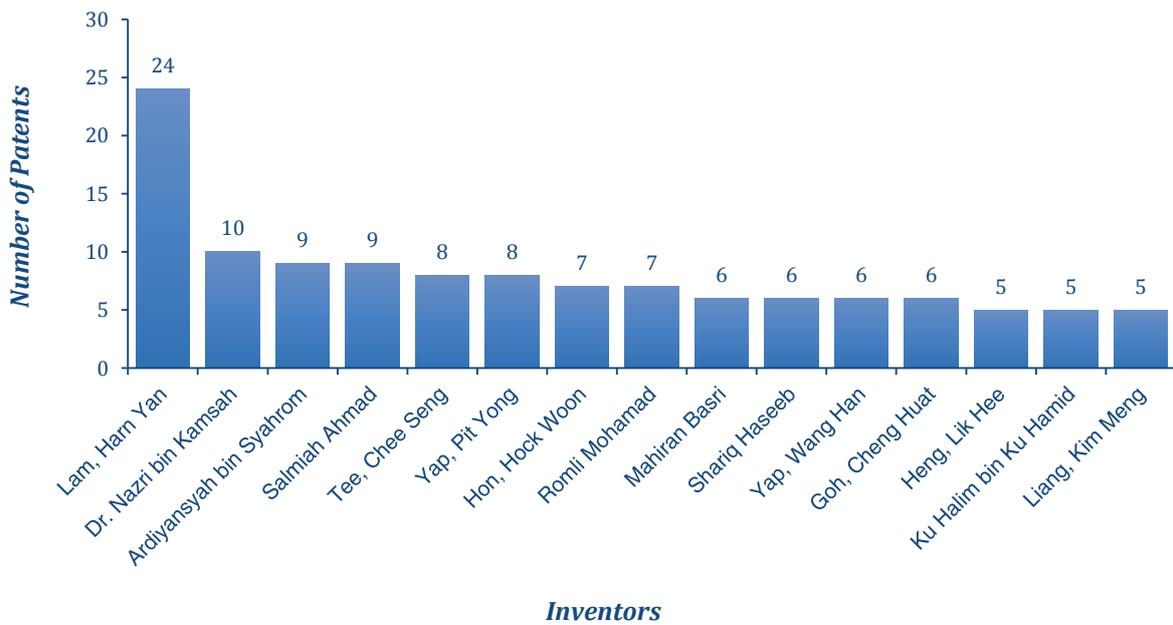
Data coverage :   MyIPO, 2001-2014.

5.3   Relative Specialisation Index (RSI)

Figure 5.15 and Table 5.3 report the relative strength of selected institutions and organisations in technological fields that have attained the level of – or outperformed – the national average. There are fifteen institutions and organisations that have attained RSI value above one for specific technological fields. Many private firms appear to have pursued a diversification strategy that led to specialisation in many fields.

There are two oil and gas multinational companies – Shell and Schlumberger – that exhibited specialisation in Engineering and Basic Materials Chemistry. Schlumberger stands out in Environmental Technology; Materials, Metallurgy; while Shell stands out in Chemical Engineering; Thermal Processes and Apparatus; Surface Technology, Coating; Transport; Mechanical Elements; Other Special Machines and Handling.

There are four Electrical & Electronic and Telecommunication based firms – Intel, Motorola, British Telecom and First Solar – that exhibited strong technology competency in a number of fields. Intel records its relative strength in Computer Technology; Semiconductors and Control. Motorola exhibits strength in Basic Communication Process; Telecommunications; Electrical Machinery; Digital Communication and Control. First Solar stands out in Semiconductors; Surface Technology, Coating; Thermal Processes and Apparatus; and Handling. Robert Bosch – a machine and tools multinational company – performed in Machine Tools; Audio-visual Technology; Electrical Machinery; Basic Communication Processes; Mechanical Elements and Measurement.

There are two locally owned companies that exhibited strength in number of technologies. PETRONAS, on the one hand, performed in Engines, Pumps, Turbines; Organic Fine Chemistry; Mechanical Elements; Basic Materials Chemistry; Chemical Engineering; Materials, Metallurgy; Thermal Processes and Apparatus; Measurement; Transport and Control. Sime Darby, on the other hand, recorded strength in Food Chemistry; Basic Materials Chemistry; Biotechnology; Measurement; Pharmaceuticals; Organic Fine Chemistry and Macromolecular Chemistry, Polymers.

Five institutions from the public sectors – MIMOS Berhad, Universiti Sains Malaysia, Universiti Putra Malaysia, Universiti Malaya and Malaysian Palm Oil Board – and one private university – Universiti Teknologi PETRONAS – had also performed in terms of relative strength in patenting activities. MIMOS Berhad specialised in Digital Communication; Microstructural, Nanotechnology; Computer Technology; Measurement; Basic Communication Processes; Control; Telecommunications and Optics. Universiti Sains Malaysia specialised in Materials, Metallurgy; Biotechnology; Machine Tools; Microstructural, Nanotechnology; Surface Technology, Coating; Pharmaceuticals; Environmental Technology; Textile and Paper Machines; Measurement; Telecommunications and Control . Universiti Putra Malaysia specialised in Biotechnology; Food Chemistry; Pharmaceuticals; Textile and Paper Machines; Other Special Machines; Basic Materials Chemistry; Environmental Technology; IT Methods for Management; Chemical Engineering; Medical Technology and Materials, Metallurgy. Universiti Malaya performed in Microstructural, Nanotechnology; Machine Tools; Optics; Medical Technology; Biotechnology; Pharmaceuticals; Mechanical Elements; Engines, Pumps, Turbines; Materials, Metallurgy and Basic Materials Chemistry. Malaysian Palm Oil Board attained relative strength in Pharmaceuticals; Organic Fine Chemistry; Basic Materials Chemistry; Food Chemistry; Other Special Machines; Biotechnology and Machine Tools. Universiti Teknologi PETRONAS in Medical Technology; Basic Materials Chemistry; Electrical Machinery; Handling; Computer Technology; Mechanical Elements; Other Special Machines; and IT Methods for Management.

Figure 5.15 RSI of Selected Institutions and Private Organisations
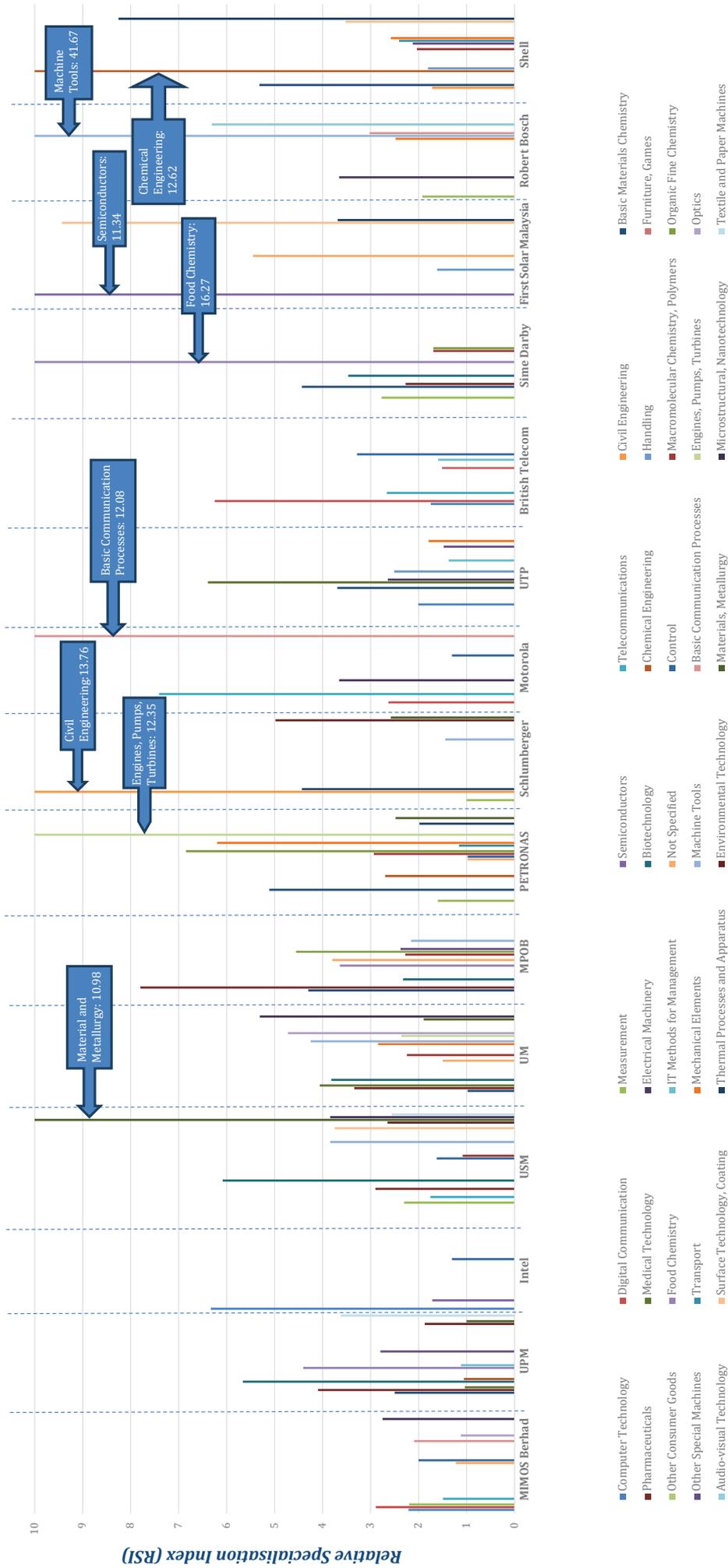
Data coverage : PCT, 2001-2014.

Table 5.3   Performing Fields of Selected Institutions and Private Organisations

Institution/ Organisation	Fields
MIMOS Berhad	Digital Communication (2.89); Microstructural, Nanotechnology (2.75); Computer Technology (2.21); Measurement (2.20); Basic Communication Processes (2.09); Control (2.00); Telecommunications (1.49); Optics (1.12)
UPM	Biotechnology (5.66); Food Chemistry (4.40); Pharmaceuticals (4.10); Textile and Paper Machines (3.62); Other Special Machines (2.79); Basic Materials Chemistry (2.50); Environmental Technology (1.87); IT Methods for Management (1.12); Chemical Engineering (1.05); Medical Technology(1.04); Materials, Metallurgy (1.00)
Intel	Computer Technology (6.33); Semiconductors (1.71); Control (1.30)
USM	Materials, Metallurgy (10.98); Biotechnology (6.08); Machine Tools (3.84); Microstructural, Nanotechnology (3.84); Surface Technology, Coating (3.75); Pharmaceuticals (2.90); Environmental Technology (2.65); Textile and Paper Machines (2.56); Measurement (2.30); Telecommunications (1.76); Control (1.62)
UM	Microstructural, Nanotechnology (5.31); Machine Tools (4.25); Optics (4.72); Medical Technology (4.06); Biotechnology (3.82); Pharmaceuticals (3.34); Mechanical Elements (2.84); Engines, Pumps, Turbines (2.36); Materials, Metallurgy (1.90); Basic Materials Chemistry (1.00)
MPOB	Pharmaceuticals (7.80); Organic Fine Chemistry (4.55); Basic Materials Chemistry (4.30); Food Chemistry (3.64); Other Special Machines (2.38); Biotechnology (2.33); Machine Tools (2.16)
PETRONAS	Engines, Pumps, Turbines (12.35); Organic Fine Chemistry (6.85); Mechanical Elements (6.20); Basic Materials Chemistry (5.11); Chemical Engineering (2.70); Materials, Metallurgy (2.48); Thermal Processes and Apparatus (1.98); Measurement (1.60); Transport (1.16); Control (1.00)
Schlumberger	Civil Engineering (13.76); Environmental Technology (4.98); Basic Materials Chemistry (4.43); Materials, Metallurgy (2.58); Machine Tools (1.44); Measurement (1.00)
Motorola	Basic Communication Processes (12.08); Telecommunications (7.41); Electrical Machinery (3.65); Digital Communication (2.63); Control (1.30)
UTP	Medical Technology(6.39); Basic Materials Chemistry (3.69); Electrical Machinery (2.64); Handling (2.51); Computer Technology (2.01); Mechanical Elements (1.79); Other Special Machines (1.48); IT Methods for Management (1.37)
British Telecom	Digital Communication (6.25); Control (3.30); Telecommunications (2.66); Computer Technology (1.75); IT Methods for Management (1.60); Furniture, Games (1.51)

Institution/ Organisation	Fields
Sime Darby	Food Chemistry (16.27); Basic Materials Chemistry (4.43); Biotechnology (3.46); Measurement (2.77); Pharmaceuticals (2.27); Organic Fine Chemistry (1.70); Macromolecular Chemistry, Polymers (1.70)
First Solar Malaysia	Semiconductors (11.34); Surface Technology, Coating (9.44); Thermal Processes and Apparatus (3.68); Handling (1.61)
Robert Bosch	Machine Tools (41.67); Audio-visual Technology (6.31); Electrical Machinery (3.65); Basic Communication Processes (3.02); Mechanical Elements (2.48); Measurement (1.92)
Shell	Chemical Engineering (12.62); Thermal Processes and Apparatus (8.25); Basic Materials Chemistry (5.32); Surface Technology, Coating (3.52); Transport (2.41); Mechanical Elements (2.58); Other Special Machines (2.12); Handling (1.81); Civil Engineering(1.72)

Data coverage : PCT, 2001-2014 .

Note : Figures in parentheses indicate RSI value. In the event that a subclass has been classified under multiple technology specialisations, the subclass were sorted in the dominant field for the purposes of this study. British Telecommunications showed specialisation in Furniture, Games due to a network-enabled toy that relates to gaming platform.

