THE ROLE OF R&D AND UNIVERSITIES IN PATENTING AND SCIENTIFIC PUBLICATIONS, AND ECONOMIC GROWTH: A STUDY OF MALAYSIA

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FACULTY OF BUSINESS AND ECONOMICS
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THE ROLE OF R&D AND UNIVERSITIES IN PATENTING AND SCIENTIFIC PUBLICATIONS, AND ECONOMIC GROWTH: A STUDY OF MALAYSIA

ABSTRACT

Using patents, industrial designs, and scientific publications, this study examines the R&D performance of Malaysia over the period from 1996 to 2017. In doing so, the thesis also examines the state of research and patenting participation of Malaysian researchers, universities, and firms. Although not all patents eventually attract commercial value, given the complexities associated with R&D spillover, it is still widely used as an innovation output to support economic growth. In this regard, this thesis uses patent-to-GDP ratio alongside Catch-up Index estimate R&D expenditure and R&D performance gaps. The use of GERD-to-GDP is a weak indicator of innovative progress among particularly developing countries because a significant share of it do not go to supporting economic growth. Hence, studying this gap will allow us to understand the extent of commercialization that takes place from R&D investment in Malaysia. Using a variety of sources of national and international data on patent and growth, and the Error Correction Model, and Autoregressive Distributed Lag (ECM-ARDL) approach, we construct an analytical model using the theoretical concepts of Romer's endogenous growth on innovation and Griliches's knowledge production framework to advance this study, though we eventually criticize the Romer and Grichiches' models for not including innovation inputs (e.g., R&D investment) and output (e.g., patents, especially domestic patents). The model consists of patent, industrial design, GERD, fixed capital formation, employed scientific human capital and GDP growth to measure the process of innovation, and their association with economic development. The results show that both patents and industrial designs are significantly correlated with economic growth in the overall sample but is negatively correlated in the short run in the Malaysian data, though the long run relationship between Malaysian patents and the trade structure is positively correlated. Also, patent-to-GDP and industrial design-to-GDP ratios affect patenting activities in Malaysia. Consequently, while it is fine to continue the focus on scientific publications, the knowledge created should also be used to file patents and industrial designs. The science, technology and innovation (STI) infrastructure in Malaysia requires a revision to raise the focus on patenting and commercialization. Malaysia remains a strong candidate among the Asian-8 economies to make the transition to high-tech developed country status if the increasing trend of R&D investment is translated into patenting. That the potential exists cannot be dismissed as the country has witnessed a sharp rise in scientific publications since 2005. In addition, there is a need to improve university industry linkages to overcome such a shortcoming. In doing so, efforts must be taken to reinvigorate the science and number parks in Malaysia through requiring researchers granted research incentives and grants to undertake prototyping and new product development.

Keywords: Patents, industrial designs, economic growth, technological catch-up, Malaysia, developing country

PERANAN R&D DAN UNIVERSITI DALAM PENDAFTARAN PATEN DAN PENERBITAN SAINTIFIK, DAN PERKEMBANGAN EKONOMI: SATU KAJIAN TERHADAP MALAYSIA

ABSTRAK

Berpandukan paten, rekebentuk preindustrial, dan penerbitan saintifik, kajian ini mendekati prestasi penyelidikan dan kemajuan (R&D) Malaysia dalam jangkamasa antara 1996 hingga 2017. Dalam pada itu, tesis ini juga meninjau kedudukan penyertaan pengkaji, universiti dan firma Malaysia dalam penyelidikan dan pendaftaran paten. Biarpun bukannya semua patent akhirnya menghasilkan nilai komersil, memandangkan kerumitan berkaitan kesan rantaian R&D, ianya masih digunakan secara berleluasa sebagai kaluaran innovasi untuk mendukung pertumbuhan ekonomi. Dalam konteks itu, tesis ini menggunakan bahawa nisbah paten-KDNK bersama-sama indeks pengejaran boleh digunakan sebagai penghitung meninjau jarak antara perbelanjaan R&D dan prestasi R&D. Nisbah perbelanjaan kasar R&D (GERD)-KDNK adalah satu petanda yang lemah kemajuan innovasi terumanya antara negara membangun kerana sebahagian besar daripadanya tidak disasarkan untuk mendukung pertumbuhan ekonomi. Jadi, usaha untuk meninjai jurang ini akan memungkinkan kita memahami setakat mana pengkomersilan dijelma daripada perbelanjaan R&D di Malaysia. Berasaskan berbagai sumber data kebangaan dan antarabangsa terhadapa paten dan pertumbuhan, dan, *Error Correction* Model, serta pendekatan *Autoregressive Distributed Lag (ECM-ARDL)*, kami membentuk satu model analitik dengan menggunakan konsep teori pertumbuhan endogenous Romer dan kerangka pengeluaran pengetahuan Griliches untuk memanjangkan tinjauan ini, meskipun kami akhirnya mengkritik pendekatan Romer and Grichiches yang tidak menggunakan input (contoh: pelaburan R&D) dan hasil innovasi (contoh: paten, terumanya paten dalam negara). Modelnya mengandungi paten, rekabentuk perindustrian, GERD, bentukan modal tetap, modal minda saintifik yang dilantik dan pertumbuhan KDNK untuk menghitung proses innovasi, dan hubungan mereka dengan pembangunan ekonomi. Dapatan menunjukkan bahawa paten rekabentuk perindustrian berkorelasi kuat dengan pertumbuhan ekonomi dalam sampel keseluruhan tetapi ia menunjukkan korelasi negatif dengan pertumbuhan ekonomi Malaysia dalam jangkamasa pendek biarpun hubungan ini positif dalam jangkamasa panjang. Selain daripada itu, nisbah paten-ke-KDNK dan rekebentuk perindustrian-ke-KDNK mempengaruhi kegiatan kelulusan paten di Malaysia. Dengan itu, sementara tumpuan keatas penerbitan saintifik baik, pentehuan yang dijanakan itu perlu digunakan bersama untuk memohon paten dan rekabentuk perindustrian. Infrastruktur sains, teknologi dan innovasi di Malaysia perlukan rombakan demi menambahkan tumpuan keatas kegiatan pendaftaran paten dan komersialisasi. Malaysia masih kekal sebagai calon teguh antara Asia-8 negara untuk mengalami peralihan kepada taraf negara maju berteknologi tinggi jika peningkatan pelaburan R&D dapat dijelma dalam kegiatan pendaftaran paten. Bahawa kewujudan potensi tidak dapat di tolak kerana negara ini telah mencatatkan kenaikan curam dalam penerbitan saintifik sejak 2005. Tambahan pula, adalah perlu untuk mengukuhkan hubungan talian university-industri demi mengatasi kekurangan itu. Dalam pada itu, usaha perlu diambil untuk memulihkan taman sains dan teknologi menerusi penekanan terhadap penyelidik yang menerima insentif dan geran agar mereka menjalankan prototaiping dan pembangunan barangan baru..

katakunci: Paten, rekabentuk perindustrian, pertumbunhan ekonomi, pengejaran teknologi, Malaysia, negara membangun

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I hope the learning that my supervisors gave to me will never go to waste. Once upon a time, I pledged and will continue to do so at the bottom of my heart with the following quote:
"As academicians, we cannot afford to operate in silos but we need to connect with one another for knowledge sharing."

Thank you to both Professors. You are always the champions in my heart and mind forever.

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LIST SYMBOLS AND ABBREVIATIONS

APEX	Accelerated Programme for Excellence
AR/ARDL	Autoregressive Distributed Lag
ASEAN	Association of Southeast Asian Nations
BERD	Business Expenditure on Research and Development
COEs	Centre of Excellence
CUSUM/CUSUMSQ	Cumulative sum; cumulative sum of squares
ECM	Error correction model
EMPHC	Employed tertiary educated human capital
EPO	European Patent Office
EU	European Union
FDI	Foreign direct investment
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GFCF	Gross Fixed Capital Formation
GLC / GLIC	Government-linked companies
GRI	Government research institutes
HC	Human capital

HEI	Higher education institutions
HICoE	Higher institutions centre of excellence
HSIP	Hsinchu Science-Based Industrial Park
IC	Integrated circuits
ID	Industrial designs
IND	India
IRPA	Intensive Research Priority Areas
IP or IPR	Intellectual Property Rights
IPC	International Patents Classification
JPN	Japan
K	Capital
KOR	South Korea
KPF	Knowledge production framework
KPI	Key performance indicators
KIST	Korea Institute of Science and Technology
KAIST	Korea Advanced Institute of Science and Technology
KINS	Korea Institute of Nuclear Safety
KIET	Korea Institute for Industrial Economics and Trade

ETRI	Electronics and Telecommunications Research Institute of Labor
MNCs	Multinational corporations
MyIPO	Malaysia Intellectual Property Organization
MYS	Malaysia
NIS	National Innovation System
OLS	Ordinary Least Squares
PAT	Patents
PCT	Patent Cooperation Treaty
PTID	Patents and publications
PUB	Publications
RU	Research University
R&D	Research and Development
RSE	Researchers, scientists and engineers
SDG	Sustainable Development Goals
SME	Small medium-sized enterprises
SOEs	State-owned enterprises
STEM	Science, technology, engineering, and mathematics
S&T or STI	Science, technology and innovation

TFP	Total Factor Productivity
TTO	Technology Transfer Office
TVET	Technical and Vocational Education and Training
UIG	University, industry, government
USA	United States of America
USPTO	United States Patent and Trademark Office
WIPO	World Intellectual Property Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Research and development (R&D) is defined as systematic creative work undertaken to increase the stock of knowledge based on basic research, applied research and experimental development, which is then used to invent new applications (OECD, 2013) while basic research is defined as the experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

Basic research is an important collaboration and feedback loops to the R&D activities in the innovation chain. It is part of the NIS to either create various intermediate goods or discover a technology breakthrough. Such knowledge-based begins with a linear flow of interrelated activities starting from basic research to applied or production of the goods or services and then knowledge diffusion takes place to improvise it or a new creation can be produce in conjunction with the effective regulatory actions until a mission target is reached. It can go through multiple development paths, some adjustments along the way, to create new scientific ideas or knowledge which may or may not be commercialized immediately but serves as a basis for commercial products in the long term as shown in Figure 1.2.

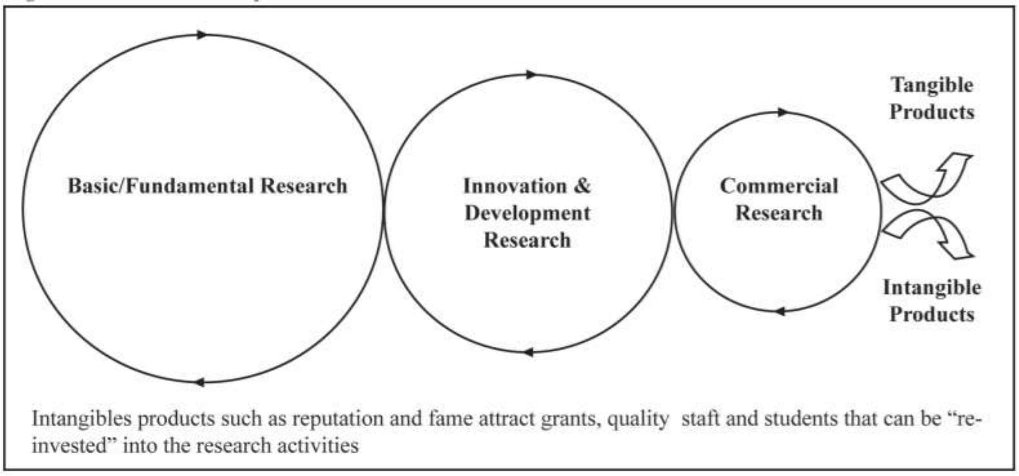

Figure 1.2: R&D Drivers

Source: Zainuddin (2004)

Beside basic research, another part of the NIS is the universities. The universities must make profit to be financially sustainable. As such, Rasiah (2015, 2017; see Figure 1.5) found that the government plays an important role to expand S&T not just to drive education advancement but also to produce sufficient pre-employment high-skilled labor force to drive industrialization progress as net exporter country. This can revolutionize the higher education system in the Malaysian universities to foster more innovation by upscaling their research capabilities and laboratories to stay financially sustainable, attract more targeted investments to strengthen competitive industries program and high-skilled employment opportunities.

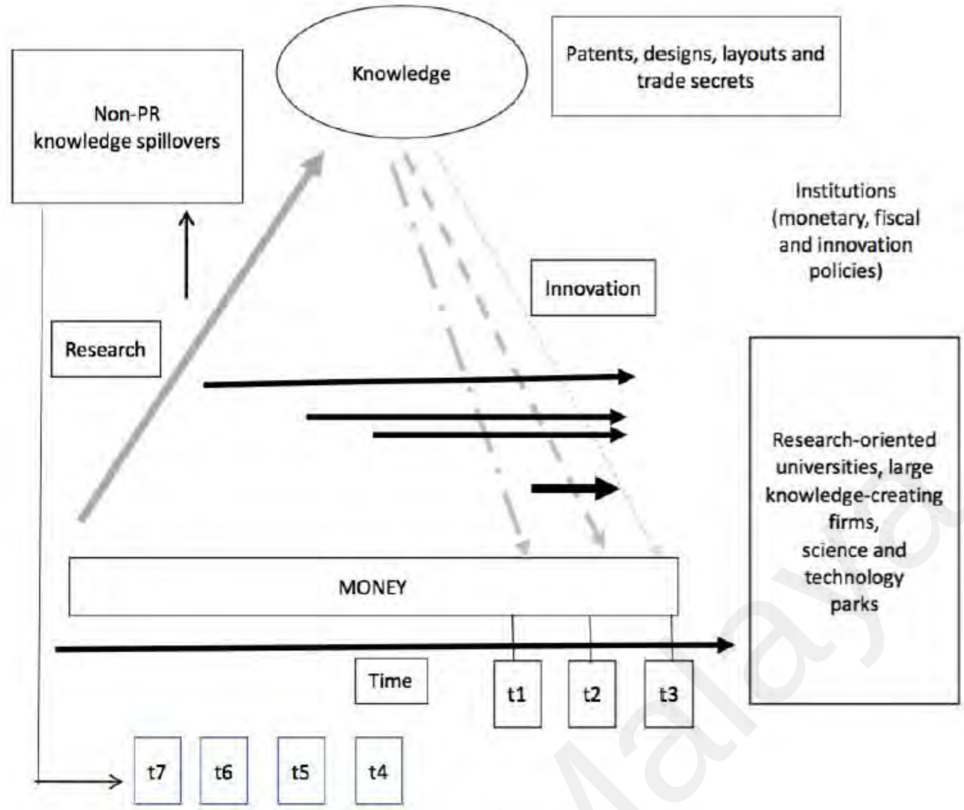

Figure 1.5: New stock of knowledge speed up innovation on latecomers when new knowledge is appropriated without paying for it and sell products from t4 to t7 while incumbents only sell at t1 to t3

Source: Rasiah, 2017

Hence, the study is motivated to link the innovation and economic growth and investigate the grassroot levels that impede the speed of research and innovation in universities and seek to address the gap within the appropriate model that measures the types of R&D for the period between 1996 to 2016 (Chapter 3), but not to dismiss the previous efforts done in Malaysia. In particular, the thesis will examine the importance of patents and basic research as the economic indicators to innovation activities and a country's economic growth. Basic research will accelerate the development process and generate deeper understanding to expand fundamental knowledge. The work of Mazzucato (2018) is that the government must be mission-oriented on basic fundamental research which are realistically feasible within given time period and not solely prioritizing applied research as the former can have dynamic stimulators to multiple sectors on the horizontal policies such as education, skills, training and innovation and vertical policies by industries such as healthcare, modern farming, environmental, etc which will enhance the entire R&D value chain.

Past studies seem to show that the growth of technological progress and higher education market in developing countries are part of the economic advancement process but have not been similar to those of developed countries due to differences in political, economic and social structure across countries. Hence beside to investigate what impede the speed of R&D innovation to economic growth, this study is also motivated to re-examine the role of government in incentivizing firms to make more advances in conducting basic research and to offer some tentative answers on the important role of R&D in universities to enhance fundamental technical knowledge and to advance Malaysia as a scientific nation. However, many past studies in the last 10 years (2007-2017) had largely overlooked or is not niche enough to identify the root cause to underdevelopment when it comes to developing countries despite high spending on R&D. Scientific and technological innovations cannot arise if there is weakness between R&D investment and policies associated with research activities and patents that could vary between countries, as concurred by health science Professor Zainul Zainuddin from Universiti Sains Malaysia (Zainuddin, 2004).

1.2 R&D, Patenting and Economic Growth

Patents and industrial designs are proxies for innovation measured by R&D expenditures, patents, patent's bibliographic publications and RSE resources. Among these, patent's publications also set to measure the size and spread of the technological activity and invention process. Past estimates suggest that there are positive impacts between R&D expenditures, patenting and productivity but trade-off between stern or weaker IP rights would not be addressed in this study. It is widely recognized that R&D

has primarily been a positive critical determinant of long-run growth and GDP per capita of a country. For example, the positive impacts arises in OECD countries when tax relief given to firms to deduct from their taxable profits or allowing quick depreciation on the machinery and buildings used for R&D purposes have created positive and significant spillover effects. This induce firms to performed R&D on their own to stay ahead of competition in the international market and align with national innovation target, and not solely waiting for government funding alone.

Furthermore, selection on the type of R&D is crucial, therefore Schumpeter (1934: 61-62; 1942) had distinguished incremental and radical innovations with the former defined to include all changes and adaptations made to existing sources of knowledge, technologies and products while the latter set to include more scope in both the creation of new stocks of knowledge and the adapted diffusion of existing sources of knowledge and technologies that radically transform different industries. While Schumpeter (1942) had glorified large firms for their ability to finance R&D at the frontier, the development of knowledge networks that connected the individuals, firms, organizations also have enabled and benefitted small firms to undertake such activities at the frontier (Rasiah, 2019). Connectivity and coordination between these socioeconomic agents have first created the triple helix in several countries (Etzkowitz, & Leydesdorff, 2000; Tsai and Cheng, 2006; Best, 2001, 2018), and subsequently formed quadruple helix in countries when societal based value-add to co-evolute and develop massive knowledge networks of relationships to raise knowledge democracy supporting the regional innovation system, such as Sweden (Rasiah, 2019).

With the formation of knowledge networks, the traditional growth models pioneered by Robert Solow[1] that technological progress as an exogenous output that vary with time have been superseded by new models developed by Romer (1986) which indicated that technological progress and new knowledge are in fact endogenous to the amount of investment made although R&D and as a costly activity. So, a well plan on what types of R&D to invest will avoid insufficient allocation of resources to the productive sectors.

The above kept the sense of urgency on basic research patenting as a tool to test knowledge creation and application thus the role of government is extremely important to coordinate these activities productively, particularly when ASEAN countries predominantly good at import-based exports of intermediate goods. Catching up and leapfrogging of a developing country with the developed countries would not be possible without sufficient investment in basic research which is aim at strengthening a country to be a circular economy innovation (Chapter 2). The concerned is also highlighted in the UNESCO study on Science Report Towards 2030 (UNESCO, 2015) whereby Asia Pacific has rapidly emerged as technological powerhouse, but by reducing a substantial amount of basic research or good science by some governments to reduce overall debt issues could have short-sighted solution due to such R&D spending implementation not knowing the negative implications to innovation community.

Furthermore, a country's innovation systems is also heavily reliant on the higher education system which remained one of the highest coffer in government spending. This is because high-wage states must be nurtured with a well-educated workforce, but this will certainly increase the government spending to bolster economic growth. The R&D

[1] Solow and Swan (1956) presents that increase in GDP are caused by technical progress, capital or labor input per unit of time, but dismissed diminishing returns of scale caused by those inputs and assume perfect substitution between labor and capital, and investment has mobile to move from one location to another more attractive location.

benefit from these investments have make many countries embarked on complementing higher education with R&D investment. The key element to radical innovation is to change how the way both the physical and human capital are used. On productivity, it is empirically revealed in economic theory that R&D innovation stock and technology have significant long-run impact on output and total factor productivity rate (TFP). However, short-run impacts tend to be mixed.

For Malaysia, such mission to raise patenting activity have become more challenging when scientific higher education milestones have shown a continuous falling trend and interest among students as a study discipline and a profession of choice (Cheong and Selvaratnam, 2019). The challenge is although higher education[2] is among the common economic indicators of scientific advanced countries to produce high-wage states with high literacy rate or skilled workforce, it may be insufficient to depend on a pool of tertiary-educated workforce to leapfrog the economy. Tertiary education is not a good replacement to technical education. Consequently, spending on higher education alone to boost economic development will not be able to upskill to higher value-added scientific activities unless reskilling is integrated to improve the capability of the students that eventually become part of the workforce, a finding which the European Commission coined as *European Paradox*[3].