5.4 Summary

For the period of 2001 to 2014, a total of 3,611 patents from Malaysia were filed under the PCT. The fields of Computer Technology (400 patents) and Digital Communication (317) have the highest number of patents filed. MIMOS Berhad (788) filed the most number of patents under PCT, followed by Universiti Putra Malaysia (133). Successful collaborations are seen between academic institutions with industries.

On the other hand, MyIPO granted a total of 2,461 patents for Malaysia during the years 2001 to 2014, with the fields of Civil Engineering (163 patents) and Chemical Engineering (98) leading with most patents granted. MIMOS Berhad (185 patents) has the most patents granted, followed closely by Universiti Teknologi Malaysia (181).

From the Relative Specialisation Index (RSI), many private firms – including Shell, PETRONAS and Schlumberger – appear to specialise in a portfolio of fields. Most institutions from public sectors – such as MIMOS Berhad, UPM, USM, UM and MPOB – attained relative strength in many technological fields. UTP stands out as a performing private institution in patenting activities.

Data from both databases of PCT and MyIPO show that there are a number of successful collaborations between academic institutions and industries. While we are ahead of neighbouring countries such as Thailand, Indonesia, Philippines, and Vietnam; we are still significantly behind Singapore.

CHAPTER 6:
PATENT CITATIONS

CHAPTER 6:   PATENT CITATIONS

6.1   Introduction

This chapter reports the patent citations recorded by Malaysia from 2001 until 2014. Patent citations can be used as a measure of the quality of the patents applied in the respective patent office, namely PCT. It also indicates the impact of the particular patents. Although patent citations may show the relative impact of the patent, it also has some limitations – therefore, the analysis should be interpreted with caution. Time lag in recording the patent citations should also be considered.

6.2   Patent Citations in PCT: Summary of Findings

During 2001-2014, Malaysia recorded a total of 3,611 patents in WIPO, PCT. These patents recorded 2,335 citations in total over the period of 2001-2014. Annually, on average Malaysia recorded 256 patents, 167 citations and 0.65 citations per patent.

Figure 6.1 indicates that the highest citation count of 401 was recorded in 2008, followed by 385 and 373 citations in 2009 and 2010, respectively. In general, the number of citations shows an increasing trend from 2001 to 2008, after which the trend slowed down from 2009 to 2014. Citations per patent – measured as ratio of citation counts to the total number of patents produced – displays a decreasing trend starting from 2009. The increasing trend for number of citations for 2010 to 2014 is yet to be observed due to time lag.

Figure 6.1   Yearly Patents and Citations Counts with Citations per Patent
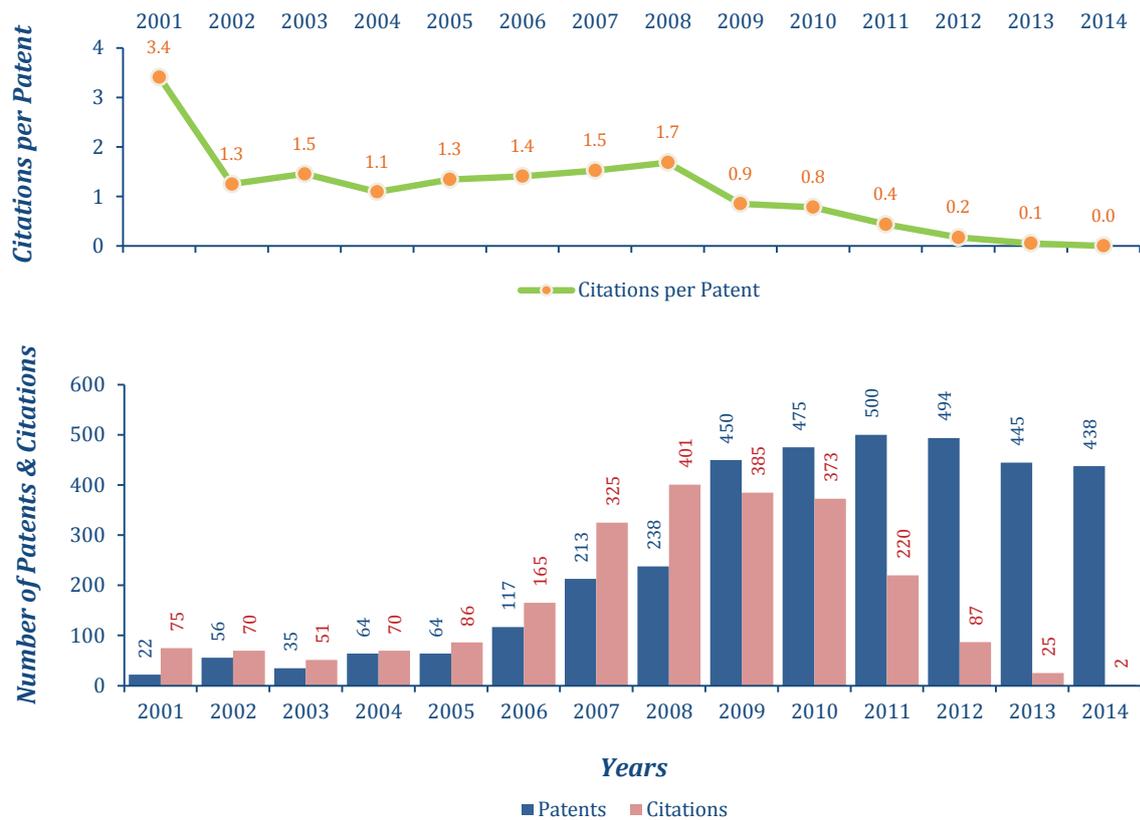
Data coverage : PCT, 2001-2014.

6.3   Malaysia's Citations Based on Joint Assignees, 2001 to 2014

Table 6.1 shows the patent citations for patents that have at least one co-patentee who is Malaysian (whether as the 1st assignee or otherwise). A total of 1,377 citations were recorded where a Malaysian is the 1st assignee. For patents where Malaysians worked with other countries and the other country's co-patentee is the 1st assignee, USA recorded 221 citations, followed by Germany (139), Singapore (167), and the UK (105). Patent 1st assignees with at least one Malaysian assignee from Canada, Australia, France, China, Japan, Switzerland, India, Denmark, and South Korea recorded less than 100 citations each. Nevertheless, patents with 1st assignees from the Netherlands, UK and Denmark recorded the highest citations per patent.

Table 6.1   Malaysia's Citations Based on Joint Assignees

1st Assignee Address	Patents	Citations	Citations/ Patent
Malaysia	2,594	1,377	0.53
USA	422	221	0.52
Germany	137	139	1.01
Singapore	111	167	1.50
UK	64	105	1.64
Netherlands	55	99	1.80
Canada	32	41	1.28
Australia	31	43	1.39
France	29	14	0.48
China	19	28	1.47
Japan	19	18	0.95
Switzerland	12	7	0.58
India	10	4	0.40
Denmark	8	32	4.00
South Korea	8	6	0.75

Data coverage : PCT, 2001-2014.

Note   : Patents with at least one Malaysian assignee. The Malaysian assignee can be the first assignee or otherwise.

6.4   Patent Citations by Fields of Research

Table 6.2 shows the patent citations by fields of research. In terms of total patent citations by field of research, Basic Materials Chemistry (208) emerged as the dominant field with the highest patent citations. Fields of research that have citations in the range of 100 to 200 include Computer Technology (172), Telecommunications (141), Measurement (140), Pharmaceuticals (138), Semiconductors (125), Other Consumer Groups (125), Civil Engineering (123), Digital Communications (114) and Medical Technology (106). Nevertheless, citations per patent were highest for the field of Other Consumer Goods (1.67), Basic Materials Chemistry (1.28) and Food Chemistry (1.07).

Table 6.2   Number of Citations by Field of Research

No.	Field of Research	Patents	Citations	Citations/ Patent
1	Basic Materials Chemistry	163	208	1.28
2	Computer Technology	400	172	0.43
3	Telecommunications	175	141	0.81
4	Measurement	217	140	0.65

No.	Field of Research	Patents	Citations	Citations/ Patent
5	Pharmaceuticals	159	138	0.87
6	Other Consumer Goods	75	125	1.67
7	Semiconductors	216	125	0.58
8	Civil Engineering	168	123	0.73
9	Digital Communication	317	114	0.36
10	Medical Technology	157	106	0.68
11	Electrical Machinery	152	84	0.55
12	Food Chemistry	74	79	1.07
13	Furniture, Games	77	73	0.95
14	Handling	80	70	0.88
15	Macromolecular Chemistry, Polymers	71	69	0.97
16	Organic Fine Chemistry	71	66	0.93
17	Chemical Engineering	103	63	0.61
18	Other Special Machines	68	49	0.72
19	Biotechnology	139	47	0.34
20	Engines, Pumps, Turbines	45	45	1.00
21	Control	71	42	0.59
22	Machine Tools	50	36	0.72
23	IT Methods for Management	73	33	0.45
24	Thermal Processes and Apparatus	35	30	0.86
25	Transport	60	30	0.50
26	Optics	45	25	0.56
27	Audio-Visual Technology	44	21	0.48
28	Mechanical Elements	56	20	0.36
29	Surface Technology, Coating	41	17	0.41
30	Others-Unclassified	71	17	0.24
31	Materials, Metallurgy	28	13	0.46
32	Environmental Technology	29	5	0.17
33	Textile and Paper Machines	15	4	0.27
34	Basic Communication Processes	46	3	0.07
35	Microstructural, Nanotechnology	20	2	0.10

Data coverage : PCT, 2001-2014.

Note : Patents with at least one Malaysian assignee.

6.5   Institutions Ranked by Citations and Citations per Patent

Table 6.3 shows the patent citations and citations per patent. MIMOS Berhad appears to have the most patents (788) and citations (211), respectively. Nevertheless, citations per patent are low at 0.27 citations per patent. Private firms have the highest citations per patent, namely British Telecommunications (1.58), Schlumberger Limited (1.08) and PETRONAS (1.06). Other institutions and organisations have citations per patent that is lower than 1.

Table 6.3   Patents, Citations and Citations per Patent by Institutions

Institution/Organisations	Patents	Citations	Citations/ Patent
MIMOS Berhad	788	211	0.27
PETRONAS	52	55	1.06
Schlumberger	50	54	1.08
UPM	133	53	0.40
British Telecom	31	49	1.58
MPOB	67	28	0.42
UM	68	26	0.38
Shell	25	24	0.96
Robert Bosch	26	20	0.77
UTP	36	18	0.50
Intel	117	14	0.12
Sime Darby	30	10	0.33
Motorola	39	9	0.23
USM	94	8	0.09
First Solar Malaysia Sdn Bhd	28	0	0.00

Data coverage : PCT, 2001-2014.

Note   : Patents with at least one Malaysian assignee.

6.6   Institutional Ranking According to Patent h-Index

Table 6.4 shows Malaysian institutions ranked by h-index. Patent h-index shows the cumulative impacts of the patents. MIMOS Berhad tops the list with an h-index of 5, followed by Universiti Putra Malaysia and PETRONAS with 4 each. Universiti Malaya, Malaysian Palm Oil Board and Universiti Teknologi PETRONAS have equal h-index of 3 each, followed by Sime Darby, Universiti Kebangsaan Malaysia and Telekom Malaysia of 2 each. Universiti Sains Malaysia, MIT Innovation and Standards and Industrial Research Institute of Malaysia (SIRIM) have an h-index of 1 each.

Table 6.4   Malaysian Institutions Ranked by h-Index

Institutions	h-Index
MIMOS Berhad	5
UPM	4
PETRONAS	4
UM	3
MPOB	3
UTP	3
Sime Darby	2
UKM	2
Telekom Malaysia	2
USM	1
MIT Innovation Sdn Bhd	1
SIRIM Berhad	1
First Solar Malaysia	0
Lembaga Getah Malaysia	0
Quantum Electro Opto Systems Sdn Bhd	0

Data coverage : PCT, 2001-2014.

Note   : Patents with at least one Malaysian assignee.

Table 6.5 depicts the h-index of the international collaborators. Schlumberger tops the list with a score of 5 for h-index, followed by British Telecommunications (4), CeramOptec (3) and BASF (3). A few of the firms based in Penang namely Intel, Motorola and Robert Bosch have attained h-index of 2.

Table 6.5   International Collaborators Ranked by h-Index

International Collaborators	h-Index
Schlumberger	5
British Telecom	4
CeramOptec Inc	3
BASF	3
Intel	2
Motorola	2
Robert Bosch	2
Shell	2
X-Fab Semiconductor Foundries	2
Ansell Healthcare Products	2
Freescale Semiconductor	2

Table continued on next page

International Collaborators	h-Index
Infineon Technologies	1
Laird Technologies	1
PINTAS Pte Ltd	1
Altera	1

Data coverage : PCT, 2001-2014.

Note : Patents with at least one Malaysian assignee.

6.7   Inventors Ranked by Number of Citations

Inventions by Lam Harn Lian and Lam Harn Yan accumulated the most number of citations (Figure 6.2, 26 citations). The other top 15 inventors have accumulated less than 20 citations each, with Choong Khong Neng coming second at 17 citations, and Rogers, Holbrey and Rodriguez coming third with 16 citations, while the lowest number is seven citations. Patent citations at the individual level remained low, with the highest being only 26 citations.

Figure 6.2   Top 15 Inventors Ranked by Number of Citations: PCT
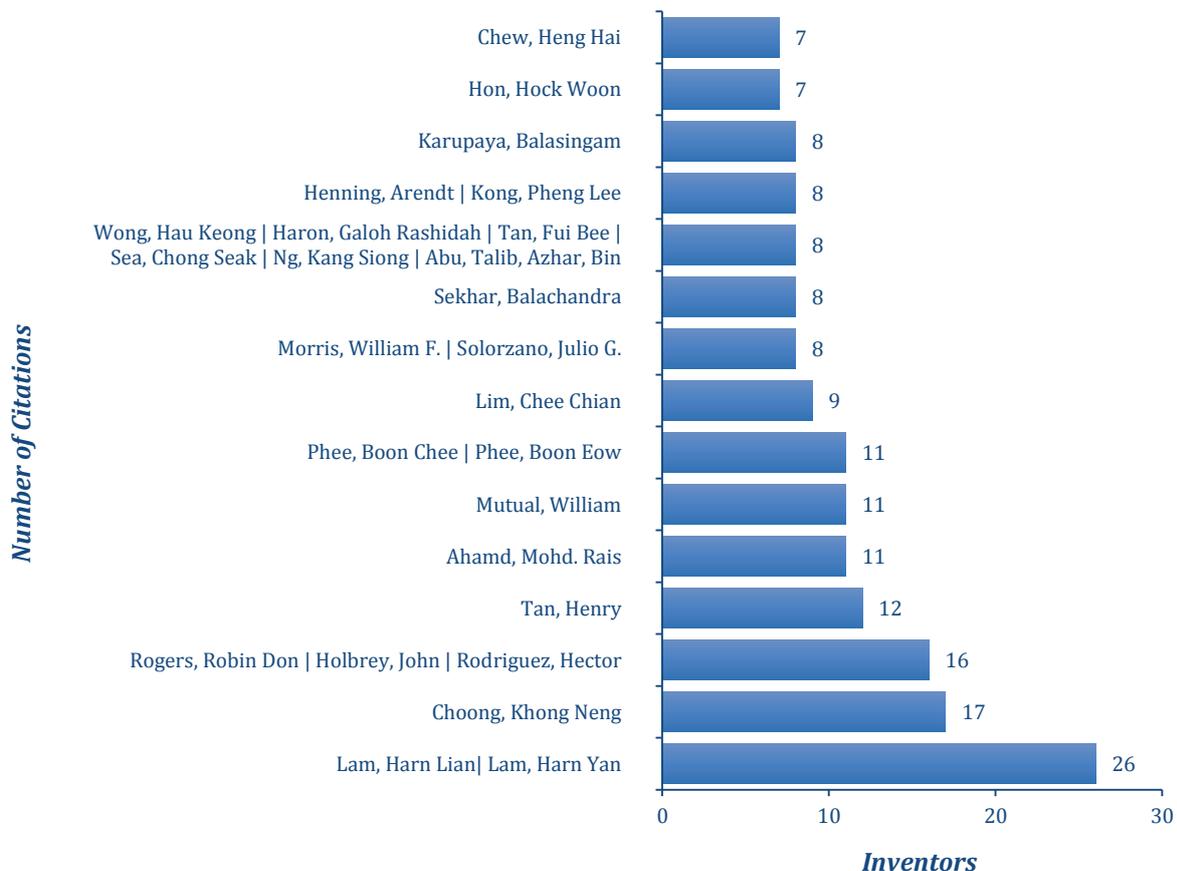
Data coverage : PCT, 2001-2014.

Note : The top 15 inventors in citation counts are sorted based on the data extraction of the first top 100 inventors by patent counts.

6.8   Relative Impact Index (RII)

Figure 6.3 reveals the institutions and private organisations that have generated impactful PCT patents, which are reflected by RII values. It shows the organisations and firms that have attained the level of – or outperformed – the national average. MIMOS Berhad, UPM and UM emerged to have attained impactful patents in many fields. MIMOS Berhad gained in Digital Communication; Computer Technology; Basic Communication Processes; Microstructural, Nanotechnology and Other Consumer Goods. UPM stands out in Organic Fine Chemistry; Engines, Pumps, Turbines; Medical Technology; Transport; Basic Materials Chemistry; Materials, Metallurgy; Mechanical Elements; Other Consumer Goods and Pharmaceuticals. UM is strong in Semiconductors; Optics; Medical Technology; Pharmaceuticals; Biotechnology and Food Chemistry.

USM achieved in Materials, Metallurgy and Machine Tools. UKM scored in Medical Technology; Materials, Metallurgy and Pharmaceuticals. Meanwhile, MPOB attained impactful patents in Organic Fine Chemistry; Basic Materials Chemistry and Pharmaceuticals. SIRIM Berhad has one impactful field in its patents, which is Pharmaceuticals.

UTP – a private university – gained in Computer Technology; Basic Materials Chemistry; Mechanical Elements and Handling. This probably can be attributed to the linkages established between the firms, PETRONAS and other oil and gas companies.

Sime Darby, Telekom Malaysia, PETRONAS and MIT Innovation emerged as the few private organisations to have built impactful patents. While Sime Darby gained in Basic Materials Chemistry and Food Chemistry, Telekom Malaysia focused on Telecommunications and Optics, and MIT Innovation achieved in Other Consumer Goods. PETRONAS stands out as the most competent company in terms of producing impactful patents. It gained in Control; Engines, Pumps, Turbines; Transport; Basic Materials Chemistry; Materials, Metallurgy and Handling.

6.9   Patenting Network

Figure 6.4 shows the co-patenting network structure for PCT patenting activities. The network is mapped based on co-patenting between the 30 most productive assignees from 2012 to 2014 using VantagePoint visualisation tool. The co-assignee information is used to map the network. The size of the bubble indicates the productivity level of patenting activities. Relatively, MIMOS Berhad is the most productive organisation. Other organisations – both public and private – appear to have gained similar productivity levels in term of PCT patenting. Interestingly, it seems that there are virtually no linkages in terms of co-patenting activities in Malaysia. Most patents are assigned to individual organisations.

Figure 6.3   RII of Selected Institutions and Private Organisations
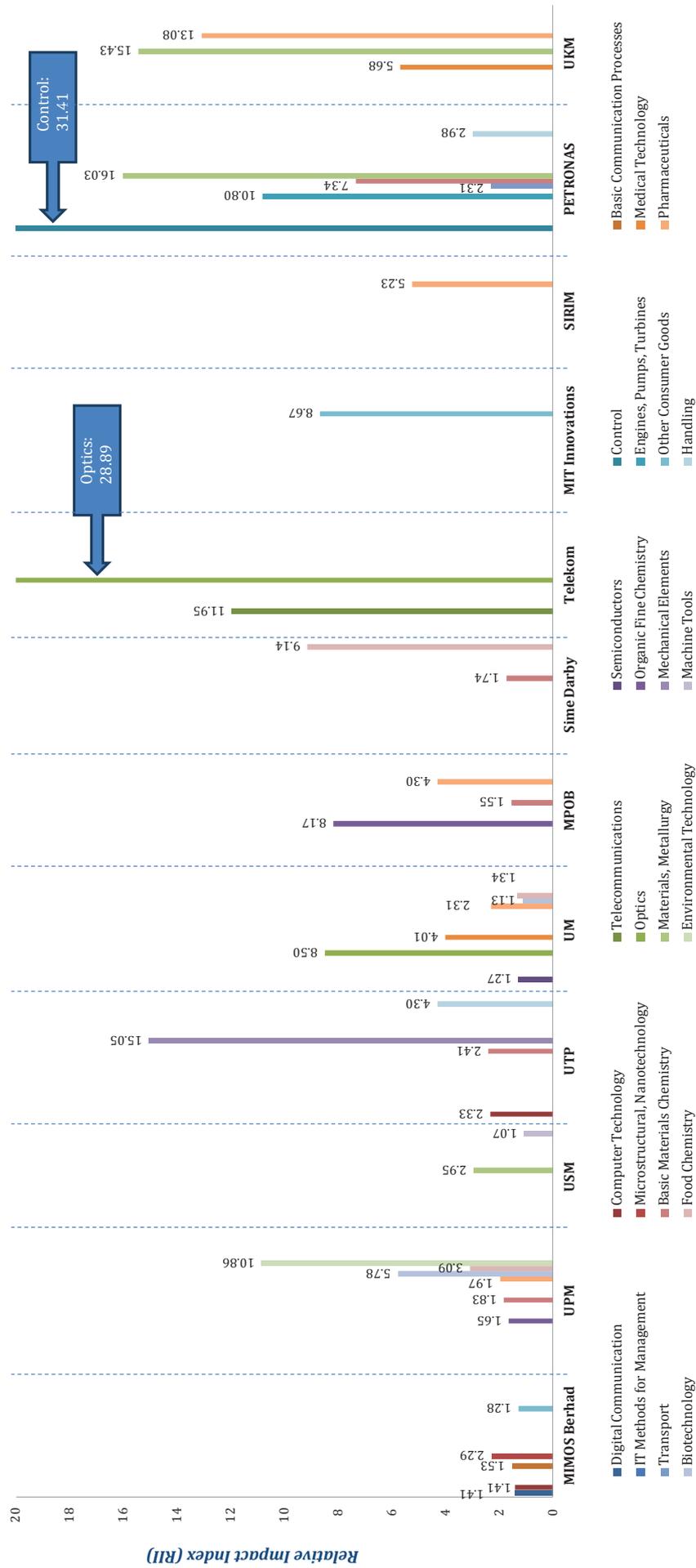
Data coverage : PCT, 2001-2014.

Note   : Patents with at least one Malaysian assignee.

Figure 6.4 Malaysia's Co-Patenting Network, 2012–2014
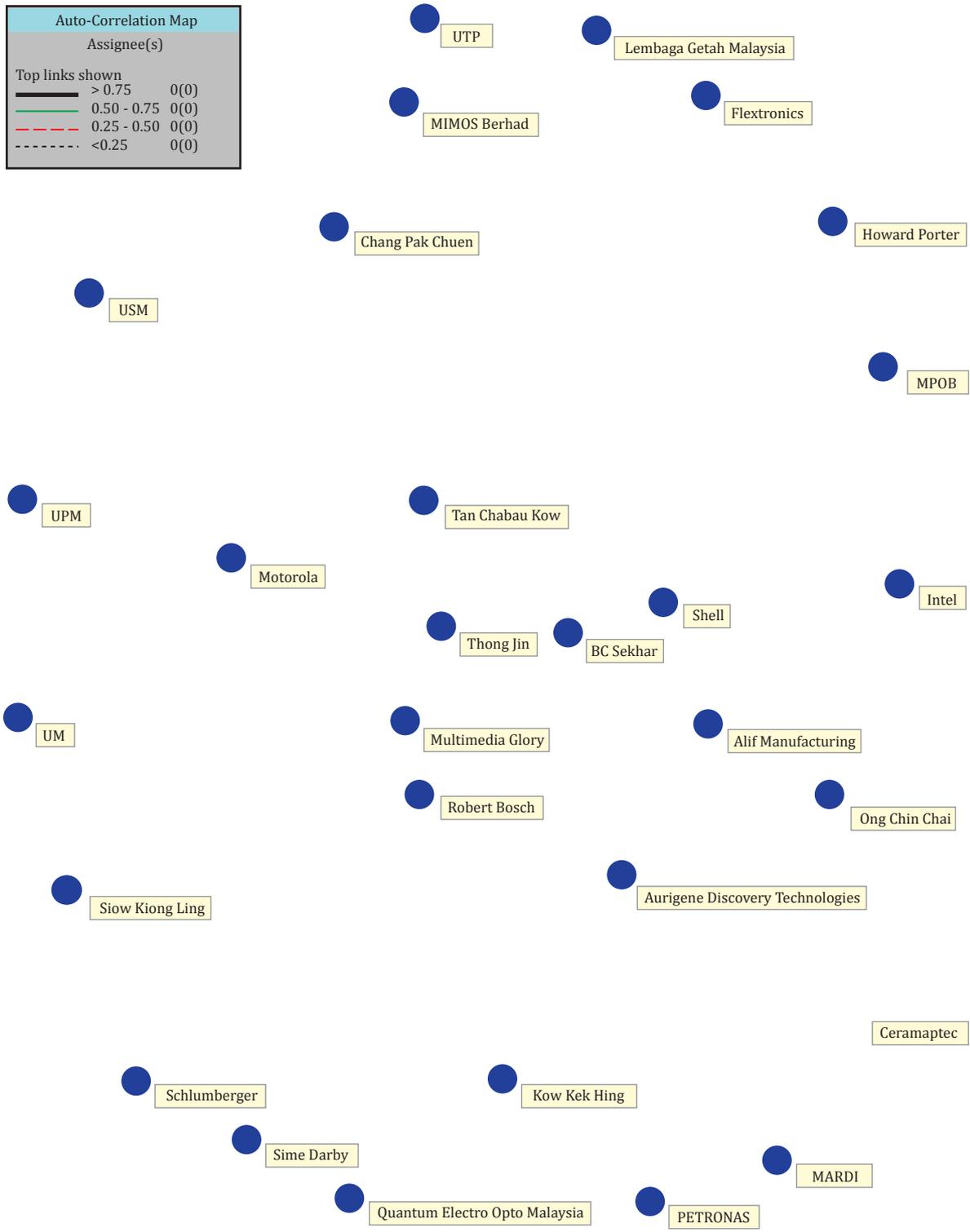
Data coverage : PCT, 2012–2014.

Note : Patents with at least one Malaysian assignee.

6.10   Patenting Landscape

Figure 6.5 depicts the technological fields ventured into by the institutions and private organisations in Malaysia for the period of 2001-2014 using the MyIPO database. The visualisation of patent cluster landscape is performed via keywords extracted in each patent's claim over time that forms the basis of technology clusters. The landscape is plotted using PatSnap Patent 3-D Visualisation tool. It measures connectedness among the keywords and places them accordingly into clusters based on similarity of the extracted keywords. It also depicts the intensity of each cluster via the level of its peak.