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[2] Refers to education beyond high schools and is often measured by education attainment.

[3] Phenomenon of having good higher education systems, good R&D infrastructure in European region but failed to translate these huge investments into marketable innovations including basic research activity. Worst still, top 10 most innovative companies in Europe are not European origin.

1.3 R&D Trends in Science, Technology and Innovation Infrastructure

In the past, R&D activities[4] are concentrated in developed countries such as United States (US), European Union (EU), Japan, South Korea, and Taiwan with more matured R&D policies. Since R&D is proven to benefit economic growth, Brazil, Russia, India, China, South Africa (BRICS) countries and the Association of Southeast Asian Nations (ASEAN) have taken this on seriously in their development plans and raised their R&D expenditure in GDP (UNESCO, 2015). With such R&D spending trend, the Asian countries are accounted for 41.8% of global R&D (Industrial Research Institute, 2016; Svensson, 2008). Figure 1.1 shows the R&D expenditure in GDP (GERD) of selected countries in 2015. Figure 1.1 also shows that in contrast to popular perception, notably that the small countries such as Israel, South Korea and France are also leading in the GERD and basic research to total GERD in a relative measure among these countries to their R&D expenditure.

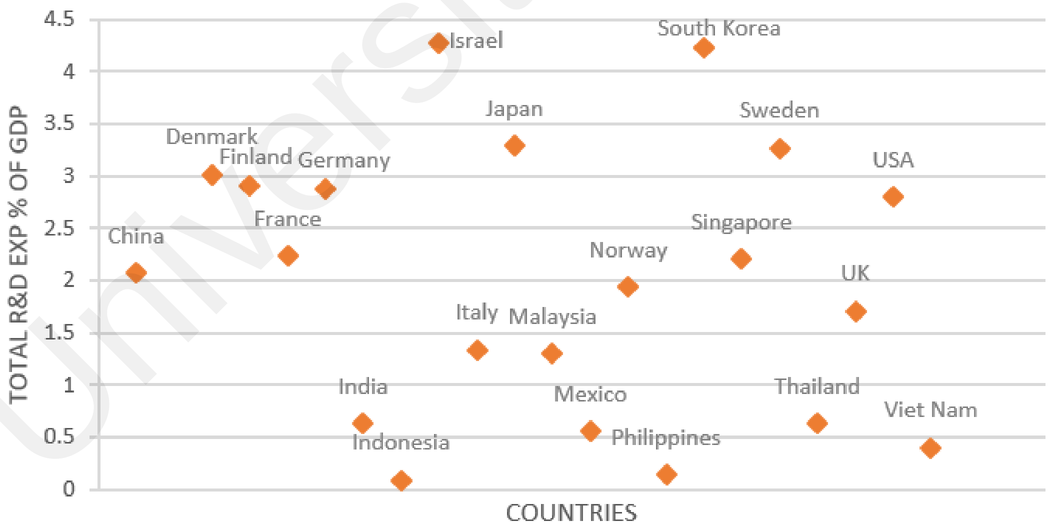

Figure 1.1: R&D Expenditure in GDP, Selected Countries, 2015 (%)

Source: UNESCO UIS Statistics (2020)

[4] These include any forms of intellectual property such patent, industrial design, copyright, trademark.

OECD countries shown a classic case that basic research experiment is now public sector or education driven. As of 2012, on average 77% of basic research expenditures were performed by the government and higher education institutions (OECD, 2013). Compared to 2004, the OECD countries' growth in R&D investments was previously largely driven by the private sector (68%), followed by universities (17%, majority funds goes to government-owned universities) and public sector (12%).

This included major upper-middle income countries and Malaysia were R&D and higher education initiatives were established as the driving force behind clusters of innovation ecosystem to accelerate the economic performance, acquire new funding to upgrade domestic capability building and new job creation in new industries. This marked an important change that not necessarily only developed economies can be successful in R&D but it is possible for the latecomer economies such as South Korea and Taiwan which have mission concerted effort to first gain understanding, upgrade within same industry and subsequently leapfrog to enter a new promising industry[5].

To enhance the pace of development and close the gap with the developed country, the universities then play a crucial role in generating sufficient basic research impacts to the next level (such as applied research or prototype) to improve scientific knowledge, forge close partnerships with the industry and government, boost economic development and create high quality, high-skilled, high-tech jobs. While creation of basic research IP is not the end itself, it reinforces the universities to take greater responsibility on the graduates' productivity and employability to institutionalize the innovations into a

[5] Semiconductor firms in Korea and Taiwan started from integrated circuit (IC) packaging or testing (low value-added activities), then moved to IC fabrication and eventually to IC design (highest valued added). Tatung in Taiwan has made successive entries to new activities since 1960s, starting with black and white TVs in 1964 to TV chips integrated circuits (ASICs) in 1980s, and workstation clones in 1989. Samsung Group in Korea began with light manufacturing industries such as textiles, then entered consumer electronics, followed by semiconductors, telecommunications equipment, and flat panel displays.

product through incubation centers in particularly when most developing countries are required to transform their manufacturing sectors and manufactured goods in the future.

To advance these industrialized developing countries, the three key drivers to support competitiveness of a country's economic growth cannot be neglected such as (1) factor accumulation, (2) high-skilled labor force, (3) scientific and technological progress i.e. patents intensity and innovation on patent-intensive industry, because it interacts between the meso-organizations i.e. universities, laboratories and incubators[6], and STI policies (described elsewhere in Chapter 2). The take off in manufacturing with transformative R&D as a public good may generate positive social rates of return but largely determined by industry competitiveness, IPR rights, subsidies to R&D costs, spillover effect from foreign know-how and university research, and size of the knowledge workers. But when the fundamental change in basic research to patenting is weak in most countries, it has hampered the process and techniques of implementing behavioral changes in improving patenting standards in the country.

So, a strong industry required R&D expenditure (GERD) such as Gross Expenditure on R&D and Business Expenditure on R&D to promote industrial value creation in the innovation growth. It involved commitment not only by the public sector but also the private sector (Williams et al., 2013; Hsiao et al., 2012). Beside higher GERD, the innovation growth should consider the bibliometric indicators and IP rights which are also essential to understand the size, growth and global spread of research that leads to higher innovation rate (Meo et al., 2013; Hu & Png, 2010). Although GERD is essential, but the shortcoming is that is not an accurate indicator to get the entire economy to catch-

[6] Rasiah (2014) reported that gap has widen between ASEAN countries innovation capabilities although Malaysia is the second highest take up of patent in US after Singapore (Table 1, p.1), and should have coordinated technological catch up policy to strengthen the meso-organizations and solve collective problems and needs.

up with the developed economy in terms of R&D performance on the quality of creativity and appropriate research environment.

Instead, patents accumulation would give a competitive advantage to the country's high quality research environment regardless they are the exporting country or is a recipient country like the Germans. First, the occurrence of R&D spillovers to other firms or countries can lead to rising returns to scale. Second, it enhances the economic integration between at least two countries or more. Third, this explained much of the variations on per capita income between countries due to increasing returns on such properties in a different ways. Thus, it becomes increasingly clear that capturing these research innovations leads to improvement of living standards multifold, incentivize the human capital to create new knowledge and for policy makers to understand the types of R&D activities that should take place to drive growth in the long run.

As a pro-growth policy, we should also consider taking government budget as a constraint. Naturally, increase number of firms will lead to higher patent competition but may not correct the failure on lower productivity or lack of resident patents. Haruyama (2015) reckoned to subsidize high productivity firms while the low productivity firms should be taxed so as to allow resources be utilized optimally, thus forcing the low productivity firms to exit, and shift these resources from low to high productivity firms for innovation to accelerate.

Therefore, proactive attention lies in linking the science, technology and innovation communities and capture these interactions to promote research within all universities, and not just research universities. Investment in R&D and higher education have positive correlation on long-run economic growth. Meanwhile, patent-intensive industries will benefit more from the human capital accumulation and stronger patenting activity. It reinforces the multiplier effects on scientific outcomes when sufficient human capital formation with innovation output to make tertiary education technical and realistic enough to be the driving force rather than purely academic certification. Such positive effects are for every 1% education expenditure will increase GDP growth by 0.9% or every $1 spent will increases GDP by $20~$21 (Carmignani, 2016). Sahin (2015) also found a 1% increase in R&D spending (GERD) is projected to increase GDP by 0.61%, and Inekwe (2014) found the R&D expenditure eventually increases 0.08 % in real GDP for upper middle-income countries. Bassanini & Ernst (2002) found that positive externality stemmed from R&D was influenced by the education level, and Hu & Png (2010) showed that a 1% increase in patent rights is associated with 11.1% increase in annual growth for patent-intensive industries such as pharmaceutical, life sciences, chemical, and biotech industries.

1.3.1 Why Malaysia R&D is at a crossroad

According to Industrial Research Institute (2016, p.12), Academia spends the highest allocation of GERD on basic research 56% and Asia is still left behind in terms of basic research spending compared to US and would be worst if China, Japan, South Korea, Taiwan and Singapore are excluded (IRI, 2016, p.25). Clearly Malaysia has an important role to play in Asia if the increase in higher education and S&T-related spending can be translated into competitiveness for the country but in actual it failed to do so.

In the early 1990s, Malaysia and China began economic reforms to transition themselves into high-income country (Rasiah, 1999; Zhang & Rasiah, 2015). In the early days, both countries including Japan and South Korea had to be large scale technology importer in order to speed up the innovation system as their preferred catch-up process. Along their expansion paths, different approaches are noticeable on how both countries contributed differently to sustain their own NIS.

China started huge reforms and mobilized a lot of resources in its quest to become world leading innovation using the National Middle to Long Term Plan for Science and Technology Development 2006–2020. Their NIS was originated from investment-driven approach back in 1980s but something was amiss. The ratio of basic research to GDP was still extremely low compared to many developed countries although the total R&D expenditure to GDP was double-digit growth year-on-year. The basic research in China only accounted for 5.1% of total R&D spending compared to OECD average of 22%, 30% in Switzerland, 17.3 % in the US, 12.3% in Japan, 13% in Israel, 25% in South Korea, and 25.3% in France (Liu et al. 2017; UNESCO 2018). Although basic research ratio to total R&D spending is relatively lower than OECD or EU average, the success of China catch-up comes from the 97%; an extremely high success rate of experimental development which ASEAN countries have no capability to catch-up with. But the Chinese government also foresee potential flaws to stay competitive in the long run against the large frontiers e.g. US and Japan. Thus, the Chinese government quickly shifted its focus to be innovation-driven since 2013 and developed niche S&T policies such as Program 863 (for applied research), Program 973 (for basic research; to be describe further in Chapter 2) (see Figure 1.2) and Tuspark[7].

[7] Tuspark is a purpose-built science park by Tsinghua University.

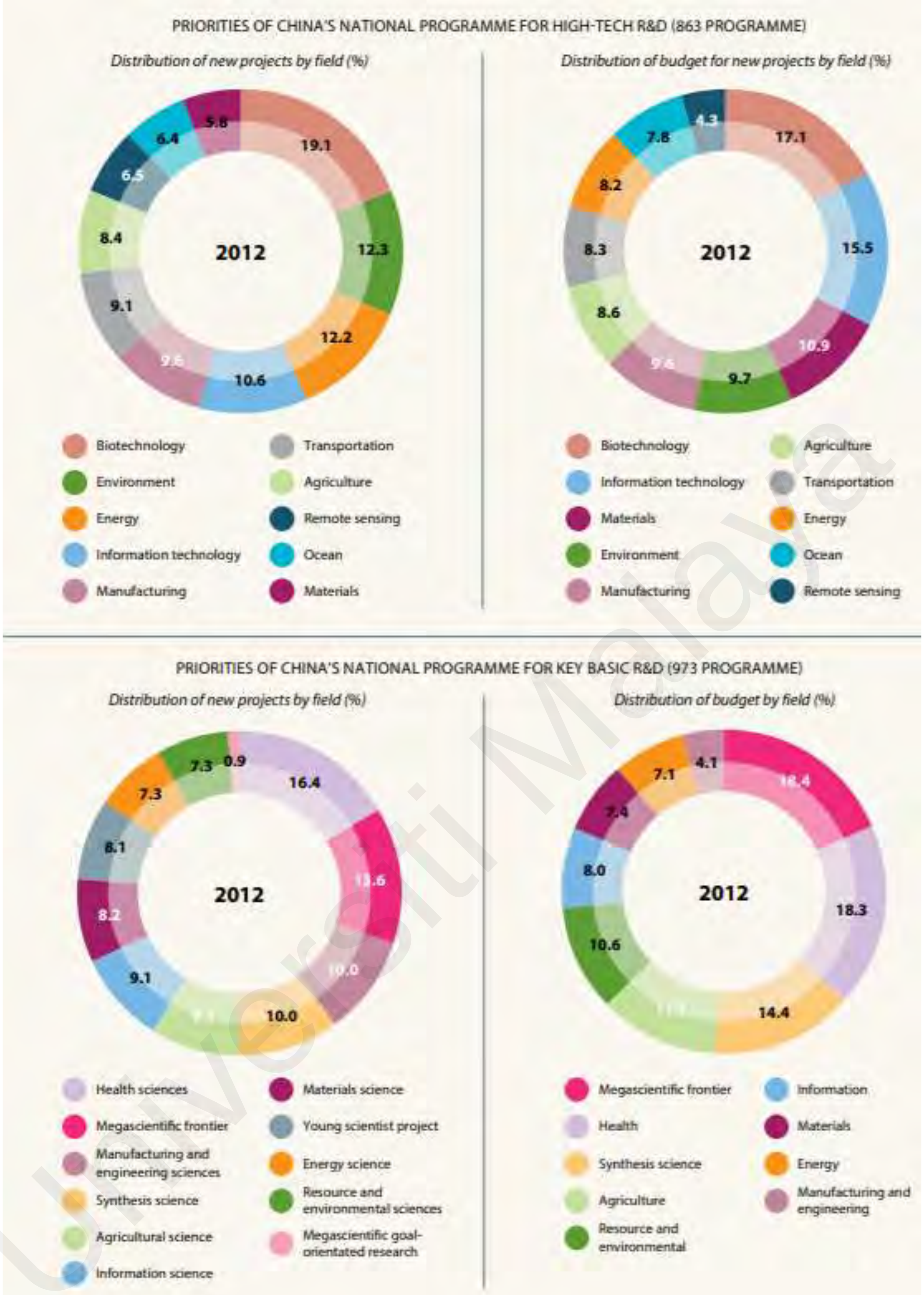

Figure 1.2: Priorities of China's Basic Research and High-Tech R&D 2012

Source: Ministry of Science and Technology, 2013

The stimuli for academic internationalization pursuit in higher education can vary. For-profit universities aim at profit generation and establish new entities with overseas links while the nonprofit universities aim to enhance research capacity and increase cultural understanding (Altbach & Knight, 2007). Faced with globalization, higher education system and R&D has become more complex and commercial-driven than ever to transform into entrepreneurial university concept to focus on commercializing industrial research, attracting high-tech talents and spin-off high-tech companies.

Similarly, the Malaysian government did made serious effort to raise economic growth using tertiary level education and basic research as the pillar of growth from 11% to 34% but the low level of experimentation 15% have undermine the R&D investment in basic research to gain more comprehensive knowledge under observation or competing to catch-up against the technology frontiers. Though structural and economic reforms in the higher education system were done since 1970s via a centralized education system, the priorities are just for Malaysia to invest dramatically in its higher education and R&D expenditure since the adoption of Malaysia Higher Education Blueprint 2015-2025 but not for Malaysian industries to enable owned technologies as the essence of R&D. Each university have implemented their own national grant policy including the 5 research universities modelled after successful South Korea and Singapore. In addition, public and private sectors have undergone massive higher educational policy reforms to develop their high skilled human capital since 1990s but weakness still persist in the creativity on productive resources.

Since the Eighth Malaysia Plan till 2021, various policies to help capacity building such as the generic National S&T policy have increased R&D spending to 1.5% of GDP, recruitment of 60 RSE per 10,000 labor force, and encouraged cluster technopreneur such as Malaysia Super Corridor, Malaysia Digital Free Trade Zone hubs, and MOSTI's

Malaysia Grand Challenge to commercialize products, create more job opportunities and enable the facilitation of collaborative-based innovation. Many public grants such as FRGS, HRDF, DAGS, IGS, MGS were also made available and entities such as MOSTI, MDEC, Academy of Sciences, etc. were set up.

Various positive developments took place in the 1980s to speed up technological progress such as Look East Policy, liberalization on private HEIs after 1986 with the Private Higher Education Act 1996, first APEX university USM, STI focus in RMK-11, and Shift-7 Innovation Ecosystem in Malaysia Education Blueprint 2015-2025 to transform Malaysia from an importer to an exporter on education with year-on-year compounded annual growth rate (CAGR) at 11% (to as high as 16%) demand increase from local and international students (see Figure 1.3).

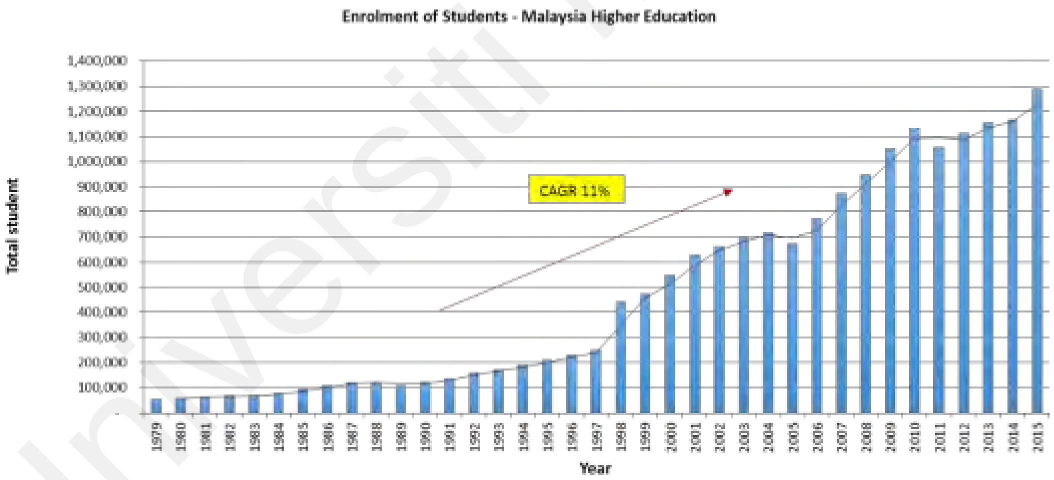

Figure 1.3: Annual enrolment of students in Malaysia higher education from 1979 to 2015

Source: Author 2016; MOHE 2016; UNESCO 2016; Sivalingam 2007

As of 2021, there was a total of 637 HEIs and 1295 TVETs in Malaysia (MOHE 2016; MyRIVET 2022). With the expansion plan, Malaysian universities and country ranking have improved but leads to rising public expenditure on higher education and R&D. While Malaysia are not shortfall in number of universities in the country, quantity does not imply quality on the research and patenting environment. Five of the public universities were upgraded to research university (RU) in 2006 and given additional R&D funding. But the development of university system in Malaysia (and even entrepreneurial university agenda) is still at infancy stage compared to RU in developed countries such as US, UK and Germany. Not discourage by the impact of the Covid19 crisis, the plan was also supposed for the universities to generate income on their own for R&D fundraising in the future. The explosion in the number of universities have raise the students' enrollments and mostly came from the growth in private tertiary education. This has raised the amount of basic research R&D on the surface nationwide but lack the ability and speed to commercialize the creation of new ideas which are competitive in the international market and be mission-oriented to address Malaysia societal gaps.

Since many past studies also suggest centre of excellence can be a positive path for innovation and socio-economic development, the Malaysian government jumped on the bandwagon to seek the universities to established higher institutions centre of excellence (HICoE) and MOHE implemented the industry clusters to further enhance academic excellence and entrepreneurship skills development in various fields from farm-to-firm kind of concept. During the HICoE boomed era, Malaysia GERD spending increased from 0.46% to 1.29% of GDP from 2000 to 2020 as shown in Figure 1.4. Although size of the R&D spending has grown but not the number of scientists and engineers[8] had slow growth from 2010 to 2015 before it peaked at 2016 and declined till 2021 (MOSTI, 2022). Unfortunately, the BERD-to-GDP also fell during the same period. The GERD-to-GDP and RSE are critical complementing growth factors to move fast enough, or it has stagnated. The trend of declining BERD-to-GDP implied the Malaysian firms are less prioritizing R&D due to resource constraint. As a nation, Malaysia only aims to spend 2.5% GERD-to-GDP by 2025 can be slow to react to nearby regional competition from other countries and post-Covid spending on R&D might deviate this national target entirely. Many of the successful innovation economies in East Asia such as Taiwan, Japan, South Korea, Singapore and China have increased their GERD-to-GDP beyond 2% accompanied by an equivalent size of increase of RSE or larger to get the outcome that the government wanted.