It should be noted that are a few dominant clusters with regards to patenting activities in Malaysia. The main clusters are: (1) Mobile, Network, Quantum, Telephone, Optical; (2) Assembly, Pallet, Panel, Light, Vehicle; (3) Implant, Simulator, Produce, Joint, Virus; (4) Air, Engine, Valve, Water, Combustion; and (5) Pile, Panel, Wall, Frame, Gate. The landscape also points out that Mobile, Network, Quantum, Telephone, Optical is the cluster with high patent intensity.

Other clusters such as (1) Image, Data, Server, Network, Trust; (2) Test, Optical, Measurement, Flow, Detection; (3) Oil, Palm, Soap, Extract, Sterilizer; (4) Detection, Gene, Produce, Lipase, Culture; (5) Palm, Oil, Carbon, Rubber, Produce; (6) Filter, Water, Oil, Separator, Waste; (7) Mould, Spray, Article, Machine, Fibre; (8) Oil, Fruit, Palm, Plant, Tree; and (9) Drawer, Table, Rail, Assemble, Guide emerged as the niche areas in Malaysia.

6.11   Summary

As a whole, Malaysia attained an increasing trend in patent citations from 2001 until 2009. Nevertheless, the citations have declined since 2010. Relatively few of the Malaysian institutions are active in patenting activities. Among those that are, MIMOS Berhad has been very productive in patenting. Nevertheless, patent citations remained low, with even lower scores of citations per patent among the Malaysian institutions.

Figure 6.5   Patent Clusters in Malaysia

MOBILE, NETWORK, QUANTUM, TELEPHONE, OPTICAL

DETECTION, GENE, PRODUCE, LIPASE, CULTURE

PALM, OIL, CARBON, RUBBER, PRODUCE

FILTER, WATER, OIL, SEPARATOR, WASTE

ASSEMBLY, PALLET, PANEL, LIGHT, VEHICLE

OIL, PALM, SOAR, EXTRACT, STERILIZER

IMAGE, DATA, SERVER, NETWORK, TRUST

TEST, OPTICAL, MEASUREMENT, FLOW, DETECTION

OIL, FRUIT, PALM, PLANT, TREE

MOULD, SPRAY, ARTICLE, MACHINE, FIBRE

PILE, PANEL, WALL, FRAME, GATE

AIR, ENGINE, VALVE, WATER, COMBUSTION

DRAWER, TABLE, RAIL, ASSEMBLE, GUIDE

IMPLANT, SIMULATOR, PRODUCE, JOINT, VIRUS

Clusters

- Mobile, Network, Quantum, Telephone, Optical
- Oil, Palm, Soap, Extract, Sterilizer
- Detection, Gene, Produce, Lipase, Culture
- Palm, Oil, Carbon, Rubber, Produce
- Filter, Water, Oil, Separator, Waste
- Air, Engine, Valve, Water, Combustion
- Assembly, Pallet, Panel, Light, Vehicle
- Drawer, Table, Rail, Assemble, Guide
- Implant, Simulator, Produce, Joint, Virus
- Image, Data, Server, Network, Trust
- Test, Optical, Measurement, Flow, Detection
- Oil, Fruit, Palm, Plant, Tree
- Mould, Spray, Article, Machine, Fibre
- Pile, Panel, Wall, Frame, Gate

Data coverage :   MyIPO, 2001-2014.

Note   :   Patents with at least one Malaysian assignee.
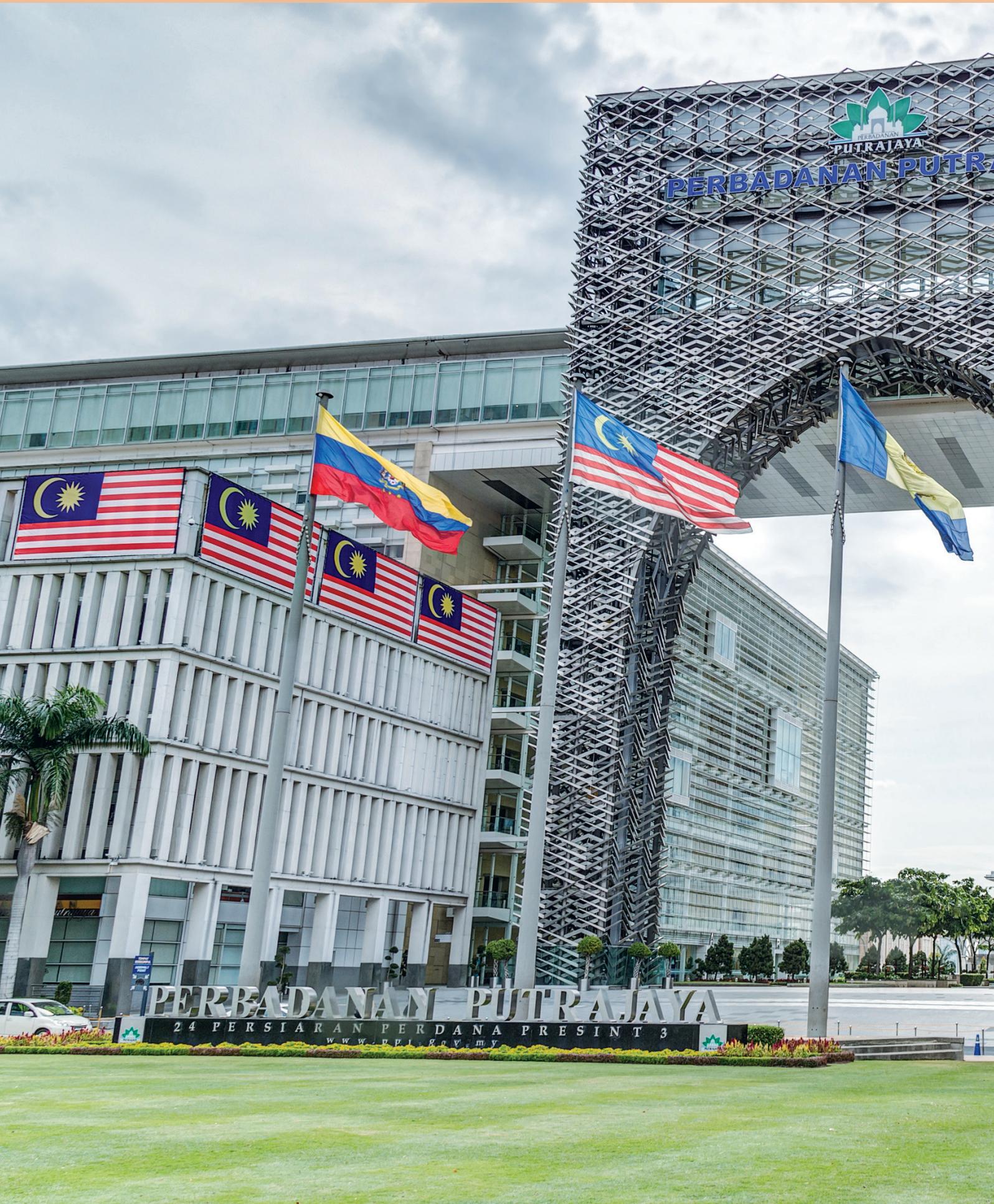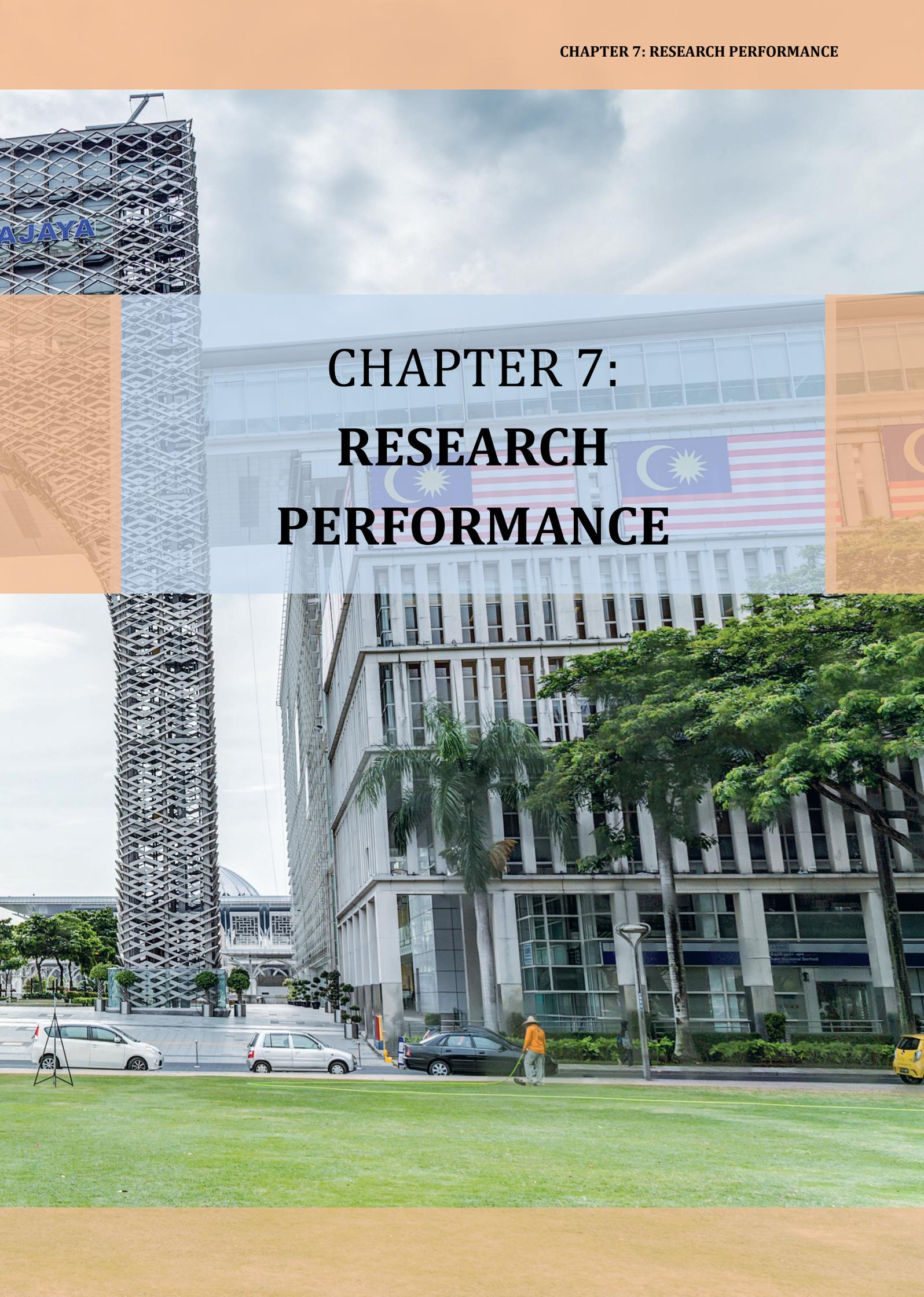
CHAPTER 7:
RESEARCH PERFORMANCE

CHAPTER 7:   RESEARCH PERFORMANCE

7.1   Introduction

Bibliometrics is a quantitative study of publication and patenting activities. It provides an overview of research performance, focus areas and strengths of a nation. It also maps the patterns of national and international research networks of the research community. In addition, it makes international comparison of the performance of a country's research and innovation systems. Nonetheless, as a quantitative research tool, bibliometric – which was initially designed to analyse and interpret research performance based on publication and patent data – has its limitations in providing detailed information on contextual factors that underpin research performance. In response to this limitation, and for the first time in Bibliometric Study in Malaysia, this chapter provides a qualitative understanding and evidence on research performance.

Overall, this chapter seeks to gauge the current trends, main drivers, binding constraints and strategies adopted by institutions and researchers in their publication and patenting activities. Also, this chapter intends to summarise the understanding of the national research systems as a whole, rather than to make comparisons across individual institutions and researchers.

7.2   Research Performance: Publication in Indexed Journals

7.2.1   Recent Publication Trends

Since the last decade, Malaysia has experienced a sizeable boom in articles published in indexed journals, as evidenced by the publication statistics presented in Chapter 3. It reflects the upgrading of competence among researchers in publishing their research outcomes in indexed journals. The Science, Technology, Engineering and Mathematics (STEM) related research activities are noted to be the leading fields of publication. Nonetheless, the number of articles in the field of Social Sciences has also increased markedly alongside the STEM publications. These trends are verified by the top management as well as individual researchers from the universities and PRIs interviewed through this study.

However, there is increasing concern about the quality of publication. Due to this, revisions of Key Performance Indicators (KPIs) for researchers, promotion criteria and incentives for researchers in universities and PRIs have been carried out in order to give more weightage to publications in top-ranked journals. There are also notable achievements by local researchers, in which their works have been published in the leading journals of their respective fields such as *Science*, *Nature*, and *Nature Communications*. In certain universities, the number of publications and impact factors has been utilised not only to assess individual researcher performance, but also the performance of the entire department and institution. Funding decisions have also been made based on the impact of publication criteria. A few universities use h-index and citation counts of the researchers as criteria in their research project selections.

Universities – especially the RUs – are largely the main contributors of publication in Malaysia. This is mainly attributed to various resources made available under the Research University Agenda, as well as other research grants provided by MOSTI and MOHE in the 10MP. For PRIs – despite being mandated to perform operational and applied research and to serve their respective ministry and society in general – their researchers have also managed to successfully publish in notable journals in their respective fields.

It is also important to note that while there is a race to publish in indexed journals, researchers are also active in publishing in the form of books, book chapters, conference proceedings and others. The number of book chapters published by Malaysian institutions during the period of 2005 to 2015 is reported in Appendix G. However, there is growing concern from the research community about the overuse of research performance metrics (such as publication and patent counts and citations) as a means of evaluating the institution and even a researcher's performance (for promotion and tenure). Such evaluation may not reflect the overall performance, and can be misleading and biased in research settings. The main argument is on the appropriateness of these publication indicators for such exercises. It should be noted that other tasks are equally important – such as teaching for universities, societal impact and industry performance facilitation for PRIs. Indeed, performance metrics should reflect the mandate given to the respective institutions.