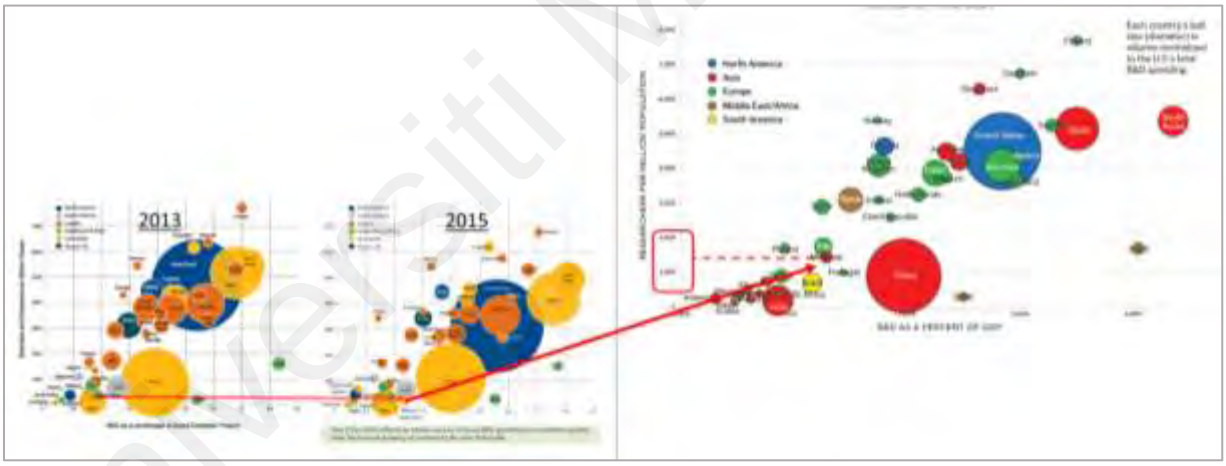

Figure 1.4: Malaysia gross expenditure on research and development from 2013 to 2020

Source: R&D World 2020; Industrial Research Institute 2016

[8] Fastest growth of RSE was only for a short period of time from 2008-2010.

In terms of the Malaysian population literacy rate, it have improved for primary-education and secondary-education but the attainment of 30% tertiary-education is still rather low based on OECD observation in 2016. To produce the desired effect, Malaysian universities are required to work closely with the industry and government to improve research and innovation that bring meaningful impact and to produce high-skilled graduates that match the competencies of advanced countries; way beyond the traditional behavior of just increasing the scale of tertiary-educated population but the Malaysian TVET still generate least a clue to raise technical education to be the Malaysian preference of choice of work and study. Arguably, the declining interest of scientific studies, the weakness of TVET schools, talent attraction and private staff retention program that does not work will make Malaysia worst off to head forward solving any existing problems and needs, or stay ahead competitively. Although recent years Malaysia has successfully diversified the economy into new sectors to generate new sources of income rather than over dependency on depleting oil and gas-related revenue to fulfil the SDG Global 17 goal to promote sustainable development. Such diversification strategy is merely income growth but not high skill-wise and high productivity. Labor productivity issue have been constantly highlighted by Malaysia Productivity Corporation.

Another issue was the publications output rises but lack citation impact although co-authored internationally. It is certain the aforesaid Malaysian initiatives have been promising and contributed to positive growth but weak in impact to the scientific community. All in all, the lack of local R&D activities, right infrastructure and patenting policies have taken a toll to the poor R&D performance in Malaysia which been highlighted in the Twelfth Malaysian Plan 2021-2025. Thus, the Malaysian government needs to have a different approach compared to the last 40 years since industrialization took place.

The major shortcoming is neglecting basic research to become high-income country for a long period have limited the growth on educational innovation. The proportion of basic research in Malaysia is low[9] thus affecting the next stage ended up with a lower experimentation research to commercialize into output (MOSTI, 2015, pp.11-12). Without any concrete base of basic research S&T policies, it would not boost its long-term competitiveness indicating such economic development strategy in Malaysia may have reached its limits.

Another shortcoming for Malaysia is that the country no longer can depend on the assembly of foreign products through the use of foreign patents and foreign technology alone, making the country unsustainable to any technology advancement. Rapid industrializers have shifted from manufacturing through the use of imported technology to innovating endogenously by actively pursuing policies to file resident patents to increase capability building, business innovation and competitiveness.

Universities have played a key role in the newly industrialized countries of South Korea, Singapore and Taiwan with China rapidly closing the gap. Although scientific publications have risen since 2006, Malaysian universities still fall behind against these countries when it comes to patenting and commercialization. Also, the R&D expenditure in GDP (GERD) and S&T staff in population have also been relatively low (TN2050; See also Rasiah, Salih and Cheong, 2021). Although the new 30-years vision national transformation plan is a sign of commitment to leapfrog the country on quality structural reforms through innovation to become a high-income advanced country, it does not provide a clear roadmap to achieve it.

[9] Applied research accounted for 50.5% compared to a lower 34% basic research and worst only 15% experiemental research when compared to Singapore, South Korea and Taiwan. Only 2% of this move from each stage of research based on MOSTI Science Outlook 2015 report. This would imply that 98% of the R&D funding ended up wasteful and inefficient allocation of resources.

1.4 Critical Issues

Despite all the transformation efforts to-date and enrolment has increased, the development outcomes are still failing to meet national objectives. As Malaysian society becomes more educated, high-skilled labor and talent start to emigrate to developed countries (such as Singapore, Australia, Europe, US for work and residence) in hope for higher standard of living for their future generation. Consequently, the higher education sector in Malaysia has been struggling to demonstrate innovative capacity building unlike countries such as US, Japan, South Korea, Taiwan and Singapore, although enrolment and education expenditure has increased, and 70% of the working-age population are between 15 to 64 years old. The disintegration results could be getting worse once Malaysia enter into an aging population country by 2030.

Malaysia's innovation and higher education is unable to close the gap with the developed countries due to poor performance from the connected issues below:

(1) The increase in R&D spending and grant do not commensurate with the low commercialization rate. For example, HLI has the highest commercialized products of 92 unit but only represent a small fraction (5-10%) when compared to GRIs and BEs commercialized products, and NGO had zero patent license. The GRIs (197 out of 930 unit) and BEs (149 out of 2850 unit) technology know-how licensing was mediocre have not created any significant milestone (EPU Twelfth Malaysia Plan, 2021).

(2) Malaysia failed to turn the 34% of basic research investment into new intermediate or finished goods. Low ratio of basic research commercialization poses a threat to remain sustainable as a high-income country. The 34% basic research claimed by UNESCO is potentially an incorrect representation and may not bring more local innovation without monitoring the country's quality of research and how it is spent. The Malaysian government is investing much lower than average EU region of over 50%,

(3) Low productivity output to create publications and patents (PTID) and commoditize them generated little GDP revenue. In addition, net revenue from patent has been in deficit till present. Dominated by non-resident patents, only 3 RUs are active applicants and bibliometric has low citation rates. Malaysia patents (six times) and industrial designs (fifteen times) grew much slower than trademarks from 1983 to 2016. Trademark has little commercial and economic values among the three as it is not attached to any technologies,

(4) The Malaysian NIS remains weak and RSE have limited access to advanced high-end technology to support frontier innovation, and the performance of the 16 HICoE deliverables is questionable on agreed objectives and outcomes. Thus, this has attracted very low-level of venture capitalists' funds,

(5) The burden of R&D funding mainly comes from government compared to private funding. Bayarcelik (2012) stressed that public R&D expenditure should be a complement to private R&D expenditure, and the latter has to be higher than the former to bring positive productivity growth to the country,

(6) The education system is politicized with political interest interfering with education needs. Higher education public expenditure is higher than other regions but low intensity R&D expenditure shows Malaysia has disconnected and inappropriate strategy for growth,

(7) Trend of 'brain drain' with many pursuing higher education and work overseas not coming back. Worst still, Malaysia is a net importer of global STEM talent (unlike US exporter of talent) and is attracting more low-skilled labor into the country compared to high-skilled ones which thwarts the speed of net income gain,

(8) A low proportion of science and technology graduates and declining interest among students enrollment in science based subjects and as profession of choice including researchers, beside low percent of tertiary graduates (30%) and RSE 58:10,000 workforce. The scientific workforce as part of knowledge workers in Malaysia is not growing in tandem with the country's needs (see Figure 1.7), and

(9) On average 19% cut in operating budgets of HEIs focus on cost-cutting measures rather than producing research, enhance education quality and competitiveness of their graduates.

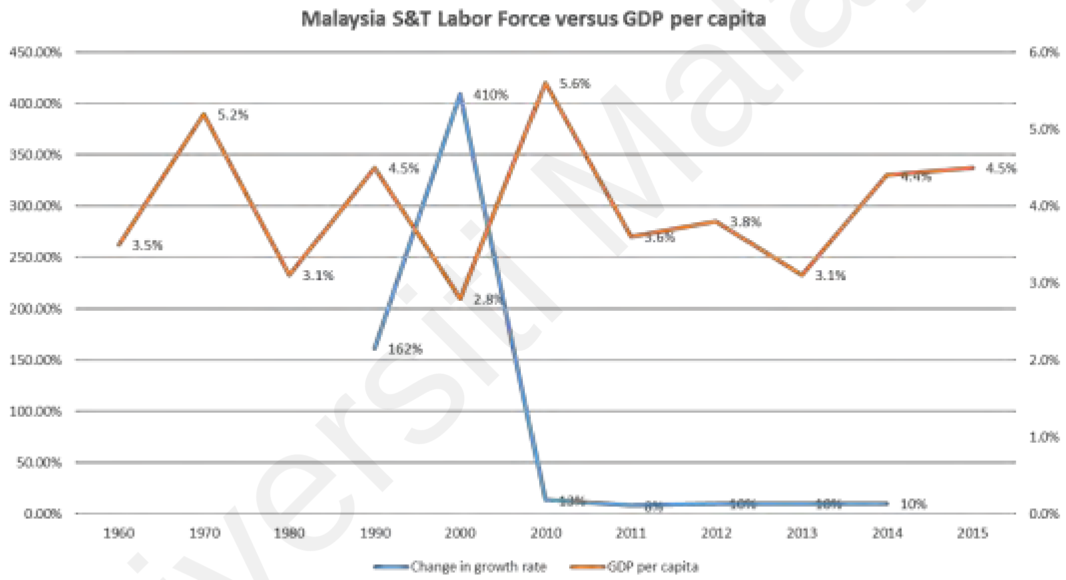

Figure 1.7: Annual growth in scientific labor force in Malaysia from 1960 to 2015

Source: Author 2016; MOHE 2016; WDI 2016

(10) Malaysia's production innovation performance have been declining since 2015 year-on-year in the Global Entrepreneurship Index 2018 while other countries such as Singapore, Indonesia and Thailand increases.

1.5 Research Objectives

Having established the importance of R&D, universities, patenting, and scientific publication in economic development, the research objectives along with the research questions we wish to address in the thesis are as follow:

1. Has there been dissimilarities to cause underperformance of scientific progress between developed and developing countries?
2. How has the supply of S&T resources (patents and tertiary human capital) affected Malaysia economic growth?
3. How has the supply of S&T publications affected Malaysia economic growth?

Past studies related to Malaysia S&T development mainly focus on R&D in general which still have limitations to identify basic research as economic determinant of R&D performance in a macro-level perspective. Hence there is no straightforward link between basic research patents and economic growth.

To draw useful conclusions on Malaysia underperformance, the three research questions above are set to examine the weak linkages of the country's effort to catch-up to become successful scientific nation. Among the research objectives are to examine the factors that contribute towards the underperformance of developing countries with respect to scientific progress as compared to developed countries. Second, it also set to investigate the low resident patent supply of R&D produced by scientists and engineers has supported Malaysia economic growth. Third, apart from resident patents, we wish to investigate the low supply of research grants in Malaysia has led to a low contribution of scientific publications and patents creation since patent is potentially publication itself or act as pre-grant disclosure to the inventions.

1.6 Thesis Outline

Using patents, industrial designs, and scientific publications, this study examines the R&D performance of Malaysia over the period from 1996 to 2017. Although not all patents eventually attract commercial value, given the complexities associated with R&D spillover, it is still widely used as an innovation output to support economic growth. We use patent-to-GDP ratio to estimate R&D expenditure and R&D performance gaps.

The present study will strengthen the existing literature which largely fail to explain how developing (and even middle-income) countries can sustain growth. The developing economies in Asia required to relies more on technology creation rather than adoption as the supply of tertiary-educated workers are increasing to advance the economic growth. We should target the Malaysian universities to become the basic place to conduct basic research as technologies are not freely available and to accelerate wealth creation with increased R&D innovation activities towards a sustainable knowledge-based economy. If we isolate teaching from basic research, it will hurt the outcome and impact on both research and teaching. As a result, poor basic research system will impede economic progress.

1.7 Contributions of the Study

The contribution of this research to the R&D and higher education industry are threefold. First, the thesis has used a different technique to analyze Atkinson & Pelfrey (2010) and Gumus & Celikay (2015) function. Using autoregressive analysis as a framework to analyze basis research R&D, the thesis has considered the local scene and factors that developing countries needs for an effective basic research realization. Second, to improve the existing methodology to analyze trends and determinants linking to R&D and university and business sectors performance as institution to diffuse knowledge.

The Malaysian experience provides an important policy lesson to other developing countries on the transformation process from agrarian into innovation-based economy using basic research R&D as key factor for growth. In the short term, importing foreign talent to contribute to Malaysian universities and transfer knowledge to local staff, including seeking scientists from industry to return back to academia are necessary to speed up the transformation. In the long term, the not-for-profit incubation model is necessary to grow the basic research R&D industry to ensure quality is sustained and surplus is reinvested for the betterment of society. In the end, if this is done right, it will lessen the long-term financial liability of the Malaysian government and grow Malaysia into an Asian scientific hub.

Although this study achieved its aims there are possible areas which could be extended as future research. First, although industrial designs (ID) and patents (PTID) through research are the most important predictors to drive innovation based economy in Malaysia, if the number of commercialized patents are still low and a weak legal protection on patentable rights would not drive GDP growth and country revenue to the desirable state. Thus, it is essential for the federal or state government to strengthen its intellectual property rights enforcement effort to minimize R&D leakages as much as possible. In this study, the patent has proven as a form of recognition and reputation in the scientific community. For example a scientist, it is a common practice by universities and firms to use patents and funding as a measure of their work performance beside academic achievement on papers or invited talks. Second, technology spill over effects on the quality structural changes of universities could not be measured or observed accurately. Lastly, this study omitted the implication of IPR laws on economic growth which could be address in future study.

CHAPTER 2

LITERATURE REVIEW

"I was not doing science for science's sake. I was doing science for the end point of better healthcare, future treatments for people. That was it. And in the process, I need to build the biotechnology industry. I needed to build basic research for the industry, for hospitals…. Biotechnology is the only industry that's all the way linked to the biomedical sciences. And it's a very long value chain."

George Yeo – the late bright Singaporean scholar, BMS research, former Minister of Health and Minister for Trade and Industry 1999-2004 (The Singapore Research Story, p.107)

2.1 Introduction of the Traditional Views of R&D on Economic Progress

2.1.1 How R&D is used as catch-up

The traditional view referred to R&D as merely an activity through which inventions are generated to yield knowledge in a linear process. As noted in Chapter 1, R&D is widely used as a measure of input to generate new knowledge to prevent decreasing returns to scale. Nevertheless, the use of R&D activities to foster long-term economic growth has solid theoretical roots.

The catch-up paradigm was important to understand how late industrializing economies are able to leapfrog the previous leaders through technological learning and eventually investments in R&D to shape the technology frontier (Freeman, 1987). Such catching up and leapfrogging experiences gained attention after Japan, South Korea and Taiwan managed to catch-up rapidly to become developed economies. However, such capital accumulation and residual effects associated with patenting activity are typically difficult to be captured when it comes to technological commercialization.

2.1.2 How R&D is used to generate innovation

Given the rising attention to incorporate R&D into innovation growth theory, efforts have increased to measure R&D expenditure as input to R&D intensity using economic indicators like patents and skilled labor as tangible output, while some have attempted to evaluate the ability to solve problems to drive economic progress (e.g., Kronjee & Nooteboom, 2008). One way to approach this question is by analysing the patenting activity of firms in particular countries. In doing so, one can use statistical approaches to measure how much time it takes before the research expenditures results in the take up of patents or just simply the number of patents filed from R&D expenditure. Second, one can differentiate R&D patents to assess invention and design patents from utility patents to examine the depth of knowledge created. Third, one can examine the link between STI policy and R&D expenditure using proxies for the former.

Since basic research is part of the experimental or to gain deeper understanding on a particular subject in the R&D, the firm and labor can discover new knowledge, understand the current market trends while the interactive participation of the different critical actors will offer the opportunity to synergize innovations, including the translation of basic research output into applied research and experimental development. Once the knowledge diffusion is from new technologies it is possible to use it as solution to solve current problems, find next targeted investment, build people competency over time to impact a country's long-term growth, especially when the developing countries are battling against catch-up process, more so if both core proprietary information are diffused either directly or indirectly to stimulate spillovers and economic competitiveness. Inevitably, excellence in purposeful scientific research offers the potential for appropriating it in material progress, which then plays an important role to determine the standard of living of a country. Instead of generic basic research, it must be mission target. It will benefit the entire innovation value chain for instance a plastic-free ocean when the basic research outcome is met as opined by Professor Mariana Mazzucato. Mazzucato (2020) believed that government needs to act as an investor of first resort providing funding to both SMEs and large enterprises towards meeting the basic research societal goals like building and making Covid19 vaccine patent a shared in a common pool and universally available and free. This implied that mission-driven government will ensure investment goes to the critical capacities, create productive relationship, better governance and higher efficiency to serve public interest when it comes to purpose driven basic research or crisis such as Covid19. This formed a more favorable and equitable public-private partnerships and capacity building among firms in the innovation ecosystem. Successful countries, such as Japan, South Korea, Taiwan and China have unique S&T growth strategies, which direct the pursuit of R&D targeted at eventually localizing imported technologies, as well as driving domestic R&D (Amsden, 1991; Rasiah, 2019). Prettner and Werner (2016) claimed that knowledge spillover occurs between basic research and applied research and the spillover effects are larger from basic research to applied research rather than the other way round because knowledge once discovered is freely available to be used by every scientist without restriction or building on new opportunity compared to patents which are generally excludable in nature.

This chapter proceeds to look at past and present approaches on R&D development in sections 2.1 and 2.2 before examining the innovation evidence across selected countries with a focus on basic research and university research in Section 2.3.

2.2 Flaws in the Neoclassical Approach

It is important to first understand why the early neoclassical growth theories were fraught with problems. The total factor productivity (TFP) approach, using the growth accounting and production function that differentiates growth in productivity from growth in factor inputs subsumed both productivity and technical change in the residual (Solow, 1956, 1957 as cited in McQuinn and Whelan, 2007). The TFP was used to measure the efficiency gained or lost from using factor inputs to produce output through technological progress. The claim of higher the TFP, the more will be the output from inputs. However, historical evidence shows that the early TFP approach mainly focused on capital deepening while assuming that the cost for acquiring new knowledge or technological progress is low or none. Importantly, this approach assumed technology to be an exogenous variable when purely measured against the residual generated by the core sources (Rasiah, Lin & Muniratha, 2015). Machinery and equipment were perceived as the primary source of income growth for the country, hence innovation costs were assumed to be low. As a result, this model does not provide the clarity which instruments generate the effect of technological advancement and subsequently failed to show any sustainable long run growth path.