7.2.2   Drivers of Institutional Publication Activities

The indexed journal publication activities in the country – especially among the five RUs – have been shaped and influenced by the Research University Agenda. The surge in the number of publications corresponded to the eight selection criteria (with different weightage) determined by the Malaysian Government, namely: quantity and quality of researchers; quantity and quality of research; postgraduate quantity; postgraduate quality; innovation; professional service and awards; network and links; and support facilities. Over and above this, apart from the existing funding and grants, RUs also receive monetary incentives from the Government to fund research and research centre activities, as well as the development and maintenance of research infrastructures to support frontier research.

Interview evidence – especially for RUs – suggests that a vibrant research culture in Malaysia only emerged after the Research University Agenda. Prior to that, there was limited critical mass of research resources, and research was not a priority of some universities. RUs funding allows for special allocation for the creation of research programmes, such as specific research clusters and large multidisciplinary projects that emphasise on high impact research. The Research University Agenda has given flexibility to universities in recruiting both foreign and local talent to head the research projects, as well as the acquisition of high-end research equipment for frontier research.

Also, R&D grants that are made available by various ministries – such as MOSTI with the Science Fund, and MOHE with the Fundamental Research Grant Scheme – have contributed to human capital development in scientific communities and the establishment of state-of-the-art labs. This eventually leads to increased number and quality of research publications. Many graduates and postgraduate students were trained and acquired competency in quality research publication through these public funding mechanisms.

Although there are debates around the intense pressure created by the 'publish-or-perish' phenomenon, it has helped improve the research performance of the universities. At the same time, non-RUs and PRIs have also formulated strategic plans to transform their institutions to be more research-oriented. The evidence also provides a valuable lesson: that with proper intervention such as through policy measures and strategies, scholars can be guided to be more productive. At the researcher level, self-motivation seems to be the driving factor for publication. Table 7.1 reflects on some of the salient factors.

Table 7.1   Summary of Main Drivers of Research Performance

Level	Drivers
National Level	• Research University Agenda that charts the path for research excellence • Increased R&D funding • Creation of High Impact CoEs
Institutional level	• Productive CoEs with adequate lab facilities and human resources • Top management commitment and support • Better rewards, incentives and monitoring system • In-house funding system for young researchers • Creation of a strong pool of productive scholars including research fellows and postgraduate students
Researchers	• Passion for research • Effective collaborative networks • Awareness and recognition • Fulfilment of KPIs

Source : Interviews, 2015

7.2.3   Issues and Challenges in Publication

Researchers in universities and PRIs have encountered a number of issues and challenges in indexed journal publication, which can be summarised as follows:

i.   Deficiency in creating a more competitive research ecosystem

The Research University Agenda is considered new in the country. Components of the research ecosystem are fragmented – governed by different ministries and institutions – which led to the problem of information asymmetry and lack of research coordination. Indeed, there are significant overlapping activities as well as lack of effort to systematically structure the research system. Similarly, the coordination of

these components within the system is almost absent. Next, there is inconsistency in research funding. The current shrinking of research funding is expected to hamper publication momentum. While the publication numbers are approaching saturation point, resources such as research budget and staff numbers are not expanding. The deficiencies in the research ecosystem are particularly obvious among the non-RUs, which have limited access to research funding.

Non-RUs and private universities have a heavy teaching load. This has made it difficult for the younger universities and junior researchers to build their research reputation. Several universities and PRIs have a higher percentage of young researchers and limited exposure on how to publish in highly indexed journals. In general, research activities among the non-RUs are also hampered by the lack of research facilities (such as labs and equipment) and budgetary constraints. Their access to public research grants is also limited. Few PRIs are fully governmental bodies, and they have restrictions in the appointment of research staff, fellows or postdoctoral researchers as well as staff training programmes in research. The administrative procedures of research expenditure are lengthy, extensive and complicated.

ii.   Lack of scholarly publication culture and skills

Publication in indexed journals has yet to become part of the research culture of the researchers in certain universities and PRIs. Institutions find it difficult to motivate certain groups of researchers to publish, despite conducting various programs to increase awareness and train researchers. Indeed, interview evidence shows that some academic staffs in universities are inactive in publication, thus making the university's optimal target difficult to achieve. In order to create the right culture, academic staff recruitment should be performance-based, and the lack of self-motivation in research publication among researchers should be mitigated. However, the 'carrot and stick' approach should be seen as a short-term strategy which will not be sustainable in the long-run. Though publication has been included as part of the staff KPIs, top leadership still faces difficulty in taking action against those who are not able to achieve the target requirements.

Given the lack of writing skills and know-how, researchers should be given more time to adapt to the new culture, especially for those who engage in social sciences research. The language barrier is also constantly cited as one of the main constraints for local researchers to publish in journals, as indexed journals are predominantly in English.

Although some universities and PRIs are able to secure funding from industry, joint industrial projects inhibit researchers from publishing their work. The industrial partners are more concerned about protecting their joint research results than publication.

iii. Need for a more holistic evaluation and reward system

The current reward system is not comprehensive enough to take into consideration the wide range of research outputs, the varying magnitude of impact factors for different research fields, and types of research approach (such as qualitative versus quantitative, sciences versus social sciences, etc.). Publication output is dependent on the discipline specificity, and a 'blanket' approach to evaluation is not entirely appropriate. To a certain extent, it has demotivated researchers in particular fields,

thereby negatively impacting their publishing of quality articles. There is also discord over the measurement method used to assess researcher performance based on publications. For instance, there is criticism of universities moving away from using book and book chapter publications as the unit of measure for tenure and promotion criteria. Both public and researcher perception is that over-emphasis on publication achievements has resulted in universities and PRIs neglecting their roles in societal development or even other forms of publications.

7.2.4 Institutional and Researcher Strategies

Some of the strategies adopted by the universities and PRIs have been effective in improving research performance. They have also served as a remedy to overcome some of the main constraints, as well as promoted researcher capabilities in publication. The following are some of the strategies:

- Setting up of high impact research projects to consolidate institutional research activities which are dispersed amongst the research groups in the institution. The multidisciplinary approach with the support of research cluster management and high-end research facilities leads to an increase in quantity and quality of publications.

- Designing high impact research programmes in parallel with the on-going National Key Economic Areas (NKEAs) and global grand challenges – to ensure there is a balance between the contribution of research to academia on the one hand, and community development arising from public R&D investment on the other hand.

- Engaging the full involvement of postgraduate students, visiting researchers and fellows as well as postdoctoral scholars in publication. Fulltime postgraduate students and fellows are among the important sources that drive publication, since they are exclusively focused on their research activities. Postdoctoral scholars play an important role in managing the scientific components of the research activities in research clusters. Unfortunately, the advantages of having postgraduate students are not available to PRIs.

- Establishing specific research awareness and development programmes such as workshops, roadshows, notable academic icon programmes, etc. to harness and inspire young Malaysian scientists and researchers. Conference grants can be provided to encourage researchers to participate in international conferences and workshops.

- Providing attractive publication incentives, establishing staff KPIs and aligning promotion criteria to motivate researchers to publish quality papers. Incentives are being revised from time to time depending on fund availability and these include, among others: monetary rewards; scholarships and priority in selection of postgraduate students; and vouchers to purchase research materials and cover payment of page charges.

- Encouraging collaborative research among researchers and between institutions through the creation of Centers of Excellence (CoEs) that leads to an increase in resources as well as shared laboratories and other research facilities.

- Engaging senior researchers to take on the responsibility of mentoring junior researchers and student interns in developing their research and writing skills.

- Revising the researcher recruitment system and appointing only those who are motivated and passionate about research and active in publications.

- Optimising the use of researcher social networks such as ResearchGate in promoting possible research collaboration and providing visibility to research outputs.

7.3 Research Performance: Institutions Patenting Activity

7.3.1 Recent Patenting Trends

In Malaysia, although there has been a steadily growing trend toward patenting activity undertaken at universities and PRIs, the culture of academic and research patenting is indeed still recent. In general, awareness on IPRs in the country – especially about patenting and other types of intellectual properties among academics and researchers – only began gradually after 2010. Institutional concern has recently shifted focus from patent filing (and granting) to commercialisation of the patents. There is a rising concern among the institutions on the quality of the patents, arising from the low level of commercialisation. Given the limited resources currently, institutions are selective in patent filing and are more stringent in screening and selecting patent applications. It is important to acknowledge that besides patents, institutions are also actively seeking other methods to protect their research outcomes. These include copyright, trademark and industrial design, among other methods.

7.3.2 Drivers of Institutional Patenting Activity

Similar to publication, the drivers of patenting are various in nature. For universities and PRIs, collaboration with companies is one of the main drivers of their patenting activities. This strategic partnership within the spirit of public-private partnership merges the discovery-driven culture of the universities and PRIs, with the innovation-driven environment of the companies. In this respect, strategic partnership with companies allows universities and PRIs to gain insights into the commercial value of their prototypes at the very beginning stages of their research.

Institutional leadership is vital in making patenting activities one of the strategic priorities in R&D commercialisation related efforts. This message has been regularly communicated to the entire academic and research community. Strong commitment from leaders is also reflected in the setting up of various institutional support entities such as Technology Transfer Office (TTO), Collaborative Research Centre, University Commercialisation Unit, etc. that provide a wide range of functions such as creating awareness on the importance of patents, patent search and screening support, licensing channels to companies, and other processes related to patent filing. TTOs at most of the universities mediate the interface between university and industry, as well as convince the researchers to disclose their potentially valuable innovations in the form of patents.

Setting patents as one of the KPIs and sharing the generated income with researchers have encouraged patenting activities. The formulation and revision of the Intellectual Property Policy of institutions – opening the way for researchers to co-own the inventions which are the result from public funding – has motivated academics and researchers to patent their inventions. Nevertheless, this has been a very time-consuming task and even more challenging than publishing articles. The principles and provisions of the Intellectual Property Commercialisation Policy launched in 2009 allows grantee institutions or funded scientists to obtain IPRs to their inventions. This has motivated researchers to venture into patenting.

It is also important to note that rather than monetary returns, providing research visibility and recognition has generally turned out to be the more important determinant factor that affects researchers' propensity to patent. Indeed, academics with more industrial exposure and consulting experience are more likely to patent. In addition, academic patenting activities are also catalysed by the availability of public funding such as Research University Grant, Science Fund, Prototype Research Grant Scheme, etc. In the case of companies, innovating companies engage in patenting to protect their most important R&D outcomes against imitation.

7.3.3 Issues and Challenges in Patenting Activity

Researchers and innovators encountered numerous issues and challenges in patenting activities, which can be summarised as follows:

i. Inconsistent funding and rising cost of patenting

Inconsistency in funding has hampered universities and PRIs in maintaining their performance in patenting activities. At the same time, there is a rising cost of patenting activities which includes, among others: cost of conducting patent search and filing; cost associated with patent lawyer advisory service; and obtaining approval from the related accredited bodies (such as the Food and Drug Agency for patents in the field of medical devices). Also, in the case of universities and PRIs, there are limited resources available for participating in bringing inventions to the market place.

The same factors limit patenting activities of companies, especially amongst the Small and Medium-Sized Enterprises (SMEs). The filing of patents and related search for patent information, cost to engage quality patent lawyers, and maintaining an in-house patent division are the main challenges. The cost is even more when companies aim to file patents in other countries. Consequently, most SMEs cannot afford to manage a large patent portfolio, and the general patent system is more favourable to larger companies.

ii. Insufficient pool of researchers with industry and business exposure

Even in the field of applied research, most universities and PRIs have a low number of commercially viable research outcomes. This can be seen through the low patent citations as well as difficulties in licensing those patents. Research ideas seem to be immature and lack industry input. In addition, there is no critical mass of market oriented research.

Several interviewees have observed that good academics are often less entrepreneurial and uninterested in commercialising their research outcomes. Also, it is important to note that academics consider reaching out to companies and commercialising research outcomes as an additional task or a 'part-time' activity, as their main priority is teaching and research supervision. Nevertheless, those with experience consulting with industry seem to be more successful in patenting commercially viable patents (Chandran, Hayter & Strong, 2015). Interviews also suggest that some of the researchers who spent considerable time with industry are more inclined to venture into commercialisation.

iii. Limited research collaboration with industries

Differences in work culture, principles and approaches hinder collaboration between researchers and industrialists. The expectations and work environment of industry and universities are different, and this extends to their perspective on IPRs. Industry is generally more concerned with return on investment and has high expectations on IP ownership. Also, industry prefers not to publish – in order to protect the secrecy of the innovation. For researchers in the universities and PRIs, there is a concern over the possibility of having publication delayed. This may discourage researchers from interacting with industry because publications are critical to their career advancement. There is little incentive for researchers who have spent considerable time on industry outreach efforts.

iv. Low perceived importance of IPRs

The culture of developing research into potentially patentable inventions is still very much lacking in Malaysia. At the university level, there is still debate on the fundamental question of *"Should all patentable academic inventions be patented?"* For companies, there is little confidence in the IP systems and their enforcement. Thus, many companies do not see the value in owning a patent. There is a general perception that SMEs can expect to benefit less than larger firms from patenting activities in terms of protection against imitation.

v. Lack of patent experts and institutional support

Most TTOs at universities and PRIs lack experienced technology transfer professionals. In some cases, public employment rules and pay-scales hinder public institutions from offering competitive salaries in order to hire such professionals. As a result, some of the TTOs lack quality resources and competencies necessary to harness a wide range of commercially viable innovations. The role of TTOs has been limited to IP promotion and awareness activities.