In contrast, the cost to acquire *A* is rather high. Schumpeter (1934, 1942) dismissed the dependency on the above said items since profit-seeking firms seek ways to replace obsolete technology or products with newer ones through R&D investment, especially in the private sector to earn monopoly rents. Hence, the biggest shortcoming of Solow's (1956) growth model is the lack of a measure of embodied technical progress as technological progress *A* did not contain R&D effects in the production function used, which impact the long-run relationship between output *Y*, capital *K* and labor *L* (Cobb & Douglas, 1928). Such a function at most only captures accumulated technical knowledge[10] from learning by doing and incremental innovations, thus offsetting the diminishing marginal product of capital, which was fixed in Solow's augmented growth model (Frankel, 1962). Pakes and Griliches (1984) subsequently developed a knowledge production function[11] (KPF) to solve the limitation in Solow's growth model and

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[10] Cobb-Douglas production function $Y=AK^{\alpha}L^{\beta}$ model to be explain in Chapter 3. A is the state of technology becomes facilitator of innovation growth and magnitude to A must be positive and large enough to gain spillover of knowledge. Read more on Solow growth model in Journal of Economic Perspectives.
[11] An improved version of Cobb-Douglas original production function. The variable *A* in knowledge production function is used to measure flow of new knowledge. $A = \delta L_A A^{\varnothing}$, $\delta > 0$, $0 < \varnothing < 1$. This pooled of *A* will enable the economy to grow through spillovers.

attempted to measure R&D effort by using patents statistics as a proxy of the firm to transform R&D into codified knowledge output.

Although patents may not hit the market to generate abnormal profits, but patenting activity remains the route firms take to protect the intellectual property in real markets, which face imperfect competition. Consequently, large firms in the past took the risks to invest in R&D to create new stocks of embodied knowledge. Yet, small firms have increasingly entered such activity following the creation of knowledge networks that connect these firms to knowledge nodes in the form of R&D labs, incubators in science parks, R&D grants offered by governments, and venture capital provided by both governments and private investors (Rasiah, 2019). While Taiwan Semiconductor Manufacturing Corporation and United Microelectronics Company are large firms, small firms, such as Phison, have managed to invest in R&D to shape the technology frontier in some industries. Especially chip design does not require scale (Rasiah and Yap, 2019).

We reviewed that Romer's findings (1986, 1994) have resolved the Solow paradox by endogenizing technology, which help explained when codified knowledge is diffused through society, it would become a public good to raise marginal productivity. Romer sighted three conditions in this transformation. Firstly, he argued that entrepreneurial skill is an imperfect substitute to normal labour. Secondly, he noted that the magnitude of A must be large enough to produce positive spillover, though new knowledge is accumulated after each research. Thirdly, argued that most of this knowledge is normally internalized in an imperfect environment. The first-generation of R&D growth models (or semi-endogenous growth) received much criticism as R&D showed little impact on productivity growth. Hence, the ideal of perfect competition and constant returns to scale came under massive criticism.

The flaws stated above with the assumptions used alongside the neoclassical production function pose a huge fundamental problem as it is vague on whether a direct link can be established between the factors of production since capital and labor have never been perfect substitutes in particularly if the labor has tacit knowledge or is skilled worker. It is difficult to achieve full employment on both factors of production, while knowledge and skills carry tremendous tacitness to carry out actual R&D experimentation and improving the product and processes.[12] In fact, Rosenberg (1982) found that researchers and scientists (scientific workforce) tend to know more than what they can document and their knowledge might not be visibly sold entirely at the marketplace. Therefore, these variables cannot be lumped together into the traditional model of physical K and L, or even using a generalized growth model differentiating countries by levels of development and market sizes. Meanwhile, firms in certain countries and industries will vary in the use of labor and capital factors (for example automotive, telecommunication or food technology will not have the same skill set of labor or equipment used), while technology is not freely available (Lall, 1992).

2.3 Heterodox Approaches to Have the Desired R&D Performance

While Romer's (1986) endogenous growth model has remained controversial among economists who are unconvinced over whether the model actually endogenizes technology (see Rasiah, 2015), we shall explore in depth some recent advances in R&D growth theory using Romer's (1989) framework to make it more comprehensive, which allows for the inclusion of innovation output and the patents which speed up the

[12] Tacit knowledge raises the competitive advantage of the inventor and typically are context specific comes with practical experience, beliefs, expressed through action of trial-and-error. The traditional view of tacit knowledge has no systematic way and hard to be communicated. See more the works of Michael Polanyi and Saviotti.

willingness of government, public- and private organizations to invest in intentional innovation.

Heterodox economists often considered Gerschenkron's[13] catch-up (convergence) theory as the basis to stimulate latecomer economic catch up cannot be done with basic research. Though depending on their value of R&D, it is clear that the new growth models among heterodox approaches here has departed from the neoclassical approaches to address the dynamic role of technology. As expected, Ha et al. (2009) showed that basic research has becomes important in technology creation when technology gaps to the frontier get narrow using pooled OLS regression with country fixed effects.

The successful growth of the United States, Germany, Japan, South Korea, and Taiwan are argued to be Gerchenkronian experiences of changes in technological and institutional regimes. Such an argument required getting relative prices wrong to promote rapid structural change from low to high value added countries (Johnson, 1982; Amsden, 1989; Wade, 1990 as cited in Roberts, Hite and Chorev, 2015). Indeed, the stepping up of production of engineers and technicians were among the central pillars in the catch-up experience of Japan, South Korea and Taiwan.

2.3.1 Can STEM education alone produced competency building in patent?

Furthermore, in the new growth model, innovation and human capital development are important economic change agents to produce high-quality basic research. Many policy reports have argued that basic research is underfunded by private and public sectors. Developing countries are facing serious demand-supply gaps in human capital, which along with institutional capacity, Lall (2001) and Polasky (2006) argued, will impede

[13] Catch-up theory first developed by Alexander Gerschenkron in 1962 to understand how the German firms successfully turnover their steel industry in the 19th century. The catch-up process is closely related to the product cycle theory developed by Vernon in 1966.

rapid economic development under circumstances of increasing globalization. Also, Krammer (2014) and Ha et al. (2009) found that while investment in high-skilled human capital is expensive, but nevertheless it a faster alternative to move closer to the technology frontier. They implied that as the country's quality of tertiary education improved, only then the production of a critical mass of high-skilled workers will improve R&D productivity and speed up knowledge creation from basic research. Indeed, several works have argued this to be a major impediment that has stifled returns from R&D in Malaysia (Rasiah, 1999; World Bank, 1995; Gill & Kharas, 2007).

Education attainment and skill training also vary across countries, which Lucas (1988) and Mankiw et al. (1992; 1995) addressed as a limitation of the Solow's growth model. To investigate the effect better, we also use the test scores and years of schooling or industrial certifications as relevant measures with respect to productivity improvement that reflect the impact of policy so as to go beyond typical factor accumulation instruments, which unlike knowledge, are rivalrous, excludable, and exhibit diminishing returns over time. This resolved the limitation of education on economic growth focused heavily on the neoclassical argument of returns to education and promoted the development of primary schooling for developing countries (Mincer, 1962, Schultz, 1961, Becker, 1964 as cited in Maringe, 2015) knowing that it was insufficient to close the catch-up gap with the frontiers. As a result, this began to change the work of Lucas (1988) but more following the work of Grossman and Helpman (1994). As much as education is required, returns to education is rationally measured by wages. The latter argument has antecedents to the Fordist regime when Henry Ford argued that high wages are necessary to attract skilled and technical labour (see Best, 1990). Indeed, significant works, especially those focused on industrial districts in Europe took this argument seriously making the case that economic development need to be driven by efficiency wages rather than performance based wages (Piore and Sabel, 1984; Pyke and Sengenber, 1990; Peri & Urban, 2006).

Evolutionary growth theorists arguably address this issue incisively by arguing over both that technology is embodied in individuals, firms and organizations, as well as the critical importance of tacit knowledge (Dosi, 1995; Rasiah, 1995). Firms generate certain learning patterns that are crucial to their innovativeness, which include firms comprised of individuals as entrepreneurs who are innovators themselves (Schumpeter, 1934; Penrose, 1959). Considering Leoncini's (2016) study of 16 European countries between 2006 and 2008 that failure is perceived as a routine experiment that brings positive impact to firms during the trial-and-error discovery process during repeated attempts to solve a problem. Such a method helps strengthen the resilience of firms to exploit new approaches and technological capabilities to suit market needs to realise their full potential, and in that way reduce the chances of an innovative project being abandoned and the likelihood of failure as was the case with the Xerox business model and the design of Airbus A380. Learning through an arduous process helps, (which includes interactions with a wide but related range of actors), such as firms, universities, governments, hospitals, and private and public research labs, and vocational skills training centres, especially in geographically close locations help stimulate knowledge externalities. The commercialization patents often requires such connections and coordination to enable them gain more from R&D investment (Rasiah, 2019).

Aside from patents and new knowledge, R&D theorists regard human capital as a critical variable to not only stimulate, but also to appropriate benefits from R&D activity. It is difficult to link existing shares of scientists and technologists in the workforce to evaluate R&D performance, which is the case with Russia, and the Central Asian republics, it is among the measures used as a proxy of human capital.

2.3.2 Are FDI induced R&D necessary?

Since R&D investment needs to be sustainably financed, the neoclassical economists consider FDI to offer strong technology spillover effects owing to their origin from economies endowed with superior high technology infrastructure (Caves, 1974)[14]. Some heterodox economists point to constraints impose by foreign capital that may not stimulate technology spillovers (Amsden, 1989; Kim, 1997). Japan and South Korea were opposed to strong FDI inflows during their initial stage of rapid manufacturing growth (Johnson, 1982; Change, 1994). While there are other heterodox economists have shown how FDI can actually stimulate positive spillovers if host-governments get it right on selection, monitoring and appraisal (Hirschman, 1970; Rasiah, 1995). Using a Veblen-Gerschenkron[15] (VG) analytical framework, whereby the spillover from FDI, in particular the multinational companies, Peri and Urban (2006) found significant positive spillovers on domestic manufacturing firms and knowledge transfer in Italy and Germany regions from 1993 to 1999. Their study showed that FDI-induced productivity in domestic firms grew by 7% to 8% in East Germany 3% in Italy respectively when the foreign firms increased by 50% at that region. The pact on the former was higher than the latter because the former was far more underdeveloped companed to the latter. Adapting to foreign knowledge to spur local conditions to grow basic research have been much of the developing economies R&D strategies back then. And FDI inflows generated strong VG effects to stimulate technology transfer to local firms.

Although the presence of foreign firms does not view FDI density as a good measurement of spillover and productivity, but it provides tremendous synergy in the modernization of least developed areas. This was the case of East Germany, which was

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[14] The prospective benefit of increased FDI to the host economy will gains from a deeper understanding of frontiers' market-oriented innovation and productivity gains on local firms.

[15] Spillover productivity effects is large when FDI concentrated at technologically backward region that subsequently gain technological catch-up. More details explained at empirical analysis on Chinese cases.

technologically backward when the Berlin wall fell. As for domestic firms' productivity spillover effect, it can be unevenly distributed as the study by Peri and Urban (2006) shown that although FDI density are concentrated across Bundesländer urban areas (included Berlin as political center, Frankfurt as financial center, Hamburg as primary port) in Germany, these firms are not necessarily receiving largest spillover effects from foreign firms.

This suggest that to boost basic research using FDI, foreign inputs and influence such as cost to acquire research scientists and engineers (RSEs) and increase imports play the larger role in patenting, but the acquisition cost is likely to differ between developed and developing countries. Another challenge is major time lags can be high as 7 years to appropriate the knowledge between R&D expenditure to revenue generation has deterred the interest to spend on basic research. To support this view, we take the example of cardiovascular disease. While speedy translation to practice is important, the time lags are inevitable. From financial aspect, it is anticipated to benefit health improvements by 9% or generate new earning of £0.39 from every £1 investment. From time lags perspective, it required 17 years to materialize these benefits which the spillovers effect is estimated around 30% benefitted the economy and industry (Morris et al, 2011). To help address this gap, our later analysis intends to examine how specific patent activity can possibly reduce the lags. However, Neves and Sequeira (2018) show that foreign inputs will lessen the distance between latecomers and first movers, which demonstrates that increased integration with the developed countries will stimulate strong technology transfer, free flow of ideas and collaboration across borders that accelerated the catching process for the developing countries and leads to increase in R&D productivity.

But Yagzan & Yalçinkaya (2018) found that private R&D have more important role as it impact bidirectional causal relationship between universities and economic growth to stimulate R&D investment compared to just generic category of R&D. Top OECD-9 countries benefitted the most when the fixed capital investments are statistically creating a larger positive impact on economic growth compared to the broader OECD-20 group[16] over the period 1996-2015.

The developing economies that have proven to produced firms that leapfrogged frontier firms in the developed countries only did so eventually by investing heavily on R&D and raise their productivity. Hence, latecomer firms from developing countries leapfrogged over the former frontier firms not by chance, but through evolving their technological capabilities designs or patents, and industrial linkages are sources of experiential knowledge that help these economies to unleash the innovation stimulate upgrading from low to high value added industries (Rasiah, 2020). As shown in Figure 2.1, knowledge in the new growth theory is a form of R&D investment. In light of the significance of R&D, and research universities and consortia connecting them in networks in countries progression in the technology ladder, these instruments are examined in greater detail below. We will also review the literature on R&D in the next section.

[16] Group of the countries by GDP value in 2015. OECD-9 countries as follows: Slovakia, Slovenia, Estonia, Portugal, Poland, Hungary, Greece, Turkey and Mexico. OECD-20 countries as follows: Norway, Ireland, USA, Netherlands, Sweden, Austria, Denmark, Germany, Canada, Iceland, Belgium, Finland, UK, Japan, France, South Korea, Italy, Spain, Israel and Czech Republic.

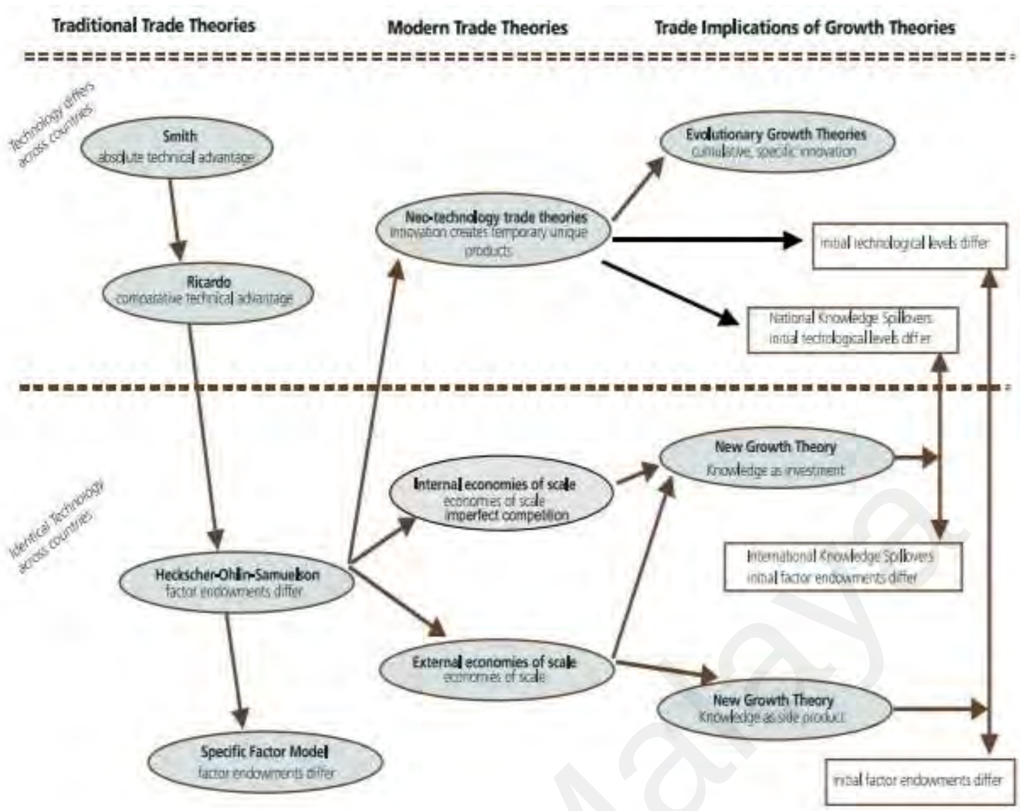

Figure 2.1: Trade Implications to Growth Theory

Source: Adapted from Berkum and Meiji (2000)

2.4 R&D is the Key to Transform and Progress Technology Ladder

Economic growth has often drive R&D investment during the early period of development, the evidence is also obvious that R&D investment eventually drives economic growth after a certain period. Innovation to production can transform or produce a brand new product when the cumulative basic research become usable. Schumpeter (1942), Solow and Sawn (1956), Lucas (1988), Mankiw and Sala (1992), Romer (1986, 1990, 1994, Weil (1992) and Phelps (1966) either argued anecdotally or modelled to show the importance of R&D in stimulating innovations. These scholars emphasized the importance of R&D to stimulate innovation spillovers and productivity, as well as the launching of new species of industries (see also Best, 2001). Others, such as Aghion and Howitt (1992, 1998), Grossman and Helpman (1994), Rasiah (2004) both modelled and demonstrated empirically the relationship between R&D and firm performance.

Furthermore, such technological progress is recently discussed on WeForum's finding in WIPO Global Innovation Index 2021 (2022). The pattern of exports became an essential proxy for structural transformation and new business opportunities on technological advancement including advancement in R&D where Malaysia have outperformed many LDCs such as Myanmar, Laos and Bangladesh but lost to many developing countries such as Vietnam and Philippines are catching up quite quickly over Malaysia. Malaysia might not have invested correctly in the critical areas that will increase the level of technological sophistication to structurally transform the entire industry and people just creating incremental improvement but not enough to have the breakthrough effect.

In this regard, mobilizing fund without innovative approaches can end up resource trapped. Minniti & Venturini (2017) found that R&D policy did have a permanent effect on productivity growth in the long-term but the direct R&D funding did not promote growth among US manufacturing firms between 1975 to 2000, arguing that federal funds were spread through a variety of fields rather than allocated to R&D-intensive projects using panel data. Whereas the one that significantly encourage positive effect on growth is actually the indirect R&D funding, (such as R&D tax credits) significantly encourage positive effect on growth, i.e. increasing R&D tax credits by 10% would raise labor productivity (patenting rate of R&D workforce) by 0.4% per year. Still, such a positive effect arises from the indirect R&D funding in the United States is largely not observed or captured among developing countries including Malaysia. Besides, over-subsidizing R&D policy in applied research will leads to inefficiency also ended up did not show any positive impact on growth in France over the period 2000 to 2006 (Akcigit, 2016).

Consequently, they propose the optimal pro-growth policy to realign the R&D policy again which is to subsidize 50% of basic research and to reduce applied research subsidy to 14% and set the threshold of R&D subsidy of 30% tax credit on all R&D expenditures since 2008 (Akcigit et al. 2016).

2.4.1 Imitation to knowledge creation as catch-up

Next, latecomers' may consider to increase production of an existing product (e.g. smartphone) versus to spend on R&D to examine and create new products on their own as catch-up strategy (e.g. futuristic driving vehicle[17] or stem cells development). Rosenberg (1976) viewed the latter as costly and less appealing along with higher uncertainties to commercialize the R&D investment into useable patents. Not just that the residuals from technology spillover are hard to capture, not are R&D can be turn into usable patents nor the residuals also cannot be generalized between public and private investment or across the different types of research (basic or applied research) as both are complementary goods in nature rather than substitutive goods.

To enable high spillover leverage on the existing product, the learning-by-doing can be less complicated and consume less resources. Frishammar et al. (2015) exposed how proprietary knowledge can be leaked out both after and during R&D projects between collaborating firms or even transmitted through third parties, especially in the open innovation systems. Also, often tacit knowledge embodied in human capital are exploited by latecomer firms through hiring and paying these experienced people with attractive salaries for their knowledge and past successful works, which is how a significant numbers of firms in South Korea and Taiwan are caught up in critical industries learning-by-doing (and not by coincidence), such as electronics, machine tools and automotive

[17] Autonomous driving, connectivity, energy-efficient.

components (Rasiah and Lin, 2005). [18] Thus, it seems that both codified and tacit knowledge have been exploited by latecomer firms making use of least and best resources.

On the other hand, a number of firms also undertake this without hiring experienced staff from lead firms, but instead do it by inspecting the latest products in the market and extracting as much of the knowledge embodied in them as possible (Grossman and & Helpman, 1994). Despite massive litigation costs involving such violations of intellectual property rights (IPRs), Japan, South Korea, Taiwan, and China have appropriated massive technology transfer this way (Rasiah and Wong, 2021). For instance, the initial evidence of the catch-up experience of South Korea, Taiwan, Hong Kong, Singapore (then middle-income economies) and China showed that firms in these countries drew largely from minor improvements to existing processes and product designs from abroad to catch up (Amsden, 1991; Rasiah, Yap and Yap, 2015). Beside developing local talents, both South Korea and Taiwan also have successfully attracted and retained human capital endowed with tacit knowledge from abroad to spearhead their domestic industrial catch up (Saxenian, 2006). Nevertheless, one constraint is that several middle-income countries have not really evolved their institutional quality framework to support rapid industrial upgrading bound by their limited R&D resources (Radosevic & Yoruk (2018).