At the national level, there is still a lack of quality local patent agents capable of drafting technical claims for patent application. The time taken by agents in giving feedback on patent application is long, and in some cases there is inconsistent consulting advice from the patent agents. On the other hand, the time taken for scrutinising patent applications and for patent approval seems to be lengthy. The average time frame for patents to be granted in Malaysia is between 2 to 3 years, which is considered long by some companies – especially Information and Communication Technology (ICT) firms, given the short life cycle of their products. The technology would be obsolete by the time the patent for it is granted. Besides this, certain universities and PRIs do not have TTOs that can facilitate patenting activities.

7.3.4 Institutional and Researcher Strategies

Listed below are strategies adopted by universities and PRIs to overcome the main constraints and to increase academic and research patenting activities:

- Utilising public funding for IP preparation and registration activities that are made available under various R&D and pre-commercialisation grants such as Techno Fund, Science Fund, Commercialisation of R&D Fund, etc.

- Strengthening the existing Collaborative Research Centre or Innovation and Commercialisation Centre to provide advice and training to researchers in patent application.

- Applying stringent patent screening processes to ensure only prototypes with high commercialisation potential are selected for filing. Experienced entrepreneurs and industrialists are involved in the screening committee to evaluate the commercial value of the application. Some institutions require applicants to have industry partners before beginning the filing process.

- Identifying patents from the existing pool that have the greatest commercial value for further commercialisation processes (such as business plan development, investment, etc.) through consultation with techno-entrepreneurs locally and abroad.

- Building a good understanding and long term partnership with quality patent agents, engaging them in developing the technical knowledge required for patent claim drafting. Such engagement not only expedites the patent drafting process but also reduces the patent filing cost.

- Motivating staff participation in patenting activities through attractive reward systems such as a cash incentive per disclosure scheme, as well as for filed and granted patents.

- Setting up a multidisciplinary team to obtain comprehensive information about the potential research. Such supporting data and information from various sources are crucial to ensure the outcomes of the research are patentable.

- Conducting specific awareness and competency development programmes such as workshops, roadshows, etc. to inform innovators on the importance of IP, understanding institutional IP policies, and developing basic skills in preparing patent claims and documents.

- Sending managerial staff and officers of TTOs to local (e.g. MyIPO) and international (e.g. WIPO) training sessions on patent disclosure, prior arts research, claims, and others.

7.4   Summary

This chapter provides the qualitative insights into the current trend of knowledge production activities, main drivers, issues and challenges, and strategies taken by the respective institutions. Main findings from the interview sessions indicate that both publication and patenting activities are on an upward trend. However, it has been suggested that the quality of publications and patents should be a concern, as the cost of knowledge production has tremendously increased over the years.

The evidence highlights the need for a more competitive research ecosystem that is conducive enough to research and innovation activities among the universities and PRIs. The Research University Agenda is crucial, since it has contributed to knowledge performance by allocating more research funding and providing autonomy to the RUs in managing their research.

CHAPTER 8:
CONCLUSION AND THE WAY FORWARD

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8.1   Introduction

This chapter summarises the main findings on publication and patent outputs as well as citations for publications and patents for the years 2001 to 2014. This chapter also reports the main qualitative findings and sets the recommendations that serve as the way forward in improving research performance in Malaysia.

8.2   Malaysia's Progress in Publications and Patents

8.2.1   Publication and Patent Outputs

A total of 90,128 international articles and proceedings were published from 2001 to 2014. Malaysia's publication output has grown exponentially since 2008, and 83% of the publications are associated with RUs. As such, it is the direct consequence of increasing R&D funding and the promotion of the Research University Agenda that promotes research excellence. Materials Science and Crystallography are the main fields of research recording the highest number of articles.

As for patents filed under PCT, a total of 3,611 patents from Malaysia were filed from 2001-2014. Computer Technology and Digital Communication have the highest number of patents filed. MIMOS Berhad filed the most number of patents, followed by Universiti Putra Malaysia. In MyIPO, 2,461 patents were granted and the major fields include Civil and Chemical Engineering. MIMOS Berhad has the most patents granted followed closely by Universiti Teknologi Malaysia.

8.2.2   Publication and Patent Citations

In terms of publication citations, generally it shows an increasing trend over the study periods. The field of research garnering the highest citations per article for Malaysian articles is the field of Immunology (10.86), followed by Environment/Ecology (8.72). However, the number of citation counts has decreased since 2012, even though the number of articles published has grown exponentially over the years up to 2014. Nevertheless, citations per article – measured as ratio of citation counts to the total number of articles produced – displays a decreasing trend over the period under study.

Patent citations amount to 2,335 citation counts during 2001-2014. Per annum, Malaysia recorded 256 patents, 167 citations and 0.65 citations per patent. Since 2009, citation trends have been declining. Similarly, citations per patent are still low. In terms of total patent citations by field of research, one field emerged as the dominant field with the highest patent citations, Basic Materials Chemistry (208). Interestingly, it seems that there are virtually no linkages in terms of co-patenting activities in Malaysia – most patents are assigned to individual organisations. The mapping exercise indicates that main patent clusters include: (1) Mobile, Network, Quantum, Telephone, Optical; (2) Assembly, Pallet, Panel, Light, Vehicle; (3) Implant, Simulator, Produce, Joint, Virus; (4) Air, Engine, Valve, Water, Combustion; and (5) Pile, Panel, Wall, Frame, Gate.

8.2.3   Research Performance

Overall, the progress of publications and patents has contributed to the global ranking of Malaysia in various reports. In the Global Innovation Index (GII) Report (Cornell University, INSEAD & WIPO, 2015), the increased publications and patents in Malaysia contributed to the improvement in ranking in areas related to knowledge and technology output pillars – especially towards knowledge creation in domestic resident patent applications, PCT resident patent applications, scientific & technical articles, and citable documents h-index. As Table 8.1 indicates, Malaysia has improved its position significantly in GII for scientific and technical articles, moving from rank 79 (value 6.2) in 2011 to rank 54 (value 13.9) in 2015, respectively. Malaysia also improved its citable document h-index, moving from rank 52 (value 125) in 2014 to rank 51 (value 145) in 2015, respectively. Malaysia has maintained better ranking from 2011-2015 for domestic resident patents (rank between 45-50) and PCT resident patent applications (rank between 31-42).

As for the Global Competitiveness Report (GCR), the increase in patents contributed to the improvement in the scores of the Innovation pillar (pillar 12), especially PCT patent applications. Malaysia's rank for PCT patent applications per million population improved from 34 (value 9.6) in 2012 to 33 (value 11.6) in 2015. Scientific Infrastructure has been emphasised in the IMD World Competitiveness Yearbook (Bris, 2014), and the improvements in scientific articles and patent applications in Malaysia has significantly contributed to the improvement of the scientific infrastructure pillar in the report.

Table 8.1   Global Ranking of Malaysia

	2011	2012	2014	2015
Global Innovation Index				
Domestic resident patent applications/tr PPP$GDP	Rank 50 (12.7)	Rank 45 (3.0)	Rank 50 (2.3)	Rank 49 (1.7)
PCT resident patent applications/ tr PPP$GDP	Rank 31 (11.8)	Rank 34 (0.6)	Rank 35 (0.6)	Rank 42 (0.4)
Scientific & technical article/bn PPP$GDP	Rank 79 (6.2)	Rank 67 (3.5)	Rank 53 (16.9)	Rank 54 (13.9)
Citable documents h-index	N.A	N.A	Rank 52 (125.0)	Rank 51 (145)
Global Competitiveness Report				
PCT patent applications per million population	N.A	Rank 34 (9.6)	Rank 32 (12.6)	Rank 33 (11.6)

Source   :   Global Innovation Index 2015 and IMB World Competitiveness Yearbook 2014.

Note   :   Figure in parentheses is value.

8.3   Major Challenges

Rapid progress is being made in a number of developing countries in terms of investment in R&D, in order to attain international competitiveness in publication and patenting activities. One notable example is China. Despite Malaysia showing progressive performance as a whole, evidence from quantitative analysis – especially since 2006 – suggests that there are three major challenges and concerns. Among them are:

i.   **Increasing the momentum of publication and patent production**

- Overall, the publication trends have been increasing over the years. However, the growth rate for publication seems to have been decreasing after 2009. As for patents, comparatively the patent counts are still low. Indeed, for Malaysia to catch up in patenting activities, the average growth rate should be higher than the present growth rate. In the meantime, patenting activities are mainly productive among foreign multinational companies.

- The trend in growth rate for both publications and patents also reflects the funding cycle. Most often, a slowdown is recorded at the end of funding cycles. The issue of increasing the publication and patent outputs momentum will be crucial in the future.

ii.   **Low citations**

- Despite the increase in publication and patent outputs, citations remained low – indicating publications and patents with low impact. Indeed, citations per article and citations per patent are relatively low compared to other countries and companies respectively. Concentrated strategies are required to improve the quality of publications and patents.

iii.   **Dominance of multinational companies in patenting**

- In the private sector, multinational companies – specifically foreign multinational companies from the USA and Japan – dominate patent filing and granting. In transforming the innovation landscape, more Malaysian companies should be incentivised to participate in patenting activities in order for Malaysia to progress to an innovation driven economy.

Likewise, the sustainability of publication and patent production as well as the number of citations are further hampered by the issues and challenges identified in Chapter 7 through the interviews. Those challenges include:

- Deficiency in creating a more competitive research ecosystem
- Lack of scholarly publication culture and skills
- Need for a more holistic evaluation and reward system
- Inconsistent funding, compounded by rising cost of patenting
- Insufficient pool of researchers with industry and business exposure
- Limited research collaboration with industries
- Low perceived importance of IPRs
- Lack of patent experts and institutional support

8.4   Recommendations

There should be a shift in the approach of policymakers in perceiving research performance as a long-term national research agenda. In this context, research publication as well as patenting outputs are some of the key results of the continual effort of the research community. Thus, strengthening the research foundation of universities and PRIs should be on the policy priority list, rather than emphasising strategic thrusts that are merely perceived as short-run initiatives. The focus should be on improving and sustaining research performance and providing the needed inputs that are of importance.

In order to improve the performance of publication and patenting activities, the following is recommended as a way forward.

8.4.1   Increasing the Production of Publications and Patents

Increasing the current momentum of publications and patents is crucial. The following can be considered as the future policy direction.

i.   **Optimising resources and improving research productivity**

Better resource optimisation strategy is needed, especially with regards to human capital. The underutilised human resources need to be retrained and motivated to participate in publication and patent activities. Some of the strategies taken by the respective institutions can be emulated, and new strategies can be further fostered. Likewise, physical resources can be shared in order to foster collaborative research activities and thereby promote research excellence. Only when critical mass is achieved can the research outputs be further increased and sustained.

ii.   **Establishing consistent stream of funding**

There is a crucial need to provide consistent funding even during times of financial uncertainty. There is no doubt that funding uncertainty will slow down the progress of research and eventually lead to a decrease in research output and quality. Hence, making research funding sustainable and consistent is vital for sustaining and increasing the research output of research communities. Indeed, funding should also be streamlined in order to support more quality research. Monitoring and evaluation is important in this aspect, so that funding can be streamlined to those productive organisations and researchers.

iii.   **Creating a seamless research ecosystem**

A good research ecosystem attracts and retains quality researchers. Thus, efforts to improve the research base of the universities and PRIs should be strengthened in order to make these institutions a magnet for skilled resources and foreign investment in research activities. Empowering the National Research Council similar to other countries will allow the facilitation of research activities in a more meaningful way. A national research outlook enables the formulation and coordination of a more effective research ecosystem in Malaysia.

iv. **Promoting scholarly publication culture and skills**

Given that publication and patenting activities are relatively inadequate, various incentives as well as programmes should be formulated to create the needed scholarly culture and skills. Apart from incentives, mentoring and training programmes are also effective in promoting a healthy research culture. Aligning research performance with the researcher KPIs has proven to improve the research culture within the university system. As a whole, creating research culture also requires setting a more holistic evaluation and reward system, encouraging collaboration, and providing the researchers with more industrial exposure.

8.4.2   Improving Citation Counts

Best international practices show that various efforts can be taken to improve the citation counts. These include:

i. **Improving research visibility**

Efforts at the national, institutional and researcher level should also be taken to increase the visibility of the research outcomes, as this improves citations. The following are the recommendations to improve research visibility.

ii. **Expanding the international network – star researchers**

Malaysian researchers should be encouraged to collaborate and work closely with other well-known researchers (the so-called 'star researchers') from abroad. Joint researches will likely lead to higher impact in such publications. Joint research work with industry or other well-established research institutions that results in patenting improves the chances for potential commercialisation.

iii. **Promoting outreach activities with industries**

Consulting activities should be encouraged among researchers as it gives more exposure to them, especially in gaining tacit knowledge and market know-how. Indeed, PRIs should promote outreach activities by researchers with industries. Significant recognition should be given for such outreach activity efforts.

Table 8.2   Efforts in Promoting Research Visibility

Level	Efforts
National	• Continuing MCC's critical role in promoting Malaysian journals and also articles written by Malaysians in other sources. • Highlighting and promoting Malaysian researchers who have published in the top 10% ranked journals. • Establishing a system that filters and ranks journals, similar to the practice in Australia – e.g. Excellence in Research for Australia (ERA) by the Australian Research Council – to ensure that researchers publish only in credible journals in their respective fields of research.
Institutional	• Promoting good articles via email system and in the website of the institutions. • Establishing working paper series for the respective division/faculty. • Continuing the effort of establishing systems that prioritise journals. There is an urgent need to provide guidance to the researchers and academic community on the quality of journals that they should publish in, since journal quality has a high correlation with citation counts. Currently, there is no one system that informs researchers about the quality of journals they have been publishing in. In the case of Australia, the Australian Research Council initiated ERA in order to assist in the evaluation of research produced by universities. Indeed, the list of journals that was ranked accordingly provides an important guide for the research community and steers researchers away from publishing in bogus/predatory journals. This guide will also help consolidate the impact of publishing for Malaysia, given that more concentrated efforts can be put in place for creating more impactful publications. • Providing training and seminars to researchers on how to improve visibility. • Establishing a unit within the institutions to promote active researcher profiles and research outputs.
Researcher	• Participating in social media to make their research more visible. Uploading research results in various open source repositories or institutional repositories and international networks that are specific to the research fields (e.g. ResearchGate, Academia and others). • Ensuring consistency in author name and affiliation in articles. • Utilising staff webpages or creating personal homepages. • Optimising keywords in the abstract of the publications. • Repackaging the research outcomes for different audience, e.g. as seminar and working papers, policy briefs and others.