2.4.2 Basic research has the ability to turn the negative spillover to positive

Past research found differences between investment in basic and applied research. Therefore, it is important to examine the basic research activity optimal returns is best from the private or public R&D labs (UNESCO, 2015). Although, commercialization

[18] For example, knowledge management repository and recording are used in Information Technology/Information Systems to articulate the tacit knowledge into explicit knowledge.

benefits accrue far more to applied research as the latter is close to prototyping and scaling up processes (Rasiah, 2019), basic research in time t_1 is essential to support applied research in time t_2.

Gersbach et al. (2018) did a study on the OECD countries on their 5-years moving averages over the period (2005 to 2010) and found that investment in basic research conducted at the industries, such as pharmaceuticals, can achieve a high rate of return as high as 43% at this region when the four determinants are executed. While this is an interesting finding, their model used a factor-based approach and assumed that typical Type 1 firms will remain at the frontier, and that no successful leapfrogging of Type 2 innovative firms will take place to become Type 1 – which limits the efficacy of their model. Indeed, Type 2 innovative firms from South Korea and Taiwan have successfully leapfrogged the Type 1 firms in the US and Japan. The four determinants are rather country-specific, which works well when the country is at a strong developmental stage with domestic firms' gaining ownership of the basic research to deters foreign competition, strong manufacturing base with domestic firms showing higher investment in basic research to stimulate positive productivity gains, openness in relation to exports and imports, and foreign ownership of domestic firms is low.

Akcigit et al. (2016) showed that 29% of French firms invest in basic research with results showing a positive relationship between basic research intensity and multi-industry presence. Indeed, their results show that successful basic research shall increase by 60% productivity of applied research innovation, as well as on average, 8.3 years high-quality follow-up innovations, especially when the knowledge is still in demand[19]. As such, in the absence of basic research applied research tends to have lower spillover effect

[19] Known as hot product lines and prevent knowledge from depreciating in value before it cooldown as the age of the patent increases. However, the profitability correlation to basic research intensity is rather small (0.04) although positive.

in the long run as it only generates incremental innovations within the targeted industries. Interestingly, they also foresee that the returns from basic research would be faster to turn into consumer products if it is undertaken at private labs, especially when they evaluate the spectrum of activity from each production stages i.e. from upstream (acquired the latest technology) to downstream (producing final goods in a competitive market).

Basic research investments level tends to be higher when the country is nearer to the technological frontier (Gersbach et al., 2013, 2017). However, this finding raises a challenging question as to when should developing countries raise the focus on basic research. Should developing countries continue to rely of adapting incrementally technology that is created in the developed countries? On this question, Rodrik (2009) mistakenly claimed that South Korea and Taiwan took this route to develop. In dismissing this claim, Rasiah (2015) that R&D is essential not only to comprehend and proliferate incremental innovations but also to bulwark catching up and leapfrogging. Also, Gersbach et al. (2013) argued that the first option is the better choice for a country, though the latter option is a cheaper alternative in their study using panel data on OECD countries from 1981 to 2005. They advance four reasons: first, basic research will have a positive impact on applied research; second, it would yield higher employment opportunities and wages for skilled labor in basic research, especially in intermediate goods sectors to foster growth of domestic firms; third, it increases productivity and consumption in the country; and fourth, the successful innovation output from basic research will allow domestic firms to enjoy monopoly rents. Their results showed a positive correlation between the degree of openness and basic research R&D for baby-steps innovation, while large technological progress by foreign firms at domestic market would inversely impact the local economy.

Their findings also imply that since government[20] is the main push factor supporting basic research activity, weak governments may not be able to support such R&D activity.

2.5 The Spillover Effect of Universities in Supporting Basic Research

Existing evidence also shows that universities play a critical role in supporting basic research, which includes the successful progression of firms to the technology frontier in the US, Germany, Japan, South Korea and China (Best, 2018). Universities at home supporting basic research R&D[21] often help stimulate accumulation of endogenous knowledge to spur rapid economic development.

University research brings positive impact especially on the small firms. An innovation-led economy must recognise universities excellence as an important criterion to attract and retain the talents in country, and grow these communities through greater diffusion of knowledge and technology (OECD, 1996; EIU, 2011). The university has a leading role to create new industries through enhancing latest curriculum and manpower development, filling the structural gaps through each cycle, and upgrading the best practices through basic research to stay competitive (see Figure 1.6). Such flow allows the university to stay focus on creating new ideas or products, and induce them quickly to the next stage to commercialize these ideas either through start-ups, public-private partnerships, or group of venture capitalists. Indeed, Rasiah (2019) argued with evidence of how small firms are connected with knowledge networks, (including research universities), to participate in basic research.

[20] On average 77% of basic research expenditures were performed by the government and higher education institutions (OECD, 2012).
[21] Basic research is a continuum of multiple research from one point to another. Basic research can be pass on to community or translational research using the following example: To understand hypercholesterolemia, the researcher needs to study the different types of good and bad cholesterol, monitor routine health assessment on the diet and drugs given to the patients to address specific cholesterol problems and subsequently give prescription to reduce cardiovascular disease of the public. Only then the basic research can be pass on to community or translational research.

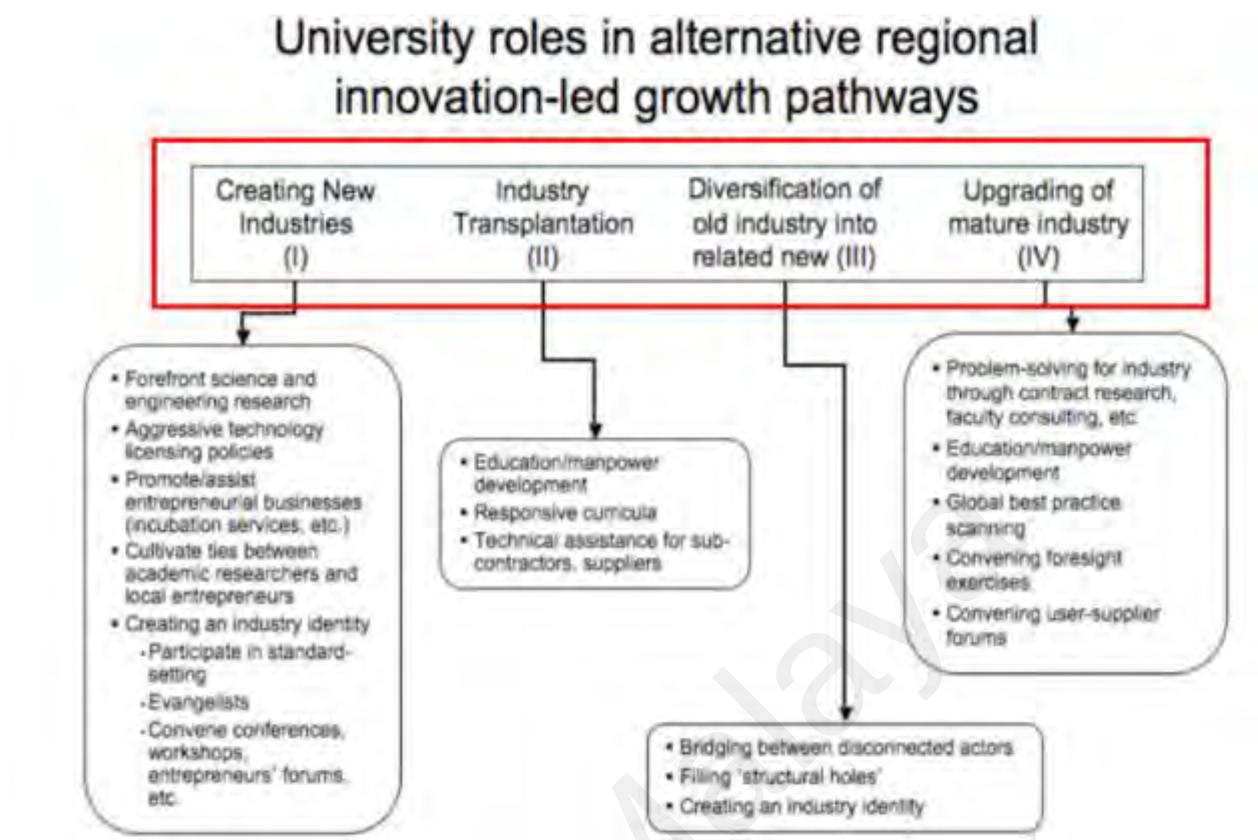

Figure 1.6: University roles in regional innovation-led growth pathways

Source: Lester 2005, p.28

Since basic research is primarily undertaken at universities, these universities also produce high-quality skilled workforce and new knowledge to speed up innovation. In this regard, human capital and universities are economic agents that positively correlate with economic growth as they create positive externalities (Stark 2003). Supporting this efforts are also Cole (2010), Pelfrey (2010), Mansfield (1977; 1991; 1995), Lichtenberg (1991, 1992) and Adams (2011) argued that basic research in universities will stimulate technological change to be sustainable. They make the point that scientists and engineers are significant predictors of income level. So, the federal government must support basic research. Large countries that are technology exporters have reported high numbers of RSEs who help to speed up technology adoption and explore newer technologies. As a result, it upscaled the research capabilities at universities and make them both incisive in supporting cutting edge R&D but also to stay financially sustainable.

This enables the universities to emerge as a major pillar of research consortia and industry-government coordination councils that allocate R&D grants and revamp R&D policies whenever intervention is required. The phenomenon of agglomerating firms in a science park or technology district in the *Triple Helix* concept cannot be isolated so that it can create positive spillovers between participating firms. These days the promotion of such networks have become more aggressive following the evolution of the Triple Helix and later the quadruple helix councils in Sweden (Chaminade et al, 2010; Ezkovitz, 1995; Rasiah, 2019).[22] Served as an incubator, the strong links between universities and firms have shown higher productivity compared to those that have not. Homegrown science parks are designed to modernize the physical infrastructure and thus lead to positive impacts on patenting activity and upgrading technological capability of local firms.

With the rise of research and entrepreneurial universities, several firms have begun to collaborate with universities, including sponsoring R&D, with major sprouting of spin-off firms from science parks. According to Sung et al. (2003), spin-off companies financed by venture capitalists have high success rate up to 50% when they reside within a University, Industry, Government (UIG) designated area. Jaffe (1989) opined that geographical mediated spill overs exist from university research to commercial innovation, and Veugelers and Rey (2014) found that if universities and firms reside together at the technological frontier itself, a thousand dollars of research education-type spending per person in the cohort raises patents per person by 6 per 100,000. Universities will learn and adapt to become entrepreneurial and able to speed up the technology transfer through licensing of universities, patenting and spin-offs. Such UIG development has led to a meaningful way of supporting more basic research by identifying the fields or specializations that particular locations should focus on or invest in, and reduce the

[22] Became popular when the ICT industry boom that leveraging on external knowledge can to produce more products and services, and entrepreneurship became the positive moderating factor to realize open innovation.

risk of market failure. It is a win-win situation to take advantage of the infrastructure and talent on university campuses for businesses and higher learning institutions during budget cuts, as demonstrated by some eminent examples such as Cambridge Science Park in US, Tsinghua Science Park in Beijing and Hsinchu Science Park in Taiwan on focus in basic research.

The other example is the United States's NIS agglomeration effects also created significant positive impacts between university and industry due to close geographical location, supply of technical workers, access to suppliers, share fixed costs and common infrastructures which have speed up the economy growth and adaptation rates of start-ups (including spinoffs companies from universities), promoted collaborative learning and informal communication of the local production. Saxenian (1996) found successful regional clusters such as Silicon Valley and Boston Route 128 are important to shape their strategies and promote solutions to common problems rather than relying on a single firm or the government. Various clusters were built across different regions, for example Michigan has battery cluster, New York a nanotechnology, West Virginia a biometrics cluster, Ohio a solar energy cluster doing basic research at University of Toledo. Beside success rate, Mansfield (1995) also noted that the social rate of return can be as high as 40% compared with private returns of 36% from such research. However, incentives to boost researcher productivity are normally not well documented. Moreover, the 40% noted by Mansfield (1995) does not account for the cost of development, marketing, or building factories.

The transformation of research universities (RUs) into entrepreneurial units have increased their capacity to commercialize technologies from their continuum of applied research. Patents have become a major innovation output of the universities, which has increased their academic reputation to attract massive private endowments and stay financially able on their own with less dependency on government funding. According to Kronjee & Nooteboom (2008), government funds must be divided by fields to finance scientific research, which is strongly followed in the US and the Netherlands. The success of US research universities is strongly linked to industries that increase the flow of new products and services and enhance export activities. In the US, 80% of the new industries are generated by Ivy league and top university-based research (The National Academies Press, 2012). The core cutting edge scientific research activities are happening in the universities in the US, and these universities largely draw large private endowments from their own efforts, thereby reducing their dependence on government funds.

In the next section, we will review the empirical works that address the link between R&D investment and economic performance.

2.6 Empirical Works Linking R&D Investment to Economic Performance

Rodrik (2009) claimed that increasing the R&D investment and patent applications (or better still patent commercialization) has been part of the globalization process to obtain sustainable productivity gains rather than just focusing on factor accumulation. While trade openness has been important (Helpman and Krugman, 1989; Grossman and Helpman (1996), investments into R&D and its translation into patents have acted as a game changer to spur domestic firms to raise their participation in R&D activities (Rasiah, 2019). As a result, the demand for networking with S&T parks have risen, and the focus on human capital development has evolved strongly, including massive injections of R&D grants to support innovative activities in research universities and deliberate attempts by governments to attract back their diaspora endowed with tacit knowledge (Rasiah, Lin and Anandakrishnan, 2015).

Universities engrossed on seeking patent filing have raised their emphasis on applied research, and are strongly involved in launch spin-off companies with collaboration with venture capitalists shown by the experiences of US, Europe, Singapore, Taiwan, Japan, South Korea and China. The Bayle Dohl Act then offered the universities to participate in such activities from output of government funded research in the United States (Rasiah, 2019). It is important to note that US, South Korea and France have rather different growth paths compared to China and Malaysia when comes to industry-specific R&D innovation. The US and France spent almost half of their R&D investment in basic research. The American private sector performed 22% of the basic research in US while in France is 15%. Such basic research investment should be replicated in Malaysia respectively to increase innovation resulted from basic research R&D.

We confine the empirical review to China, South Korea, and Taiwan, which are three successful latecomer countries that have managed to reach the technology frontier in critical industries. We examine Malaysia after that to assess its location against these countries.

China

China has increased investment into R&D activities since 2000 as government focus has shifted from attracting FDI to spawn domestically spawned R&D. The country R&D spending in GDP was 2.15% in 2017, a significant share of which is directed at the over 80 science parks in the country. Shang et al. (2012) observed that China's filing of patents grew by 2000% over the period 2001-2008 and WeForum reported that China already overtook Japan as the No.2 patent filer in the world and very soon to overtake US as well.

Prior to 2000, the Chinese high-tech firms experienced positive TFP growth, albeit at a low 0.8% per year from 1980 to 2012) when evaluating their returns from R&D expenditure. In 1995, the high-tech firms at Haidian district in Beijing demonstrated that a 1% increase in domestic R&D generated 0.08% increase in TFP (Boeing et al. 2016). Furthermore, it is not unusual that in China most of the R&D investments were dominated by state-owned enterprises (SOEs) that were launched prior to structural reforms in 1978 (Zhang and Rasiah, 2015). When reforms set in to promote local competition after 1978, the number of privatized firms increased but especially after 2001 R&D stimulus by the Chinese government sped up innovation.[23] By 2016 R&D expenditure in GDP doubled to exceed 2.1% by 2016, which raised Chinese patent applications by domestic firms between 25 and 40% a year since (Lei et al. 2015).

Align their national STI plan to recognize the importance of basic research, the Chinese government in 2014 also pledged to invest more in basic research R&D through megaprojects, including in fields, such as drug discovery and infectious diseases. The Chinese government encouraged large private-owned[24] firms, such as Huawei, Alibaba and ZTE to participate in the ambitious Made in China 2025 plan to increase technological innovation in the key industries of brain research, biomedical, military, and space exploration. Increased R&D funding drove Chinese universities to file about 6,000 patents in China in one year, which is a close to what US universities do, and six times larger than the number filed in the UK by British universities (Atun, 2007). Such open-door policy has make the private firms more efficient in instrumenting R&D spending through collaboration with universities to design and manufacture high-tech components. The Chinese R&D policy has progressed well when Boeing et al. (2016) showed that

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[23] Accounted 20% of global R&D expenditure. Currently ranked 2nd after US in patent applications. To overtake US by 2020.
[24] On average 12% R&D growth rate in private-owned firms (CSIS, 2018). Read more at https://chinapower.csis.org/china-research-and-development-rnd/

private firms contributed highest to the patent filings (on average 6.75), 2.6% higher productivity, 0.95% higher R&D intensity and 0.059 forward citations after publication especially when the firms are located in the policy zones. The existing firms (also attracted new firms) participate actively in patenting activity especially after 2007 to enable their classifification as high-tech firms to qualify for government R&D funds. Again, Boeing et al. (2016) reported that industry-science R&D collaboration between firms, research institutes and universities have intensified considerably when domestic industrial capability are able to produce more domestic patents, which went up to 700,000 per annum from 2011 onwards.

Much of the R&D success including basic research came from the FDI plugging on to specialized R&D clusters to improve the technical capability of local Chinese firms. For instance, Guangdong province in China, (which is China's first developed city to attract large flows of FDI accounting for a third-FDI inflows to the country, became the leading electronics cluster to export around 35% of high-tech exports since the 1990s. In fact, Guangdong province have experienced the highest rate of industrialization in China since the 1978 economic reforms. Like South Korea and Taiwan, China managed to appropriate synergies from migration trajectories to turn brain drain into brain circulation (e.g. Panyu population with Hong Kong, Xinyi population with Malaysia, Hong Kong and Singapore) (see also Saxenian, 2006). Also, the Guangdong provincial authorities also have link up the SME enterprises to reap the benefit from the FDI inflows at the economic zones of Shenzhen, Zhuhai, Dongguan, Zhongshan, Nanhai, and Shunde (Vogel, 1991; Arvanitis et al. 2003). Among these economic zones, Shenzhen has experienced the most S&T development where 97.1% of 521 S&T research facilities were set up by private enterprises (dominated by foreign firms), such as Meidi/Midea, Galanz, GREE, Kelon, Jinlin, Jinyue, which drove Guangdong province to account for more than half of 65,000 huge patent registrations in 2001 (Arvanitis et al. 2003).

In addition, China's sheer size offers the scale from its large local market that is supported by the presence of high-quality skilled labor and good administration. The FDI has brought in many foreign knowledge and positive spillover experiences which the Chinese government can leverage on and went on to develop their own major production hub in IC design and manufacturing in 1990 at Xiamen. As a result, Torch High-Tech Industry Development Zone at Xiamen managed to increase IC[25] growth in the electronics industry with the achievements of United Microelectronics Corporation (Taiwan), Tsinghua Unigroup and Xiamen Sanan Optoelectronics. Tsinghua's Professor Wei Shaojun claimed that such a technological catch only left with a small gap between China's HiSilicon and US's AMD, which since 2008 is owned by Global Foundries. Another study by Chung (2005, 2006) using case studies examined the local characteristics that attracted large FDI and spillovers to increase the productivity of local Chinese firms. He showed the types of FDI relocating in China, including MNC R&D in knowledge-intensive rather than in labour-intensive activities. MNCs engaged in strategic R&D have upgraded their R&D activities to survive competition from other foreign and local firms in the domestic market.

This gave the triple-helix locational advantage to China in expanding their transnational networks and entrepreneurial talents who operated at the R&D-intensive location of Silicon Valley, manufacturing and developmental location of Hsinchu-Shanghai, and marketing location of Beijing played a key role to gradually spawn R&D in China as reciprocal R&D and new business opportunities. Chung (2005, 2006) used case studies to compare the experience of China Beijing Zhongguancun (ZGC) Science Park and the Tsinghua Science Park with the US Silicon Valley and Taiwan's Hsinchu

[25] Sixth largest contributor to China's revenue in 2017. For quarter 1, 2017 generated RMB4.08 billion yuan, increased 32% from previous year (SCMP, 2017).