Source   :   Interviews, 2015.

iv.   **Leveraging genuine public-private collaboration**

There should be a structured program for researchers to be placed in industry, and vice versa. For researchers who are working in public funded institutes such as universities and PRIs, their interaction with private firms provides competitive advantages to them in framing industry driven research projects. In this context, researchers and students will be exposed to cutting-edge business models and service designs. Strengthening the existing on-campus TTOs and industrial liaison offices through partnership with industry can eliminate traditional academic and research silos, and drive a new multidisciplinary culture of the research organisations. This eventually generates a pool of academics and researchers with deep understanding of industry and business experience.

v.   **Establishing a national centralised patent administration and support unit**

Currently, administration of patents is left with the individual organisations. Resources are also scarce at the individual organisation level. Synergy is needed to create the critical mass of expertise at the national level. There should be a one-stop patent monitoring unit to keep track of patent filing from public funding and provide support in the commercialisation of patents. Such a unit is expected to formulate a central funding mechanism for patent filing and maintenance, particularly for R&D and commercialisation grants that have promising IP as one of the project deliveries. Together with TTOs at the institutional level and MyIPO, the unit can assist in the patenting of patentable research outcomes of the researchers at the beginning of application process and lead it a successful completion. Besides, the unit can bring coherence and sharing of good practices among the research institutions. The unit can be instrumental for streamlining TTOs and other agencies relevant to IP.

8.4.3   Promoting Indigenous Companies in Patenting Activities

i.   **Nurturing patenting culture through tax incentives and finance supports**

Efforts need to be intensified to nurture the innovation culture among companies – especially SMEs – through corporate tax exemptions and incentives. For instance, tax rebates should be given to the company upon granting of a patent. Consistent funding for patenting activities needs to be established within the system, and making patents a form of collateral for loans should be made a viable option.

ii.   **Showcasing entrepreneurial science**

In order to increase awareness about the benefits of patenting, programmes to provide visibility and publicity about success stories in research patenting amongst scientists and researchers should be encouraged. Similarly, successful companies should be encouraged to showcase their research findings and inventions to local and international markets.

8.5   Future Study

This report has provided significant improvements compared to the 2012 Bibliometric study. Nevertheless, future study could consider the following:

- Thorough analysis of Malaysian publications in international journals in the SCOPUS database. The current study only considered Malaysian publications in international journals in WoS and Malaysian journals in SCOPUS database;

- Expanding the scope of publication analysis by incorporating analysis on book chapters listed in Book Citation Index-Science, and Book Citation Index-Social Science and Humanities;

- Expanding the current scope of patenting analysis by incorporating analysis on Malaysian patents filed at major IP offices such as United States Patent and Trade Mark Office, European Patent Office, Japan Patent Office, and China Patent and Trademark Office;

- Tracking the link between publications and patents especially to understand how publication leads to patents and vice versa; and

- Expanding the scope of study by incorporating the analysis on copyright and trademark filed at different IP offices to understand the types of IPRs activities pursuit by Malaysian entities.

8.6   Summary

Malaysia has attained a more progressive research performance over the years in both publications and patenting activities. Nevertheless, challenges remain and new policies and strategies are needed, as suggested in this study. Indeed, various institutions should deliberately undertake their own strategies in order to sustain their scientific output production, as well as the quality of such outputs.
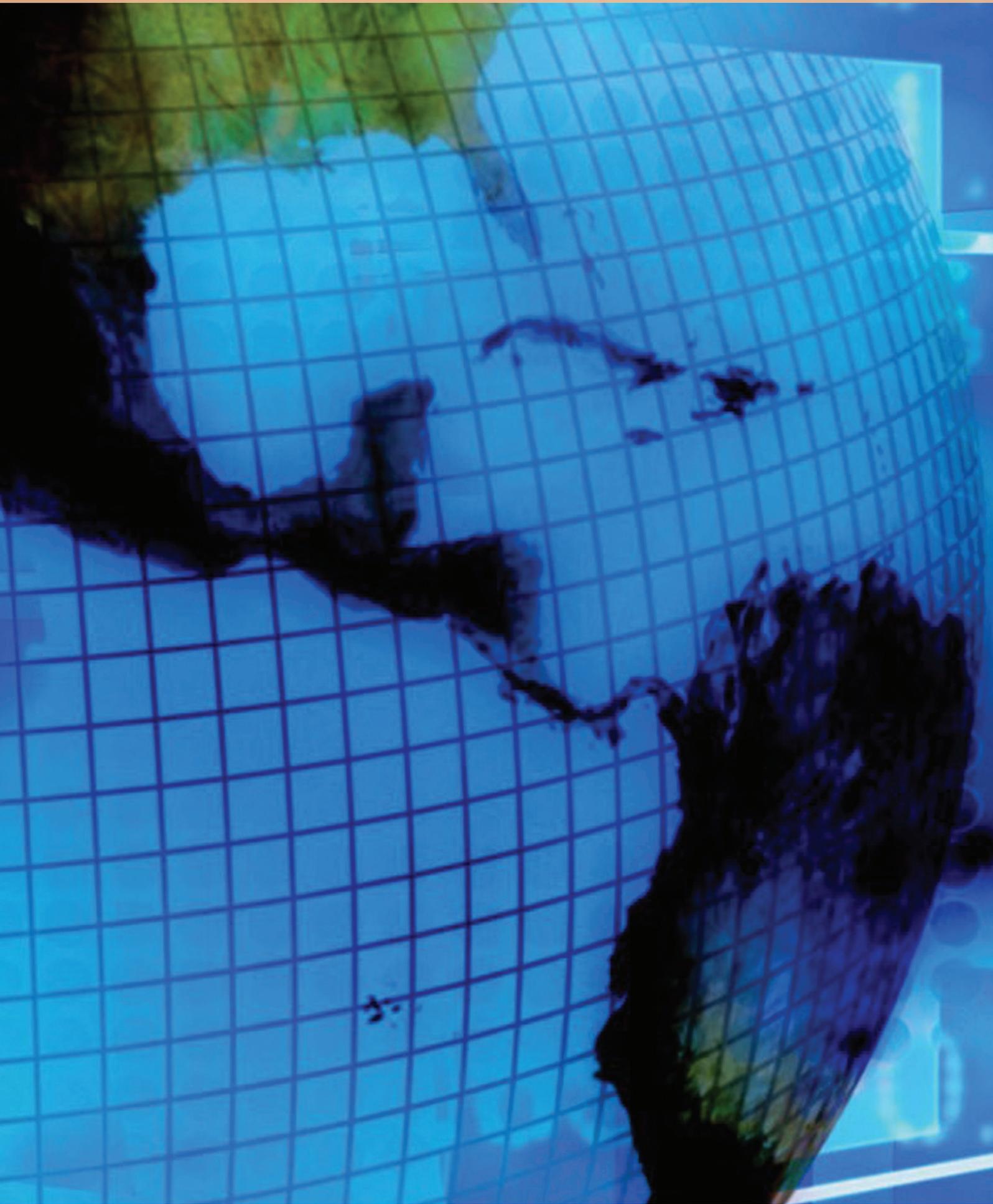
APPENDIX

APPENDIX A: Patent Applications and Granting Procedure (Patents Act 1983) Malaysia
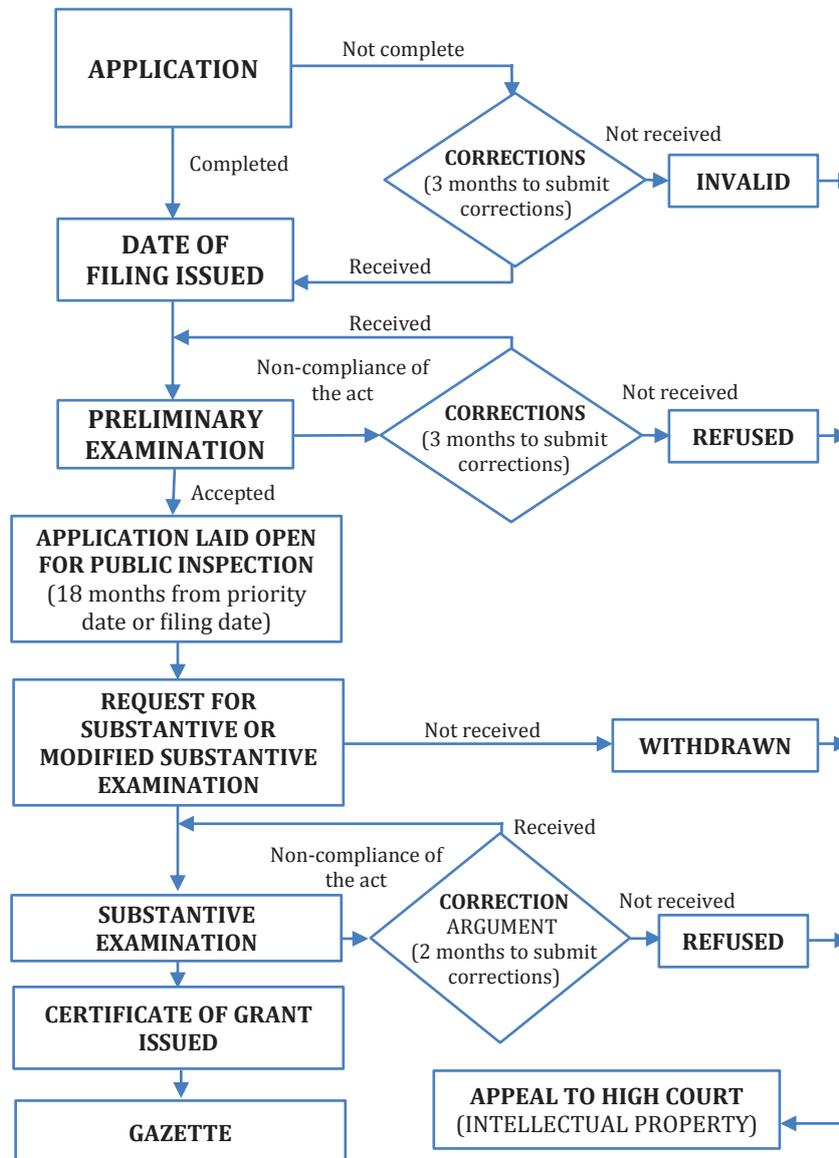
Source : MyIPO.

APPENDIX B: Total Publications Output, Articles and Proceedings, 2001-2014

Year	Articles	Proceedings	Total Publications	Growth Rate (%)
2001	960	69	1,029	
2002	1,010	93	1,103	7.19
2003	1,183	113	1,296	17.50
2004	1,378	660	2,038	57.25
2005	1,597	686	2,283	12.02
2006	1,874	1,079	2,953	29.35
2007	2,245	1,340	3,585	21.40
2008	2,905	2,515	5,420	51.19
2009	4,326	2,995	7,321	35.07
2010	5,933	2,079	8,012	9.44
2011	7,798	2,988	10,786	34.62
2012	8,173	5,197	13,370	23.96
2013	9,250	5,767	15,017	12.32
2014	10,499	5,416	15,915	5.98
Total	59,131	30,997	90,128	

Data coverage :   WoS – SCIE and SSCI, 2001-2014.

APPENDIX C: Total Articles and Proceedings by Malaysia Plans, 2001-2014

Malaysia Plan	Articles	Proceedings	Total Publications
8MP (2001-2005)	6,128	1,621	7,749
9MP (2006-2010)	17,283	10,008	27,291
10MP (2011-2015)	35,720	19,368	55,088
Total	59,131	30,997	90,128

Note   :   The scope of the study is from 2001 to 2014, while the 10MP covers the period 2011 to 2015. The recorded numbers are until end of 2014 (excludes 2015).

APPENDIX D: Top 15 Public Research Institutions Ranked by Number of Articles

No.	Institution	Number of Articles
1	Institute for Medical Research	731
2	Malaysian Palm Oil Board	620
3	Forest Research Institute of Malaysia	564
4	Malaysian Nuclear Agency	399
5	Hospital Kuala Lumpur	327
6	Ministry of Health Malaysia	314
7	Malaysian Agricultural Research & Development Institute	242
8	SIRIM Berhad	185
9	Forest Research Centre	154
10	Rubber Research Institute Malaysia	128
11	Malaysian Rubber Board	125
12	Penang Hospital	94
13	MIMOS Berhad	88
14	Selayang Hospital	79
15	Veterinary Research Institute	62

Data coverage : WoS – SCIE & SSCI, 2001-2014.