Science Park. For instance, top universities in China have exploited their academic assets such as Tsinghua, Jiao Tong, and Peking Universities have set up university-run science parks close to the universities to attract both MNCs and domestic firms (including startup companies), often through joint R&D projects using talent attracted back from abroad (Table 3.2). Using their strong alumni-student-scholar network based in ZGC and R&D projects with other major universities have helped the projects formally and informally to tap into public resources embedded in these top universities to reduce failure rates of startups and operational costs. Next example would be the successful case of Motorola R&D center in China upgraded to develop local knowledge assets by partnering with the local universities of Tsinghua and 14 other local engineering universities to set up a microcontroller lab in 1995, and subsequently collaborated with South East University in Suzhou to design new Bluetooth and microcontroller applications for China's 3G system and handset in 2003. By 1998, China became the largest manufacturing site and second largest market for Motorola. The upgrading of Motorola R&D centres increased two-way knowledge flow between China-France-Germany-Hong Kong-Singapore researchers. Motorola also invested heavily on systematic internal training at Motorola University in Tianjin to facilitate technology transfer and speed up absorption capability (Chung 2005, 2006; see also Saxenian, 2003, 2005; Young, 1992, 1995, 1998; Krugman, 1994).

However, some authors might not fully agree that the Chinese patenting policy was actually effective in producing useful patents. According to Lei et al. (2015), the provincial patent subsidies have acted as a short-term stimulus for local patent development, but it was wasteful and inefficient in the long-term to produce high-quality patent. Concerning this, Zhangjiagang served as a good example that patent could be a number game just like university ranking or patent citation rate if the quality is not regulated to produce valuable knowledge. Zhangjiagang city patenting applications had increased substantially in 2006 in Jiangsu province based on the potential net gain and financial rewards of RMB10,000 given by the local government for patents granted regardless of patent quality, while the cost is estimated at RMB8,000, which resulted in inventors attempting to split their applications into multiple filings to collect financial rewards. In contrast, in four cities of Suzhou municipal-Taicang, Suzhou, Kunshan, and Changshu patent filings remained unchanged due to their no-rewards policies (Boeing et al. 2016; Lei et al. 2015).

South Korea

South Korea is by far the largest recipient of royalties and licensing fees in East Asia since 1988. South Korea was only second to Israel on R&D spending as a share of GDP in 2018 at 4.15%. Sung et al. (2003) did a survey on 200 companies located at Daejeon between 1995 to 2000 and found a non-linear relationship between R&D investment and patent filing. These firms showed actively participation in R&D which basic technology research took up a smaller proportion (12.6%), while applied research (55%), and production (32.4%) still dominate the patenting activity back then.

The South Korean government then learnt from the Japanese model to grow their large firms (*chaebols*), such as Samsung, Hyundai, LG and Daewoo aggressively into export-oriented firms and to assimilate the knowledge from foreign technologies rather than leveraging on FDI. Some of these chaebols excel in core research areas, such in graphene technology, Samsung ranked first in 2015 producing up to 13,355 graphene patents families, which it evolved through successful collaboration with SKKU (IPO gov.uk, 2018). Despite the dominance of large chaebols, high technology industrial agglomerations in South Korea strengthened connections and coordination between the critical actors, which Schmookler (1966), Binswanger (1974), and Schrerer and Harhoff (2000) considered as critical to stimulate cluster innovation activities with strong macro-meso-micro linkages (Rasiah, 2015). Because of this favourable policy back in 1990s, it was also extended to support start-up entrepreneurs majoring in natural sciences and engineering and stimulated them to venture into high-tech industry which helped increase the patent filing in South Korea rather than being limited to the *chaebols*. Next, when the South Korean firms became more competent on their own the firms started to acquired significant technological capabilities to become a major contributor to patent applications (Kim et al. 2017). As a result of immense knowledge creating activities in South Korea internalized in the large vertically integrated firms, (such as Samsung and Hyundai), strong collaboration does exist to support patenting and commercialization growing at a faster speed.

Basic research is found to be positively correlated with higher education in South Korea. Since 1970s, massive investments were also put into capability building and setting up purpose-built areas. The Korean central government established specialized public research institutes devoted to science, engineering, electronics, heavy industries sector to achieve technological development effectively, such as KIST, KAIST, KINS, KIET, ETRI, etc, and finance a huge budget to help technology transfer between 1966 to 1995.[26] (also place the abbreviations in a glossary in before the introduction chapter) High-tech clusters, such as Daejeon metropolis were built to accelerate basic research, which hosts more than 4541 firms as of 2015. To increase creation of indigenous innovation through private firms, several science parks have been built for long-term benefits to strengthen UIG collaboration, such as Daedeok Science Town[27] and International Science Business Belt, which houses 18 universities, including the Institute of Basic Science, and Electronic and Telecommunications Research Institute – with

[26] Korea Institute of Science and Technology, Korea Advanced Institute of Science and Technology, Korea Institute of Machinery and Materials, Korea Institute of Chemical Research, Korea Research Institute of Shipbuilding, Korea Institute of Electronics Technology, Korea Electronic Technology and Telecommunications Research Institute, Korea Basic Research Institute, Korea Aerospace Research Institute.

[27] Now known as Daedeok Innopolis; a high-technopolis established by President Park Jung Hee in 1973 and host 26 GRIs, 7 universities, 1516 firms, 30242 RSEs.

collaborative links with Stanford University to transfer knowledge to Samsung, LG and Daewoo. These networks rigorously promote domestic R&D[28] in strategic high-tech industries, such as biotech, machinery and electronics using local content requirements.

Over the years, patents became more than just a protected asset. Government tends to give tax credit schemes[29] as a popular incentive to steer private firms including SMEs to actively do R&D activities and as a policy to attract new investment into the country. This led to Cho' study (2014) which adapted the Triple Helix model into a Corporate Helix Model to examine comparatively two South Korean universities - POSCO-Pohang University of Science and Technology and Samsung-Sungkyungkwan University on their R&D.[30] His findings show that knowledge production capabilities in South Korea was still weak when compared with the US, Germany and Japan. In fact, Rasiah (2020) provided evidence to show that South Korea was still a net importer of technology from abroad in 2018. Even though the South Koreans employed a high percentage amounting to 70% of PhD-holders to work at public universities, the university research level at 10% was extremely low to support significant breakthrough opportunities,[31] which is not helped by the low level of interaction between university and industry. It worsens the R&D performance when there is lack of funds and inability to replace old facilities could have withhold a competitive environment among the faculty members. Thus, since the 1990s the Korean government made educational reforms to improve this interaction to prioritize R&D growth in the university policies.

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[28] Acquired low-cost patents from Russia and foster chaebols like LG to learn from foreign firms such as Motorola, Philips and Xerox or acquired companies to raise patents ownership e.g. LG acquired Zenith in HDTV, Samsung acquired Harris in non-memory semiconductor, Hyundai acquired Maxtor in HDD and ASIC technology

[29] To balance the development, tax credits were heavily given: 3-7% given to private firms purchasing patents, income tax and property tax were reduced by 50% for respectively 4 years and 5 years for SMEs outside of Seoul.

[30] POSTECH university is funded by Pohang Steel Company (POSCO) in 1986. SKKU is an ivory tower university funded by Samsung in 1996.

[31] A phenomenon known as Double Helix classified the low-level interaction between university and industry; once fixed shall enter into triple helix mode (UIG). University then become an entrepreneurial university. The changing environment enables a competitive knowledge provider, attract more capital investment and ability to leverage on corporate funds to lessen national funding.

Taiwan

Next, we review the case of Taiwan which has gain huge success and major influence in their R&D development with high quality patents, and not limited by their small size population country as resources. Taiwan has enjoyed considerable technological upgrading since especially 1980 (Tsai and Cheng, 2006). The catch-up phenomenon of these Asian miracles China, South Korea and Taiwan, demonstrated the critical importance of R&D, firms embedded in knowledge networks with critical research universities, and strong roles for the inflow of technology from abroad and government funding, though private firms were eventually the ones that evolved the capabilities to participate in basic as well as applied research to innovate at the frontier.

Beside strong inflow of technology, the macro-meso-micro coordination links that support firms on the knowledge networks have evolved enormously in Taiwan since the formation of the Industrial Technical Institutes in 1973 (Rasiah and Lin, 2005; Rasiah, 2015). Taiwan overcame the problem associated with knowledge leakage and built strong macro-meso-micro connectivity and coordination between knowledge nodes and firms so as not to negatively impact the competitiveness of the focal firm (Rasiah, 2019; cf. Griliches 1992 as cited in Frishammar et al 2015). In addition, Taiwan evolved its own de-verticalized framework, especially in the knowledge-intensive industries, such as integrated circuit (IC) design. Different investment capabilities, scale (firm size), scope, and managerial effects played important roles in the development of major firms, such as UMC, TSMC, Taiwan Mask and Acer (Tsai and Cheng, 2006; Hsiao et al. 2012).

The Taiwanese government fostered strong process and product innovations through technology transfer programs and UIG R&D collaboration. Such positive influence has led Taiwan to be among the leading USPTO filers with 162,732 patents file over the period from 1977 to 2015. (USPTO, 2015). Selected universities were tasked to do basic research and improve STEM fields education for the future entrepreneurs, inventors and researchers, while non-profit research institutes were aggressively developing industrial technology with R&D costs significantly lower than in the US and Japan,[32] which has made Taiwan a major exporter of high-tech products since the late 1970s. In addition, the political will in IP protection laws and production of high quality patents have clearly created a government roadmap to catch up in the strategic industries through the leadership of the ITRIs, such as electronics, several leading personnel with massive tacit knowledge returned to orchestrate Taiwan's push to the technology frontier.[33] Indeed, the Taiwanese (Morris Chang in particular) pioneered the wafer fabrication only business model to manufacture fabricated wafers (Rasiah and Lin, 2005). This development was followed by the emergence of world semiconductor firms, such as United Microelectronics Corporation (UMC), Taiwan Semiconductor Manufacturing Company (TSMC), Taiwan Mask, Winbond, and Vanguard International Semiconductor Corporation (VISC).

Taiwan also do not have as many science parks as China, but the success of IC design firms in Taiwan semiconductor industry at Hsinchu City is one example that would challenge the notion that size matters. In terms of IC market shares, Taiwan (18%) ranked second after the US (53%), and ahead of a rapidly growing China (10%) market share in 2016. Taiwan successfully evolved the Hsinchu science park as a mirror offshoot of the Silicon Valley NIS model. In fact, two-way flows of knowledge, capital and skill between California-Hsinchu Taipei region dominated the interactions that drove the development of semiconductor firms in Hsinchu. Launched in 1980, the Hsinchu Science-based Industrial Park (HSIP) was established by the Taiwanese government to promote high-

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[32] The Taiwanese government enforced local content requirements (between 50-80%) policy on the foreign producers to upgrade the capabilities of local firms and use local parts and components in their product.
[33] 19,000 RSEs were brought back between 1950 to 1988.

tech intensive industries, such as IT, communications and flat panel displays (Rasiah and Lin, 2005). At the same time, National Chiao Tong University and Tsing-Hua University set up semiconductor labs to upgrade their engineering expertise to train more local high-skilled workforce to avoid manpower shortage in the industry.

Firms that located in the HSIP were 66% more productive than firms located outside of the park. Small firms have evolved into large high-tech firms to reach the technology frontier, which coincides with Hsiao et al. (2012) findings who used DEA and fuzzy-c means approach to cluster the 87 Taiwanese IC design firms at Hsinchu and Nangang science parks into four groups according to their scale. They found these firms have greater advantage because of their ability to keep their operational costs down, while increasing their revenue. As with Japan and South Korea, Taiwan drove technological catch up without relying significantly on FDI, though the latter was never prohibited (Rasiah and Lin, 2005). Wong & Goh (2015) found that Taiwan's OEM-ODM framework placed emphasis on techno-entrepreneurial activities and the development of locally owned manufacturing industries.

Malaysia

Malaysia remains a strong candidate among the Asian-8[34] economies to make the transition to developed country status. There are also several science parks in the country that were launched from the mid-1990s. The government have attempted to build the Triple Helix model in Malaysia when it embarked on launching multiple S&T parks from the early 1990s to catch up with Japan, Taiwan, and the US as a basis of inventive step. Since 1990s, MyIPO and MASTIC also observed a rise in patenting activity in the country, which was largely driven by public universities but coincidently these firms

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[34] Asia-8 economies are Malaysia, China, India, Japan, Singapore, South Korea, Taiwan and Thailand. Read more at Asia: The Growing of Scientific Research https://www.asianscientist.com/2011/04/features/asia-future-hub-scientific-research/

happened to be the highest recipients of public R&D funding i.e. five RUs and GRIs, such as MIMOS, Malaysian Palm Oil Board, FRIM, SIRIM, MARDI, Malaysian Rubber Board, to name a few.

Basic research in R&D in Malaysia were initially state-led and tailored to match the South Korean and Japanese experiences, as MyIPO[35] believes the greatest source of invention in the country are local universities (or academic patenting), though patent applications has been dominated by foreign applicants (95%). Subsequently, Malaysia launched the Intensification of Research in Priority Areas in the 1990s to advance fundamental science, create sufficient funding and facilities to increase innovative research in science and engineering.[36] This has liberalized the foreign investment and higher education has been commonly used as performance indicators to ease application of funding rather than knowledge creation beside increasing patents.

Despite spending considerably effort on R&D as shown in Figure 2.2, Malaysia evolution of network of knowledge nodes and incentives and grants to support R&D in firms remained bleak. Malaysia's S&T achievements are rather limited and several challenges arise with the disconnected between STI policy and technological breakthrough. The development of the NIS since 1991 did not give significant impact when Malaysia only spent 34% on basic research compared to 57% by Germany, 45% by France, and 40% by the UK and South Korea (UNESCO, 2017). Much of the R&D allocated to the private sector were actually government owned firms operating in the private sector with Petronas and Proton being among them which to a great extent did not promote real private firms to be innovative entrepreneurs on their own.

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[35] MyIPO is the custodian of IP laws in Malaysia setup in 2003 to administer effective IP registration matters for IP owners but less focus on IP adoption for innovation purpose.
[36] Read more https://www.nst.com.my/education/2017/04/229752/why-we-need-useless-knowledge

Perkins, Rasiah and Woo (2021) also have shown that Malaysia had not performed well on innovation output, including filing of patents. Malaysia is not just insufficient of patents with only amassed 2,690 patents between 1977 and 2015 in the United States (USPTO, 2015). On the basis of poor performance on technological indicators, Perkins, Rasiah and Woo (2021) are that Malaysia is facing a middle income trap that has prevented it from breaking out to to progress towards developed status, though its universities have done fairly well on scientific publications (Figure 2.3).[37] Akoum (2016) found the link between patent filing and real GDP per capita positive over the long run, but the short-run relationship was negative over the period 1996-2011. In addition, Kamaruddin and Samsuddin (2013) findings show that Malaysia has consistently shown low commercialization rate of innovative activities (only 3% technological R&D successfully commercialized) owing to a lack of qualified staff or entrepreneurial motivation to drive spin-off companies. The lack of opportunities has actually discouraged the return on qualified diaspora from abroad.[38] This severely constrained the domestic firms led to low filing of patents between 2011 to 2015, and close to 90% of patents filed in the US were actually by the foreign firms. There are also instances that the main patent filers are relying on larger Malaysian domestic firms such as MPOB (palm oil) and Purecircle (biotech) might further thwart the advancement of the SME firms on basic research R&D commercialization.

[37] Read more http://fcee.utm.my/kamaruddin/category/research/page/4/
[38] Phenomena known as brain drain whereby almost 50% of the talents were absorb by countries nearby like Singapore.

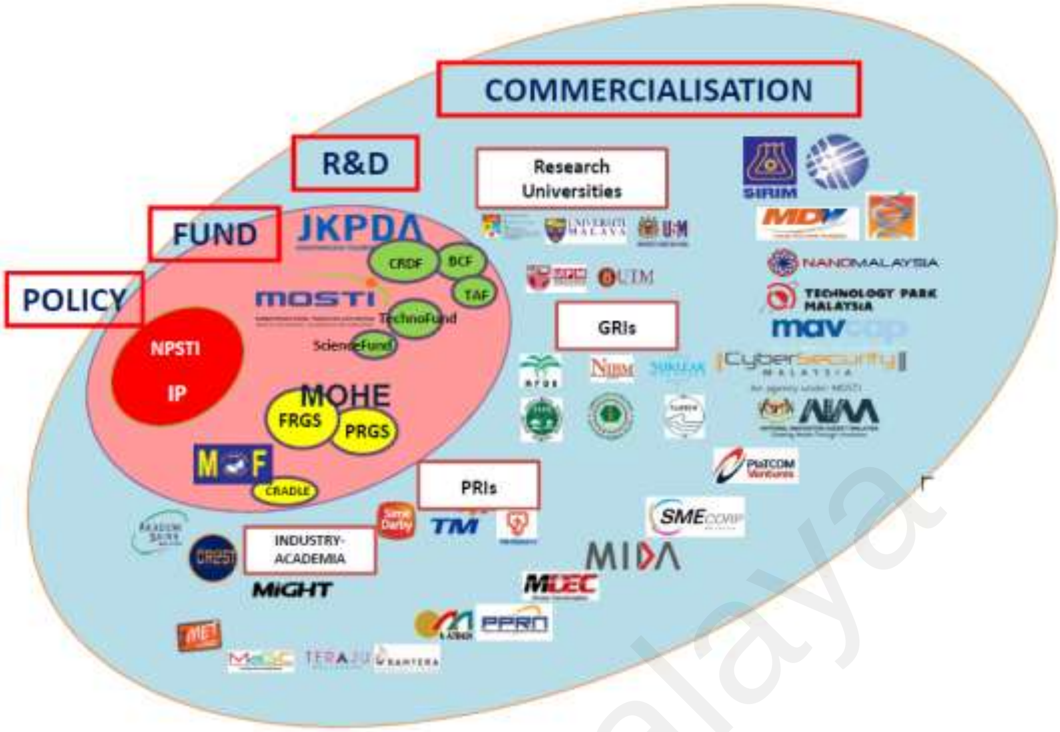

Figure 2.2: Malaysian STI Landscape

Source: MOSTI (2017)

Engineering & Technology - 2017 — Area: Engineering

	Rank	University	Papers
Top 5 Asia	4	Nanyang Technical University (NTU)	44,537
	7	National University of Singapore (NUS)	41,156
	10	Tsinghua University	92,228
	11	University of Tokyo	60,900
	14	Korea Advanced Institute of Science and Technology	35,285
Top 5 Malaysia	35	Universiti Malaya (UM)	10,944
	90	Universiti Teknologi Malaysia (UTM)	15,929
	93	Universiti Sains Malaysia (USM)	9,552
	135	Universiti Kebangsaan Malaysia (UKM)	9,006
	145	Universiti Putra Malaysia (UPM)	8,449

Based on number of papers published in SCOPUS which covers area of Engineering and Chemical Engineering

Visited 5th Oct 2017, 11:00 am

Figure 2.3: Performance of research publications, Asian universities in Engineering

Source: Kamaruddin (2017)

Furthermore, Malaysia's low R&D expenditure in GDP came to only 1.3% in 2018 (World Bank, 2020) when many countries have speed up their R&D expenditure to beyond 2% to their GDP income. The distance to incumbent Asian technological frontiers, such as Japan, South Korea, Taiwan, and China remain far, and the slow growth in granted resident patents from 11 in 1989 to 373 in 2016 (CAGR 13.4%) is too low when compared to those countries and R&D spent.

Yet at such slow speed of patent generated by the domestic firms, the foreign firms filing of patents seems indispensable and rose from 6 to 2,980 in the same period (CAGR 23.9%) demonstrating domestic firms' high dependence on foreign firms for the bulk of the manufacturing technologies. CAGR Foreign patents 22.85% per annum is almost twice the CAGR Domestic patents 13.55% (1988 to 2019) (Author's calculation, 2020 from WIPO IP Stats). There is no drastic improvement on the average rejection rate on domestic patents (still remain at 79% to 80%), the patent races to catch up with the technological frontiers remain slow when foreign patents accounted for 85% of total granted patents as of 2019 and unable to internalize the foreign knowledge transfer is a major impediment to economic growth and R&D advancement. This also implied that Malaysian domestic firms may be limited by its own portfolio to control production and exclusion from the global market.

The risk of stuck in low levels of R&D performance remain unresolved. Unlike the incisive role the returning diaspora and those still abroad participating in brain circulation found in China, South Korea and Taiwan (Saxenian, 2006), the rich pool of Malaysian diaspora abroad have not been tapped effectively to lead R&D centres in Malaysia (Rasiah, Lin and Anandakrishna, 2015). In fact, Rasiah (1999, 2011) argued that ethnic colored policies has prevented the government from appointing qualified personnel endowed with tacit knowledge. Consequently, the science parks in Malaysia have largely stayed as white elephants that do not show up among the patent filers in the United States. Consequently, despite the government launching several R&D grants and incentives to stimulate R&D activity in the country, which include the Incentives Tax Allowance (ITA) scheme since 2009, Malaysia has remained dismally way behind South Korea, Taiwan and China in the filing of patents (Rasiah, 2014).

Hence, Kendall Powell suggested that since retention of talent is a chronic issue to the developing countries or in particularly Malaysia, one way is to entice scientists working in the industry to go back to academia, while Zweig (2008) suggested for the Malaysian government and firms to actively reverse the negative impact caused by emigration of high-skilled workers by establishing a broad-based strategy to connect with the S&T scientists and scholars who remain overseas at the host country and remove barriers to allow easier access to technological skills at developed countries to help promote economic growth through science and education partnerships. In this regard, Malaysia has also taken advantage of this strategy to retain its talent and expand its transnational education by encouraging more reputable foreign degrees programs to be established in Malaysia either through international branch campuses or stand-alone and dual-degrees (Lai & Yap, 2004).

In 2021, Malaysia higher education also established the National TVET Council (MTVET) for the government and industries to work closely to develop more TVET talents and enhance industry skills that meet the latest trends.[39] However, the noticeable impact to Lai & Yap (2004) still found that Malaysia's technological upgrading pace are less successful than South Korea and Taiwan because of a small share of GERD fund (less than 0.5%) allocated between 1990 to 2000, resulted in lost years to catch up. The

[39] specialized industries which are automotive, semiconductor, marine, aerospace, air-conditioner, robotics, transportation, telecommunication, hospitality, tourism, and food technology

country still relied heavily on foreign sources of knowledge to be able to support large scale patenting. While university-industry collaboration exists, they have not evolved with strong connectivity and coordination. The Malaysia's NIS is still weak, though the five RUs namely, UM, UTM, UPM, USM and UKM have established linkages with firms, but sporadic and only in minor back up areas.[40] Much of this contribution comes from co-authored citations from scientific publications. Such weak knowledge linkages remain questionable on the long-term prospects for firms in the country to close the gap with Type 1 firms as per Gersbach (2017) study.

By and large, this pertinent issue has been highlighted many times that Malaysia has invested heavily on education in relation to its GDP over the years, but the quality of the human capital development has remained a major problem that has restricted firm-level upgrading (Cheong and Selvaratnam, 2011, 2019; Selvaratnam, 2021; Perkins, Rasiah and Woo, 2021). Another issue is Malaysia somewhat is lack of diversification only 2% to 3% of university-industry collaborations from the sample across public universities in Malaysia that used data from the last three years performance in 2017 (Afzal et al.,2017). They acknowledge that R&D investment, publications, business partners invitation to collaborate in R&D or consultation projects, and enhancement in innovation management related curricula have increased over the years at the universities, but the failure to spin-off companies have caused deteriorating performance as the commercialization levels from UIG relations have been dismal.

Next, Rasiah (2004, 2014, 2015) found that the basic infrastructure in Malaysia is excellent and is comparable to that in Japan, South Korea and Taiwan. However, his evidence placed Malaysia significantly below these countries, and China. He also

[40] The five RUs were chosen by the Malaysian government in 2007 to enable more technology transfer and commercialization activities. Subsequently the 20 public universities such as UMP, and private universities such as UTP constantly invest in R&D and raise their competitive level by participating in R&D ranking such as MyRA.

concluded that Penang has developed into a high-tech cluster and semiconductor firms build linkages with US but lacks linkages with national universities and local R&D centres, which consequently produced high-tech infrastructure index (HII) score of only 0.13 out of 5 compared to 3.18 for Japan, 2.14 for South Korea, and 0.47 for China in 2002 (Rasiah, 2004). He described that both Taiwan and South Korea were impressive in promoting the returns of their own citizens with policies that raised human capital to support innovation growth.

Similarly, agricultural sciences R&D in Malaysia also enjoyed a massive improvement when open science was launched to spearhead the development of the rubber industry. According to Alavi and Azmi (2013), Malaysian Rubber Board (MRB) and Rubber Research Institute of Malaysia (RRIM) have achieved strong innovation in rubber technologies through collaboration with University of California. Local patents increased since 1987 that benefitted domestic planters and mid-stream processors' income from better cultivation of rubber lattices, breeding new high quality disease resistant rubber clones such as RRIM900, RRIM2000, RRIM3000, and create technological advances from upstream to downstream plantation products, such as rubber shock cells for protecting structures from earthquake damages or biodegradable automotive parts. However, while the rubber industry has received a huge fillip since the COVID19 pandemic struck in 2020 through soaring demand for gloves and masks, and the long growing demand for condoms, Malaysia has yet to developed a university that shapes the technology frontier in the industry.

2.7 Summary

This chapter reviewed the two leading arguments on the drivers of technological upgrading, (i.e., neoclassical and heterodox), with a focus on R&D operations and institutional linkages that are pertinent to support such activities. Special attention was devoted to basic research and research universities. While acknowledging that measures of technical change are multi-faceted, patenting was chosen for establishing the success of countries' in driving technological upgrading. Owing to their rapid evolution as well as proximity to Malaysia, the chapter also reviewed the progress achieved by China, South Korea and Taiwan to locate Malaysia in perspective subsequently.

Following the review, we shall adopt the heterodox approach as it addresses the public good nature of knowledge, while acknowledging that technology comes with costs with significant deliberate efforts to support firm-level catch up and leapfrog (see also Schumpeter, 1942). However, unlike the old arguments reminiscent of Feldman (1928), we assume that the market is a critical influence over innovation activities that can be sustained over the long run. In doing so, while recognizing the important role governments play to facilitate the creation and development of the science, technology and innovation (STI) infrastructure, institutions and institutional coordination are important to steer the direction of innovations, including to solve both government and market failures. While both patents and scientific publications do not directly equate with economic performance, in the absence of reliable information on commercialization in Malaysia we use them as they are good proxies of innovation output.

While attempts to capture the synergistic role of constellations of firms and organizations, and the extent of connectivity and coordination of knowledge flows to examine the strength of the NIS on innovation output, it is difficult to actually amass the information required to do this. Consequently, the remaining chapters examine the role of R&D in patenting and scientific publications, as well as that of research universities in patenting and publications in Malaysia.

CHAPTER 3

RESEARCH AND DEVELOPMENT AND OUTPUT GAP

3.1 Introduction

The role of science, technology spillovers and new knowledge creation are part of the innovation growth process. In this chapter, we examine the impact of basic and applied research on patent filing and scientific publications in Malaysia. Basic research in Malaysia is conducted primarily in universities, government research labs, or by large business enterprises. As explained earlier basic research often quickens the appropriation of innovation output through the take up of designs and scientific publications. Certain underlying science and designs become clearer after much experimentation and undergoing practical performance measures, while basic research also benefits the universities by providing new knowledge to the skilled graduates before they are exploited in the working world. If the basic research conduit is undertaken effectively it will help strengthen Malaysia's NIS. For the purpose of this study, we shall focus on the key proxies of S&T, i.e. R&D expenditure (GERD/BERD), R&D personnel, higher education (S&T student enrolment, graduates), R&D output (patents, royalties), STI policies (IPR, knowledge hubs, clusters/COEs, and subsidy seed funds.

The notion of leapfrog or catch-up with the developed countries would not be possible without investment into basic research. The technological gap between countries will affect long-term growth, and given that R&D is both risky and uncertain, and requires lumpy investments, either within firms or through connecting with knowledge networks, the role of government is important in coordinating these activities effectively. Hence, studying this gap will allow us to understand the commercialization of basic research R&D in Malaysia.

3.2 Critical Issues

The study sets to examine the long-run relationships of patent on economic growth in Malaysia and whether it has undermined the technological progress on the country through first-order or higher order Autoregressive Distributed Lag (ARDL) approach. The ARDL approach first introduced by Pesaran and Shin (1999) and further extended by Pesaran, Shin and Smith (2001) would be ideal to measure patented innovation and spillovers. It can measure the process of innovation and diversity in these approaches to innovation and economic development. If these are conceptualize carefully, it can speed up the turnaround time of new product development, raise per capita income and productivity of the country to achieve higher growth rates.

Using patent and R&D expenditure to foster innovation, past studies showed positive relationship in the long run between patents growth and economic growth, and investment in tertiary level education including research activities (or R&D expenditure). However these are not easily to differentiate between major or minor innovation which the former is required to catch-up and leapfrog when mixed of foreign and domestic inventors ownership and the rights of use and commercialize the ideas.

In the real world, the entire patent systems can be rather complex and the patents growth may have irregular trends to tally with the distribution of economic activities and perceived returns. It has to balance between increase innovation, knowledge sharing and economic growth. And it is true, the challenge is also to separate the return on investment in tertiary education private or public investment due to attachment of the tacit knowledge to its owner of the design or patent itself. But we can demonstrate the significant economies of scale on a particular patent can exploit speed up or slow down the country.

Since patent is endogenous, it can be a powerful tool to fulfill novelty, inventive step and industrial application. Investing resources into such patentable R&D aim to net off the effects of these irregularities to increase the size of tangible assets. On a positive note, appropriating the return from basic research inventions can stimulate superior performance of the final valuable product, improve the living standards, produce competitive human capital, facilitate new knowledge creation and technology, and steer positive social rates of return.

Since we still believe patenting or inventive activity resulted from basic research is a stimulus rather than burden despite the experimentation costs, our aim is to conceptualize a model to exploit the two major inputs that technological progress is associated closely with in the long term i.e. patent types and the number of scientific and technical workers, and how these inputs strengthen the knowledge inflows to increase the patents stocks. Patents type become part of the critical input to build innovation pipeline. Patents have become the critical input to a firm success in medical industry or ICT such as Huawei or Lenovo. So, we attempt to fill the gap by using the Romer's innovation, Pakes and Griliches's knowledge production framework (KPF) to directly and indirectly measure the proposed model in a systemic manner how the patenting order is done to increase stock of knowledge that prevents decreasing return to scale. Griliches (1979, 1986) also explored the relationship between R&D activities and knowledge output as a byproduct to the structure of lags of R&D activities necessary to compute properly the stock of R&D capital. The compounding wealth of the country is a concurrent process associated with technological progress and these innovation activities have direct effect on the economic growth (Schumpeter, 2014; Romer, 2015).

Since R&D performance is related to the patents, the main idea is commercializing these basic research stage-to-stage would obtain larger knowledge spillovers effect, and finally turn to high technological and economic growth performance. Within this framework, research efforts and spillovers can be traced by looking at incremental growth of new knowledge which most often can be proxy by using patents statistics. With respect to external knowledge, past approach showed that 75% of the primary studies uses patents stocks compared to patents citations to measure scientific or knowledge spillover in the relevant technology field (Neves & Sequeira, 2018).

Furthermore, aside patent, market and focal industry are also important considerations to strengthen the competitiveness in the core business or to cultivate new opportunity seeds mentioned in Chapter 2. However, the growing concern is to measure this R&D investment to output gap is. The patenting propensity for developing country like Malaysia may differ and is no longer able to catch up with the frontiers on productivity. In order to speed up knowledge transfer and appropriation, one way is to be nearer proximity to agglomerate close to these frontier firms and reduce the differences in practice across different firms, increase the efficiency, subsequently transform and expand the industry moving away from low-cost and low-value added activity to enhance patenting productivity reforms as indicated earlier. So, proximity location is another close link interrelated to knowledge spillover and innovation which is measured using KPF when the flow of ideas from neighboring effect close to technology frontiers have resulted in greater regional knowledge and ideas exchanges, patent intensity, science parks, GRI, universities, and foreign advanced technology adoption rate have positive effect on R&D to stay ahead of competition. Although this can be a costly approach for the late comer and not all late comers actually survive in such intense competition coupled with high initial startup cost of such large agglomerated scale, the knowledge sources can be rewarding in the long-term towards achieving a positive KPF coefficient implies that holding other variables constant, a region that is surrounded by innovative neighbors has a higher level of innovation through positive knowledge spillovers.

These insights have led us to model the relationship between basic research and patent output or new knowledge flows to understand better where the inadequacies are. We demonstrated there are four essential factors to deliver an effective S&T discovery such as universities and its infrastructure including research institutes (HEI), human capital (HC), standardization innovations, intellectual property rights (IPR), and sufficient funding ($) as shown in Figure 3.1. The economic policies set by the government should take into account of formal education, knowledge creation and research and development of the country. Thus, effective policies steer positive growth on domestic firms' capabilities and raise the overall competitiveness of the country. Using this proposed framework, the advantage is we can investigate the deficiency in our basic research R&D performance by providing incentives to increase creation of new ideas and expand the existing stock of knowledge (see Figure 3.1 red dotted line). We will explore the model estimation on the determinants of patenting process in Section 3.4.

We consider the following simple model of R&D to our theoretical patenting decision. Romer's endogenous growth on innovation and Griliches (1979, 1986, 1988) KPF[41] framework fits the closest to the aim of our research in a generic specification as expressed in Equation (1):

$$Y = f\{A, X, K, R, \mu\} \tag{1}$$

where Y is denote as the output produced, A is amount of knowledge and technological progress, X is standard inputs variables such as physical capital, human capital, materials, and K is R&D input variables such as R&D investment, R is environmental characteristics

[41] Knowledge production function overcome the limitation of traditional Cobb-Douglas production function $Y=K^{\alpha}L^{1-\alpha}$, where $0< \alpha <1$ and α is exogenous and steady state growth. If new and existing knowledge stock serves as a factor in knowledge production, then its omission from the Cobb-Douglas PF will result in omitted variable bias and skew the estimates of R&D elasticity.

by market or region, μ is any unobserved residual factors that could influence R&D or error term.

The model above identified that the scale of these patenting activity is persuasive in the manufacturing sector in the developing countries but not necessary an indicative of cumulative in high-quality patent. This model underlay to explain the concentrated patenting activity and its causal relationships among productivity, knowledge spillovers, R&D investment as critical inputs. These patent stocks implied that the new knowledge production is a cumulative and synonymous activity with the research effort. Therefore, the R&D output with other controlling factors will directly or indirectly affect the innovation capabilities and performance. The literature posits a relationship between the level of technological knowledge and investments in knowledge production in the form of research and development, and sets before itself the task of estimating the impact of R&D activities on output and growth.

For variable *X*, there are two sectors: a goods sector that produces output, and a R&D sector that produces new knowledge. New knowledge or ideas are generated in the R&D sector, while labors are allocated between the two sectors to produce output (LY) or to produce new knowledge (LA) by time index t. Hence, the economy is subject to the following resource constraint $L_t = LY_t + LA_t$. , similar for us to conceptualize that there is a need to differentiate between academic patent and industrial patent. It can denote the size of R&D supply side effort capability.

A represents the stocks of new knowledge or the number of new ideas generated in the economy at a point in time by researchers LA employed in R&D sector, and can be modeled as a function in Equation (2):

$$\dot{A} = \alpha A^{\varphi} LA^{\lambda-1}, \alpha > 0 \quad (2)$$

where $\dot{A}$ corresponds to the average research productivity growth or newly produced flow of knowledge generated per researcher added to the existing stock, A and LA are inputs into new knowledge discovery and α, φ, λ are constant parameters. The knowledge creation process includes knowledge stock (A) on the right-hand side to account for the possibility that knowledge output depends on the stock of already accumulated knowledge. Outputs and ideas in the past may facilitate creation of ideas and outputs in the present, hence increases the research productivity of future RSE by increasing in the stock of knowledge ($\varphi > 0$)[42] when *A* (must be positive) capture positive knowledge spillover or even raise the bar for domestic technology creation or possibility of imitation at developing country to catch-up with frontiers.

Yet, although stock *A* is growing in the long run due to multiple knowledge sources domestically and internationally, but note that as additional LA grows, research could be duplicated or concurrently be done at the same time between different researchers or past knowledge has lost its relevance or ruled out when technological frontiers are competing among themselves aggressively. So, these duplicated researches would dampen the returns to research productivity or knowledge accumulation ($0 < \lambda < 1$) over time unless we can reduce duplicated jobs. In addition, if *A* (technological progress) is starting to slow down, the renewal of patents becomes lesser, so will the long run per capita growth and endogenous growth effects. Henceforth, we propose to use patents stocks as a more sensible proxy for *A* in consistent with our time series pattern, rather than TFP as used in previous Romer's model.

We will use Romer's or Griliches's KPF framework cautiously due to shortcomings of the function to model a full spectrum of basic research R&D effort. Skilled labor as

[42] Romer (1990) assumes strong positive spillovers (setting $\varphi = 1$) and that all actors at a given point in time draw upon the same stock of knowledge, and in the absence of knowledge depreciation.

the number of inventors and patent applicants can be considered as important factors to capture their man-hour and TFP on new discovery effort and cumulative gain, but the upgrading effort of physical capital i.e. research labs and science parks devoted to R&D or patent improvement (KA) that may also contribute to the new discovery process is excluded. Knowledge production function can be considered as R&D sector that develops the designs for the intermediates which constitute new physical capital (KA). In fact, R&D is more capital-intensive, so when our model takes into the accumulation of physical capital devoted to R&D it would correct any biasness in empirical estimates as described in Equation (3):

$$\dot{A} = \alpha A^{\varphi} LA^{\lambda-1} KA^{1-\lambda-\varphi}, \alpha > 0 \tag{3}$$

The different sizes of φ also require different R&D policy measures. If the parameter estimate of the knowledge production function in a sector is $\varphi = 1$, it is essential to set aggressive policy measures to encourage R&D to accelerate economic growth through new knowledge creation. If $\varphi < 1$, this means that economic growth is determined by the elasticities to produce goods and services and population growth, thus making aggressive government policy in the R&D sector less relevant (Jones, 2005).

We assume that newly patented innovations take time to be produced and may create enhancement to the cumulative asset. As a result, total number of patents will increase the knowledge discovery and patenting activity even though subjected to lags[43] and vary across years or time may reflect different levels of propensity to patent and overall ideas-to-output production before superseded by any new invention. In Equation (4), the developing country can capture A as the stock of technological knowledge, R_t is the sum

[43] Leo Sveikauskas (1986) applied a 5-year lag on basic research and 2-year lag on applied research. But a longer lag i.e. 3-year lag on applied research did not show any large R&D contribution on productivity growth.

of current R&D investment and $(1-\gamma)A_{t-1}$ is the current and lagged R&D expenditures. Thus, the measure of distributed lag effect of past research investments on productivity can be expressed as:

$$A_t = R_t + (1 - \gamma)A_{t-1} \quad (4)$$

From assumption in Equation (4), it implied that if the R&D lag effect is higher it will lower down the optimal choice of doing R&D (or in this case basic research invention). This induced us to impose a lag of one to three years between observed patenting and the variables associated with ideas production to aggregate production, in control for high lag that reduces productivity. Patents granted in any year reflect the inventive effort undertaken in prior years as observed accumulation of patents. Taken together, our empirical framework in Section 3.4 must therefore account for heterogeneity among countries, concavity in ideas production, and the lag between invention and patent grants.

In Chapter 2, we noted from past studies that universities have important responsibility to stimulate more basic research and raise domestic research capabilities for the country technological progress in the Triple Helix model. But it was uncompetitive in the case of Malaysia cause by inability to grasp the allocate R&D investment into the efficient and focal sectors. The university research experience to increase patenting commercialization was disappointing which is an important pre-requisite for successful frontiers industrial growth but failed to expand yet with state intervention. Some lower-income countries have successfully leapfrogged over the advanced countries and built their innovation niche, culture change, productive R&D clusters and research university excellence. Furthermore, some universities have become entrepreneurial universities as seen in the technological catch-up experienced by South Korea, Taiwan, Hong Kong, Singapore and China. The evidences show that substantial innovation can occur based on minor improvements to existing processes and product designs via the absorption of technology from abroad.

The common consensus to push for high-value research output among the S&T players have strengthen the trilateral networks. Gerschenkron's literature noted the transformation of the economy has been accompanied by extensive investments in higher education and proactive government to direct investment towards engineering and natural sciences education to strengthen catch-up (or innovation) activities as evidence in East Asia[44], Finland, Ireland, and Malaysia, beside increasing employment opportunities for the engineers and scientists. However, if this is not done correctly, he believed this led to relative backwardness like the case of Russia, as in why United States propel while Russia lacks behind.

Latecomer firms from developing countries can take over ready-made technology without spending huge development costs to increasingly build a competitive presence on the international stage and catch up against the technology frontier which is no longer dominated by developed countries alone. They knew the design or patent itself coupled with industrial linkages are source of experiential knowledge to strengthen teaching and research at universities to deal with R&D-centered activities or solve social needs. Hence, our concern is also when time lags go as high as 7 years between R&D expenditure and profit generation, will it deters the interest to spend on basic research in Malaysia. At present, the growth rate is highly dependent on trademarks which still account significantly to the proportion of patents in Malaysia. They contribute 16x faster than the

[44] Refer to Japan, South Korea, Taiwan, Singapore.

productivity in generating utility patents and industrial designs and resident to non-resident patents have been relatively slowing down (describe in Section 4).