APPENDIX E: 50 Fields of Research with Limited Number of Articles: SCIE

No.	WoS Category	Number of Articles
1	Limnology	42
2	Emergency Medicine	41
3	Mineralogy	41
4	Education & Educational Research	39
5	Ergonomics	39
6	Anesthesiology	36
7	Cell & Tissue Engineering	36
8	Primary Health Care	36
9	Psychology	35
10	Audiology & Speech Language Pathology	29
11	Substance Abuse	26
12	Paleontology	24
13	Social Sciences, Interdisciplinary	23
14	Anthropology	20
15	Transportation	20
16	Agricultural Economics & Policy	18
17	Geology	18
18	Social Sciences, Biomedical	18
19	Gerontology	17
20	Ornithology	16
21	Andrology	15
22	Ethics	14
23	Geography	14
24	Architecture	13
25	Psychology, Experimental	13

No.	WoS Category	Number of Articles
26	History & Philosophy of Science	12
27	Medical Ethics	12
28	Neuroimaging	12
29	Psychology, Clinical	11
30	Psychology, Biological	9
31	Linguistics	8
32	Psychology, Applied	8
33	Psychology, Multidisciplinary	8
34	Urban Studies	8
35	Psychology, Developmental	6
36	Hospitality, Leisure, Sport & Tourism	5
37	Social Sciences, Mathematical Methods	5
38	Archaeology	4
39	Business	4
40	Law	4
41	Social Issues	4
42	Ethnic Studies	3
43	Music	3
44	Philosophy	3
45	Art	2
46	Communication	2
47	Psychology, Mathematical	2
48	Sociology	2
49	Language & Linguistics	1
50	Logic	1

Data coverage ： WoS – SCIE, 2001-2014.

APPENDIX F: 50 Fields of Research with Limited Number of Articles: SSCI

No.	WoS Category	Number of Articles
1	Orthopedics	5
2	Radiology, Nuclear Medicine & Medical Imaging	5
3	Biochemistry & Molecular Biology	4
4	Music	4
5	Parasitology	4
6	Pathology	4
7	Geosciences, Multidisciplinary	3
8	Marine & Freshwater Biology	3
9	Ophthalmology	3
10	Philosophy	3
11	Physics, Mathematical	3
12	Physiology	3
13	Zoology	3
14	Archaeology	2
15	Cardiac & Cardiovascular Systems	2
16	Chemistry, Multidisciplinary	2
17	Computer Science, Hardware & Architecture	2
18	Film, Radio, Television	2
19	Gastroenterology & Hepatology	2
20	Imaging Science & Photographic Technology	2
21	Literature	2
22	Mathematical & Computational Biology	2
23	Nuclear Science & Technology	2
24	Physics, Nuclear	2
25	Psychology, Mathematical	2

No.	WoS Category	Number of Articles
26	Remote Sensing	2
27	Robotics	2
28	Transplantation	2
29	Acoustics	1
30	Agronomy	1
31	Andrology	1
32	Anesthesiology	1
33	Chemistry, Medicinal	1
34	Chemistry, Physical	1
35	Critical Care Medicine	1
36	Dermatology	1
37	Electrochemistry	1
38	Emergency Medicine	1
39	Engineering, Mechanical	1
40	Engineering, Petroleum	1
41	Hematology	1
42	Horticulture	1
43	Limnology	1
44	Materials Science, Multidisciplinary	1
45	Microbiology	1
46	Neuroimaging	1
47	Peripheral Vascular Disease	1
48	Plant Sciences	1
49	Reproductive Biology	1
50	Veterinary Sciences	1

Data coverage : WoS – SSCI, 2001-2014.

APPENDIX G: Number of Book Chapters Published by Malaysian Institutions

Year	Book Citation Index – Science	Book Citation Index – Social Science and Humanities	Total
2005	19	7	26
2006	17	15	32
2007	33	27	60
2008	47	36	83
2009	45	29	74
2010	126	57	183
2011	117	142	259
2012	109	92	201
2013	96	156	252
2014	150	120	270

Source   :   Book Citation Index–Science (BKCI-S); BKCI-SSH is Book Citation Index–Social Sciences & Humanities (BKCI-SSH), 2005–2014.

APPENDIX H: Patents Output: PCT and MyIPO, 2001-2014

Year	PCT (Filed)	MyIPO (Granted)
2001	22	0
2002	56	0
2003	35	23
2004	64	24
2005	64	41
2006	117	126
2007	213	266
2008	238	202
2009	450	268
2010	475	199
2011	500	331
2012	494	304
2013	445	299
2014	438	378
Total	3,611	2,461

Data coverage ：PCT, 2001-2014; MyIPO, 2001-2014.

APPENDIX I: Patents Output by Malaysia Plans, 2001-2014

Malaysia Plan	PCT (Filed)	MyIPO (Granted)
8MP (2001-2005)	241	88
9MP (2006-2010)	1,493	1,061
10MP (2011-2015)	1,877	1,312
Total	3,611	2,461

Data coverage : PCT, 2001-2014; MyIPO, 2001-2014.

Note   : The scope of the study is from 2001 to 2014, while the 10MP covers the period 2011 to 2015.
              The recorded numbers are until end of 2014 (excludes 2015).

APPENDIX J: Public Research Institutions Ranked by Number of PCT Patents

No.	Institution	Patents
1	MIMOS Berhad	788
2	Malaysian Palm Oil Board	67
3	Malaysian Rubber Board	12
4	SIRIM Berhad	10
5	Malaysian Agricultural Research & Development Institute	9
6	Forest Research Institute of Malaysia	2
7	Institute for Medical Research	1

Data coverage : PCT, 2001-2014.

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TECHNICAL NOTES

Introduction

This report contains information on the performance of Science, Technology and Innovation (STI) in Malaysia through the overall production of scientific literature and patents during the period of 2001 to 2014.

Objective

The main objective is to assess the status of Malaysia's research and development (R&D) achievements at the national level, especially in identifying research performance that includes publications and patents in the field of STI and Social Sciences.

Scope and coverage

This report covers national research achievements in scientific publication in STI and Social Sciences and patenting activities. It also provides international comparison on knowledge performance in the form of publications, and innovation performance in the form of patents. Networks of collaboration between researchers and institutions at the national and international levels are mapped in this report. Key drivers, main challenges, institutional strategies and recommendations for policy directions in scientific publication and patenting activities are also presented in this report.

Four types of institutions are covered in this report, namely: government agencies and departments; public and private institutes of higher learning; research institutes; and private firms.

- Publications:

  Thomson Reuters Web of Science (WoS) databases, namely Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) and Essential Science Indicators (ESI) are used in this study. While SCIE and SSCI provide historical series of published data from January 2001 to December 2014, ESI provides historical series of publication citation and h-index of the top Malaysian institutions from January 2004 to December 2014. Also, Malaysian journal titles indexed by Elsevier SCOPUS are included in this study.

- Patents:

  Databases from Malaysia Intellectual Property Office (MyIPO) and World Intellectual Property Organisation (WIPO) are used in this study. These databases provide historical series of patent data from January 2001 to December 2014. MyIPO database provides data on Malaysia's patents granted to both local and foreign residents. The WIPO database provides data on Malaysian patents filed at WIPO.

Concepts and definitions

Concepts and definitions are based on the international guidelines proposed by the Organisation for Economic Co-operation and Development (OECD) in 'Bibliometric Indicators and Analysis of Research Systems: Methods and Examples' in the year 2007. These concepts adhered to the accepted practices, thereby facilitating international comparability of data.

This report uses publication and patent indicators as proxies to measure the scientific and technology stock and the impact of national scientific R&D outputs. Publication indicators reflect the scientific literature output measured by 'article and proceeding' count – in which 'publication' is used here to designate various media for scientific texts. The term 'paper' is used interchangeably with publication to reflect the scientific outputs. Patents can be either filed or granted. Patents can be further distinguished by the assigness and the filing office.

Reference year

The reference period for publication analysis is from January 2001 to December 2014.

Methodology   This report is mainly based on the quantitative study of publication and patenting activities in Malaysia. Nonetheless, in order to provide detailed insights into contextual factors that underpin research performance in the country, a qualitative study based on in-depth interviews with various key stakeholders in research performance systems is incorporated into this report.

- Quantitative Study:

  Analyses of scientific publication achievements are based on ISI publications data from Thomson Reuters Web of Science (WoS) database. In addition, this study extends the search of scientific publications in Malaysian journals using Elsevier SCOPUS database. The study also reviews various analytics extracted from Thomson Reuters SCIE, SSCI, ESI and Elsevier SciVal to provide a comprehensive analysis of Malaysian publications and patents at both local and international levels. This study mines citations data from Thomson Reuters ESI analytical database. ESI allows us to obtain its ten year (2004–2014) citation details (citations per paper and h-index of the top Malaysian institutions in publications) of Malaysian publications.

  Patent analyses are based on patents granted from MyIPO database. Also, this study performs our cross countries-level patenting analysis using patent applications filed under Patent Cooperation Treaty (PCT) under the International Patent Classification (IPC), which are studied in detail. This study uses two patent search engines (i.e. PatSnap and Nexus) to mine the patenting data. These search engines allow us to obtain the citation details of Malaysian owned patents in MyIPO and WIPO.

  VantagePoint software is used in this study for visualising scientific and technological networks of Malaysia. In addition, this study used PatSnap's 3-D landscaping add-on tool to highlight the technological competencies of Malaysia. This allows us to identify both core and niche technological areas that would develop Malaysia's technological market.

- Qualitative Study:

  A total of 27 in-person interview sessions that involved 65 interviewees – individually, or collectively as a focus group – were conducted over the four month period of June to September 2015. The interviewees are from various entities in the national research systems, namely: public and private universities; public research institutes (PRIs); and companies. Interviews are mainly to gather insights into various aspects pertaining to scientific publication and patenting activities, including: main drivers (e.g. policy, instruments, people, collaboration, etc.); challenges and constraints; immediate and long-term strategies; and public policy prescriptions.

Citations

Citations is a legitimate and practical tool for the assessment of impact of publishing and patenting activities.

h-Index

h-Index is a computable index which gives an estimate of the importance, significance, and broad impact of a scientist's (or organisation's) cumulative research contributions. An author has index h if h of his or her total number of publications (N_p) have at least h citations each, and the other ($N_p - h$) papers have $\leq h$ citations each.

Co-authorship

The network of co-authorship measures interactions and scientific relationships between networks, teams, institutions and countries that can be illustrated through the concepts of component and cluster.

Relative Specialisation Index

Relative Specialisation Index (RSI) indicates whether a country or an organisation has a relatively higher or lower share in publications or patents in a particular science or technology field than its overall share in the national total. RSI < 1 indicates a lower-than-average activity, while RSI > 1 indicates higher-than-average. RSI = 1 reflects a completely balanced situation. The RSI is calculated as follows:

$$RSI_{it} = (\frac{Pub_{it}}{\sum_i Pub_{it}})/(\frac{\sum_t Pub_{it}}{\sum_{it} Pub_{it}}) ,$$

where the formula indicates the ratio of the number of publications of an institution i in a particular field t, divided by the total number of publications at the national level in this field, and the number of publications of an institution under study in the whole field, divided by the total number of publications in the field at the national level.

Relative Impact Index

The Relative Impact Index (RII) indicates the citations per publication for an institution in a field divided by aggregate citations per publication at national level in that field. A value above unity indicates the relative citation strength of an institution in that field. The indices will provide information on the relative strength of an organisation in specific science and technology and its relative impact as compared to that of the national level. RII is defined as follows:

$$RII_{it} = (\frac{C_{it}}{Pub_{it}})/(\frac{\sum_t C_{it}}{\sum_t Pub_{it}}) \, ,$$

where the formula indicates the ratio of the citations of an institution i in a particular field t, divided by the total number of publications at the national level in this field, and the number of citations of an institution under study in the whole field, divided by the total number of publications in the field at the national level.

Growth Rate of Publications and Patents

Growth rate is calculated based on the present value at time t minus the past value at time t - 1 divided by the past value at time t - 1 multiplied by 100.

$$GR_t = \left(\frac{Pub_t - Pub_{t-1}}{Pub_{t-1}}\right) \times 100$$

ABBREVIATION

8MP	Eighth Malaysia Plan
9MP	Ninth Malaysia Plan
10MP	Tenth Malaysia Plan
C/A	Citations per Article
CoEs	Centres of Excellence
ERA	Excellence in Research for Australia
ESI	Essential Science Indicators
GII	Global Innovation Index
GCR	Global Competitiveness Report
ICT	Information and Communication Technology
IHLs	Institutions of Higher Learning
IIUM	International Islamic University Malaysia
IP	Intellectual Property
IPC	International Patent Classification
IPRs	Intellectual Property Rights
ISI	Institute for Scientific Information
KPIs	Key Performance Indicators
MARDI	Malaysian Agricultural Research and Development Institute
MASTIC	Malaysian Science and Technology Information Centre
MCC	Malaysian Citation Centre
MMU	Multimedia University
MOHE	Ministry of Higher Education
MOSTI	Ministry of Science, Technology and Innovation
MPOB	Malaysian Palm Oil Board
MyIPO	Intellectual Property Corporation of Malaysia
NKEAs	National Key Economic Areas
OECD	Organisation for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
PRIs	Public Research Institutes
R&D	Research and Development
R,D&I	Research, Development and Innovation
RII	Relative Impact Index
RSI	Relative Specialisation Index
RUs	Research Universities

S&T	Science and Technology
SCI	Science Citation Index
SCIE	Science Citation Index Expanded
SIRIM	Standards and Industrial Research Institute of Malaysia
SMEs	Small and Medium-sized Enterprises
SSCI	Social Sciences Citation Index
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
TTO	Technology Transfer Office
UiTM	Universiti Teknologi MARA
UK	United Kingdom
UKM	Universiti Kebangsaan Malaysia
UM	Universiti Malaya
UMS	Universiti Malaysia Sabah
UNIMAP	Universiti Malaysia Perlis
UNIMAS	Universiti Malaysia Sarawak
UNMC	University of Nottingham Malaysia Campus
UPM	University Putra Malaysia
USA	United States of America
UTM	Universiti Teknologi Malaysia
UTP	Universiti Teknologi Petronas
WIPO	World Intellectual Property Organisation
WoS	Web of Science

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