It was also reported that the commercialization of academic research or patents among Malaysian research universities is still weak and unable to compete with technology frontiers and other global high-rank research universities in terms of scientific research with common issues such as inadequate infrastructure, poor linkages between universities and firms, and too few venture capitalists and business angel investors (Mahassen, 2018; Ismail et al., 2015), although the Malaysian government has spent sizeable budget in education (5.9% as of GDP), research expenditure (1.13% as of GDP) and continue to rise in the university ranking league tables and ease of doing business 2017/18 upon reforms undertaken to improve more economic development activities across borders.

The model we wish to test on the S&T factors would continuously strive for more conducive environment and trade policies for the institutions and experiential knowledge to grow in strengthening teaching and research at universities on commercialization of basic research. The universities shall create collective flows of knowledge creation and diffuse them into commercial use or to improve subsequent technology performance. The external technology spillover or knowledge tends to complement the in-house competencies of the firms and personnel (OECD, 1997; Veugelers and Rey, 2014).

There is much catching up to do for the Malaysian government in order to achieve higher productivity of R&D output and to stay ahead of competition in the ASEAN region. The R&D technology creation and adoption landscape for the country has tremendous changes over the years, so we shall conduct theoretical predictions using time series data on Malaysia to explore the implications of R&D in the country economic growth.

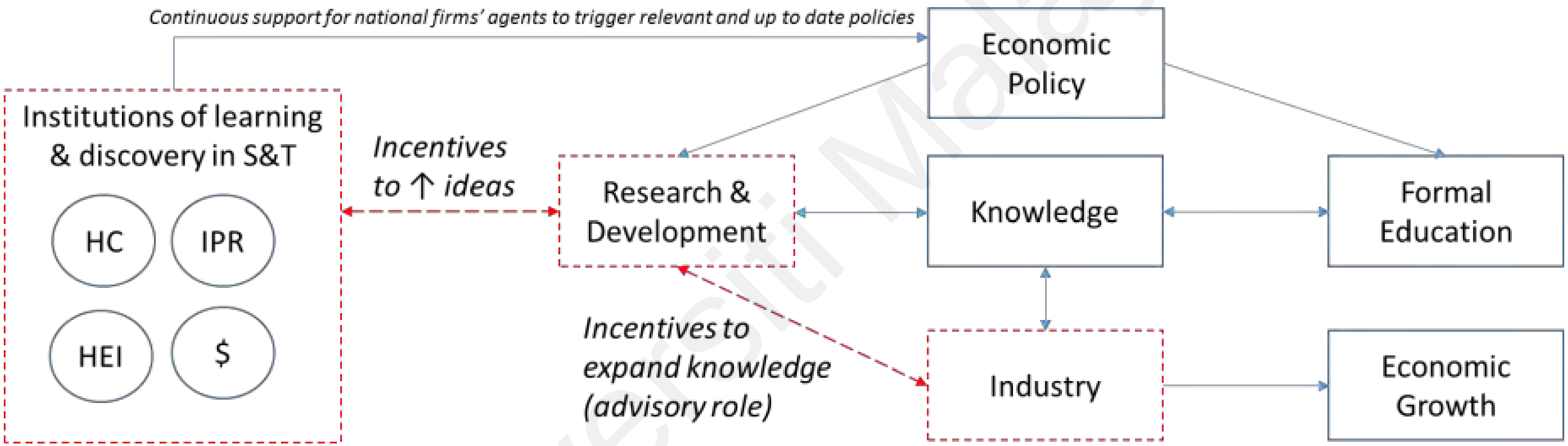

Figure 0.1: Conceptual Framework

Source: Adapted from Taylor (2006), Romer (1989)

3.3 Methodology

The statistical approach of choice for the analysis is ARDL (Pesaran and Shin, 1999; Pesaran et al. 1996, 2001), which is a time series model and is expressed as a function of its lagged current and lagged values of one or more explanatory variables. The approach suitable as there are no constraints related to stationarity of time series, which is strengthened using the cointegration test. The ARDL and the cointegration approaches have several advantages due to their ability to distinguish between dependent and explanatory variables to avoid the problem of endogeneity, while allowing the variables to exhibit different optimal lags and simultaneously estimate short run- and long run components in the model. It is widely used in measuring energy consumption, foreign investment, economic growth and is has become increasingly popular and relevant for the determination of short-run and long-run relationships between a given set of variables. Furthermore, Narayan (2005) recalculated suitable critical values for this modelling technique to improve the unbiased estimation when the sample size deployed is small.

The ARDL (p, q) regression alone in the absence of the cointegration approach is a dynamic single model equation that can lead to stationarity problems since we are using time series data that contains cumulative time deterministic trends elements. As a result, spurious regression estimates often emerge in these situations to make statistical results less accurate or misleading. A few key procedures are required to ensure no misleading outcomes. The first step is to tackle this spurious regression problem, which is to estimate the series by taking their differences (Pesaran, Smith, & Shin, 2001; Philips, 2018). The differencing method will remove the trend biases. The stationarized time series will provide clues for forecasting and more reliable statistics, but this method will tend to lose some important information as a result of taking the differences of time series data and any change on the results compared to the prior situation.

In order to verify the level of stationarity of the time series data, we will use either the Augmented Dickey-Fuller (ADF), the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) tests, while using unit root tests to identify the order of integration. An ADF value with less than its critical value underlines the series as non-stationary. In contrast, an ADF value greater than its critical value shows that the series is stationary. Also, we will carry out the Durbin-Watson (DW) test to check whether the residuals in the regression model has positive or negative correlations as generated by a first-order autoregressive process. As for KPSS, if the test statistic is higher than the critical value, we shall reject the null hypothesis (i.e. nonstationary) since null hypothesis is stationary and when the test statistic is lower than the critical value, we cannot reject the null hypothesis.

The reason for differencing is to have a meaningful inference of these statistical properties from the past to future without a trend to underestimate the mean and variance of future periods. After differencing the stationarized series, we first obtain a normal Least Square estimation to identify the initial relationship between the variables of interest, assuming we pass all standard assumptions of OLS[45] after performing the usual diagnostic test and residual analysis i.e. Jarque-Bera normality test, heteroskedasticity test on the regression by squared fitted values or visual inspection of residuals plotted against the fitted values, and identically distributed errors assumed to be normal with zero mean and covariance matrix Ω—that is, $e_t \sim$ i.i.d. $N(0, \sigma^2)$. Beside determinants from theories indicated in Chapter 2, we would also use stepwise multiple regression to predetermine a set of useful variables for our model selection. However, the results at this stage is considered preliminary and this study seeks more evidence of cointegration in the second stage of the analysis when an appropriate lag selection criterion is employed.

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[45] Must pass OLS conditions (Gauss-Markov theorem): model is linear and valid for any given sample size, errors are statistically independent from one another, expected value of the errors is zero and errors are normally distributed, independent variables are not strongly collinear to one another, and residuals have constant variance (see Hayashi, 2000, pp.3-43).

Since we are trying to determine why some developing countries grew faster or slower than other and patent has impact economic output, the advantages of ARDL modelling allow us to identify causal relationships among economic growth, set unrestricted lag of the regressors in a regression function, and estimate unrestricted error correction model. We can also run the ACF and PACF plots to check for any significant spikes, identify the coefficients of correlation between the time series and lags of itself, and correct for any autocorrelation issues. A higher-order lag is preferred to test the latency or explain the autocorrelation pattern and it assumes that lag 1 and lag 2 is correlated. The procedure also explicitly specifies the sample size to the chosen optimal lag and test the lagging effect of different types of R&D investment and R&D spillovers to do a reliable prediction. We also have sufficient 22 data points since we cover annual data. For granted patent database, we are not able to do monthly or quarterly data due to lack of information from MyIPO which is only made available in 2016.

Often than not, a common dilemma is to determine the choice of lag length. Variable Y_t does not respond immediately to X_t, so the time lapsed is called lag. This optimal model specification allows us to examine the logical aspect on how much effect of a regressor X_t on Y_t occurs over time rather than all at once, check on all lags that are significant, require only a small number of parameters when the effect occurs, must have no autocorrelation issue and is homoscedastic (error term is constant).

So, one must establish the correct ingredients for model selection to have a better sense on this econometric modelling. Note the lag length selection is an important process to assure the research findings reflect consistently to economic theories and as much of real economic simulations. First, we use Akaike Information Criteria (AIC) to find the appropriate lag lengths for small sample size of below 60 to avoid the probability of under estimation or avoid potential over-fitting for large sample size before the selected model is estimated by least square estimation and ARDL. AIC in ARDL outcomes can also give better optimize inference in identifying structural lags and break in a single equation. We would not use Schwarz Bayesian Criteria (SIC) due to various simulation studies have verified SIC does better when getting the correct order in large samples (Giles, 2013; Shumway and Stoffer, 2011; Liew, 2004). Of these two criteria, the smallest value should be chosen to specify the best model to solve our research questions. But in the event the smallest value poses autocorrelation issue, then the second smallest value should be considered. The model with the smallest AIC estimates or small standard errors and higher adjusted R^2 performs relatively better without adding new parameters to distort the R^2. The estimates from the best performed selected model become the long run coefficients. In addition, we shall run diagnostic check such as Lagrange Multiplier test of residual serial correlation to check if Y_{t-1} (first difference lagged series) has any problem of serial correlation.

Second, since the sample size is small because we use annual frequency instead of by month, we would use only short lags i.e. 1 to 3 years will be plausible in our ARDL specification. It is a useful method when sample size is small and a reliable method to measure long-term behavior. Given the above consideration, the long-run relationship between selected variables can be stipulated by past theory and a Wald test too.

Third, after determining the optimal lag length, the cointegration relationship can be examined using F-statistic since R&D, education, human capital, patent, any infrastructure and spillover cannot be capitalized instantly. Cointegration test developed by Pesaran (2001) such as ARDL bound test is applied to search for long run relationship between the selected variables in the time series analysis. Engle-Granger (1987) and Johansen (1988) develop cointegration approaches in different periods to eliminate any non-stationary problems. Cointegration will analyze the long run relations between integrated variables and re-parameterize the relationship between the underlying variables into an Error Correction Model (ECM) to capture short run and long run coefficients. Whereas in the cointegration analysis, if the two variables are integrated of I(1) and cointegrated, it is expected to Granger cause in at least one direction because one variable can help predict the other. We can then explore the knowledge production function in an error correction framework to further differentiate the short-run from the long-run effects of the explanatory variables on the number of patents created. The Granger causality tests will examine whether variable X_t Granger-causes Y_t if the lagged values of X_t or Y_t help improve the forecast of Y_t in any empirical research. And since we are attempting to relate R&D policy to stimulate innovation growth, the one-year lagged explanatory variables with respect to dependent variable is found to mitigate reverse causality problems as found by Minniti & Venturini (2017, pp.319-320) in their recent study as growth effect could be permanent or just transitory.

Critical values of bounds testing for small samples can be found in Narayan (2005), preferably ranging from 30 to 80 observations. There were two sets of critical values: one set assuming that all the variables are I(0) (i.e. lower critical bound which assumes all the variables are I(0), meaning that there is no cointegration among the underlying variables, and another assuming that all the variables in the ARDL model are I(1) (i.e. upper critical bound which assumes all the variables are I(1), meaning that there is cointegration among the underlying variables). If two or more series are cointegrated, then the variables can be interpreted as being in a long-run equilibrium relationship. A positive coefficient indicates a divergence, while a negative coefficient indicates convergence. By contrast, a lack of cointegration suggests that such variables have no long-run equilibrium relationship and can diverge from each other. The parameter can be between 0 and 1 which measures the speed of adjustment to the long term equilibrium i.e. the closer to 1, the faster the adjustment process corrected from the deviation of previous period. As such, we can use the calculated F-statistic measures to check against the lower and upper critical values determined by Pesaran and Narayan. If the calculated F-statistic exceeds the upper value, then H1 (alternative hypothesis) is accepted and conclude there is a long run relationship between the series. If the calculated F-statistic value is smaller than the lower value, then H0 (null hypothesis) is accepted and we conclude there is no cointegration relationship. However, if the calculated F-statistic is between the lower and upper values, we cannot conclude the existence of cointegration between the variables (Pesaran, 2001, pp. 289-290). In addition, we can assess the percentage of shocks in the long run trend during the period under review.

Thereafter, we can also check if the model is affected by any structural instability based on the stipulated period. We will employ cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares (CUSUMSQ) to test short and long-term relations of the series against the critical bound lines (parallel break points) as suggested by Brown et. al. (1975). If the plots of the CUSUM and CUSUMSQ statistics stay within the 5% critical bound, the null hypothesis for all coefficients in the given regression is stable and cannot be rejected. Whereas, if either one of the parallel lines is crossed, then the null hypothesis of parameter stability must be rejected at the 5% level of significance.

3.3 Analytic Framework

Based on the above framework, we can state the following hypotheses on the source of patenting in developing country:

Hypothesis1: on scientific progress and Productivity

If a country enhances its scientific appropriation (e.g., patenting), it will show high R&D productivity. While a country fails shows low levels of scientific appropriation (e.g., patenting) it will show low R&D productivity.

Hypothesis 2: on size of Innovation Input and output

If the size of S&T resources (patents and tertiary human capital) is an important source of scale on the innovation economy, a country that promotes the formation of large size patents stocks and inventors will enhance patents performance.

Hypothesis 3 on size of knowledge generated and patenting

An extension to hypothesis 2, if the supply S&T publications is an important source of scale on the innovation economy, a country that promotes higher dissemination of knowledge flow is associated with higher R&D productivity on the value of the patent.

We now introduce the variables used in empirical studies considering their theoretical relationships between the knowledge production function and economic growth. To address this gap, variables were selected to examine the role of basic research R&D in driving economic growth through home grown research excellence to fulfill the Strategic Thrusts 1 and 3 in the Malaysia national STI plan 2013-2020 by MOSTI (to describe further in this section after Eq. (7)). Several pieces of evidence in the above-mentioned literature are supportive to use Griliches and Rosenbloom past experimentations to infer changes in policy and theoretical considerations. Both showed that patents and GDP growth are positively related in the long run between patents growth and GDP growth. It demonstrated the strong positive effects of funding on knowledge production function and provided insights on the diverse phenomenon of scientific productivity using fixed effects and multiple years of lagged inputs on the right-hand side of their equations. In addition, the Triple Helix model and university catch-up model by Hirshman's (1958, 1970) FDI leveraging model also form the basis of my overall conceptual analysis below to examine the rate of technological progress in advanced and backward countries. He tends to postulate that if the relative development gap is large between these two groups of countries, this will speed up the catch-up rate. Assume this to the case of developing country, this consideration supported our hypotheses that larger technological gap led to larger spillover thus increases the rate of FDI and the extent of foreign patents penetration in Malaysia. The technological change is highly dependent on the amount of foreign operating capital. Clearly there is optimization issue arises in this context. The weakness in TTO in coordinating and facilitating own domestic technological change could have undermine the output gap in the national firms on their going forward investment decisions the foreign operating capital is non-sustainable for long-term growth and merely gain small share of access to the advanced technology. The similarity of success in South Korea, Taiwan and China on technological progress catch-up was the great improvement done at TTO level towards commercialization and less reliance on inward FDI alone.

Next, we synthesize the needs to differentiate between the different stages of R&D i.e. basic research, applied research and prototype onto the conceptual model (see Figure 3.2 label A) and explore the use of Griliches and Romer's knowledge production function in a quantitative manner since Malaysia had spent relatively huge amount of R&D investment towards higher research performance beside seeking to improve the employment levels of the RSE. All in all, the spillover effect on the national firms including research universities were much lower when this knowledge gap widens thus widen the research output gap as well. The test methods are deployed selectively to understand the purpose and empirical result derived from the tests.

Universities and firms produce new scientific knowledge by combining labor with capital or other purchased inputs. These inputs can be funded by various sources internally and externally. We hold on to the assumption that universities play an important role in producing basic research and high skilled S&T workforce, while domestic firms need could then arise to quickly have a turnaround solution to absorb and capitalize foreign technologies spillovers and develop their own basic research capabilities first through imitation and next by innovating new products to minimize the lags associated with these activities (as noted in Figure 3.2 label B). This also allows closer analysis on the possible impact on the university to carry this stewardship of higher basic research performance for upgrading the domestic needs beside spending on growing a larger group of tertiary educated workforce; common indicators such as education expenditure, education attainment, and test scores are discussed empirically in many previous studies.

Research questions were established to examine the long run relationship and gaps that can be explained between patents as economic indicator, crucial role of university performance to increase more basic research R&D to sustain economic growth competitively and upgrade technological capabilities of the country. Hypotheses are developed to test the research objectives and outcome pertaining to each of the research questions. With this work setting, using I(0) time series properties and perform analysis on the first order difference to seek how has the supply of S&T resources (patents and human capital) affected growth on GDP per capita, how has the supply of S&T publications affected growth on GDP per capita, is the current STI policy able to cater to future Malaysia S&T growth, and how can the university support the basic research initiative as we have entered the era of digital disruption? We try to synthesize the findings and propose a conceptual framework below to increase the returns or potential income from higher commercialization of basic research investment; typically viewed as a scientific breakthrough for long-term benefit and new knowledge creation that supersede the obsolete technologies by the university or too much reliance on the applied research of foreign technologies could reflect some level of biasness in its research funding bodies without building the country own technological capabilities in the long run (as noted in Figure 3.3 label C).

Among the empirical studies examined in Chapter 2, R&D expenditures, number of patents and number of scientists and engineers' employees are possible factors which complementary contributed to economic growth. Indeed 80% uses patent data or patent intensity to measure technological catch-up and R&D output, while another stream of literatures which stresses the size of researchers and technicians in R&D per million people, scientific publications or citations, assessment quality on research institutions, university-industry collaboration cannot be ignored to understand why some countries were successful in their catch-up process while others were not but stuck in huge expenditure of R&D spending that seen as either ineffective policy execution or lack of productivity. Gumus & Celikay (2015, pp.205-217) found that R&D expenditure has positive and significant effect on economic growth in the long run rather than in the short run on 20 developing countries (excluding Malaysia) from 1996 to 2010 using a dynamic panel data model. On the contrary, Hamzah (2011) found that government expenditure is inversely correlated to economic growth in Malaysia for period 1970 to 2007 using OLS regression estimation. Most of these empirical studies related to R&D preferred to use OLS (could be too simplified), ARDL (a better error correction modelling as an extension to OLS regression estimation), panel data or generalized method of moments techniques to analyze the countries local characteristics and learning curves in the R&D catch-up process to produce more innovation (Radosevic & Yoruk, 2018; Gumus & Celikay, 2015; Bozeman & Corley, 2004; Lin & Bozeman, 2006; Mueller, 2006; Griffith et al., 2000; Izushi & Huggins, 2004; Anselin et al., 1997; Hamzah, 2011; Shaari, 2014).

The use of scientific publication and citations also have recently increased to measure the knowledge flows and effectiveness of research inputs. However, compared to patents (described further in Section 4 and 5), the use of scientific publication solely to determine the basic research needs has raised difficulty to empirically prove or evaluate the R&D output quality accurately unless the indicator can be a complementary use with other important R&D indicators (to describe further in Section 6). This is because potential biasness may arise when scientific publications are typically observed on papers that have been highly cited and accepted by a journal editor. Further, biasness occurred when journal editors became the only judge to the potential article as a quality measure and their interest to keep readers of interest rather than to actually solve scientific problems or needs at the ground. The following summarizes the S&T indicators used based on the reviewed articles in Table 3.4:

Table 3.4: Summary of S&T Indicators

Category	Indicators
R&D Expenditure	1. GDP 2. Gross R&D expenditure 3. Investment by private and business sectors 4. Rates of return 5. Import, export 6. Openness in current prices, R&D partner diversity
R&D Output, STI Policy	1. Supply of scientist and engineers 2. Size of the market (demand) including export propensity (or size of firms) 3. Possess knowledge by doing own R&D activities to have positive spillover effects 4. Government funding, R&D subsidies 5. Collaboration between firm-govt-university by industry between more / less R&D-intensive 6. FDI 7. R&D intensity 8. Patent applications 9. Gross fixed investment / fixed capital 10. Labor population 11. Country risk index 12. Market size
R&D Personnel, Higher education	1. Education (tertiary, secondary level) 2. Enrolment rate 3. Tuition fee 4. Endowment fund 5. Number of graduates 6. Years of schooling

	7. Test score, Admission standards 8. Size of the trustee boards members 9. Size of manpower / human resource
Scientific Publication	1. R&D spending 2. Number of research papers 3. Number of universities 4. Bibliometric indicators 5. Citations per document or per GERD 6. H-index

Source: Author, 2018

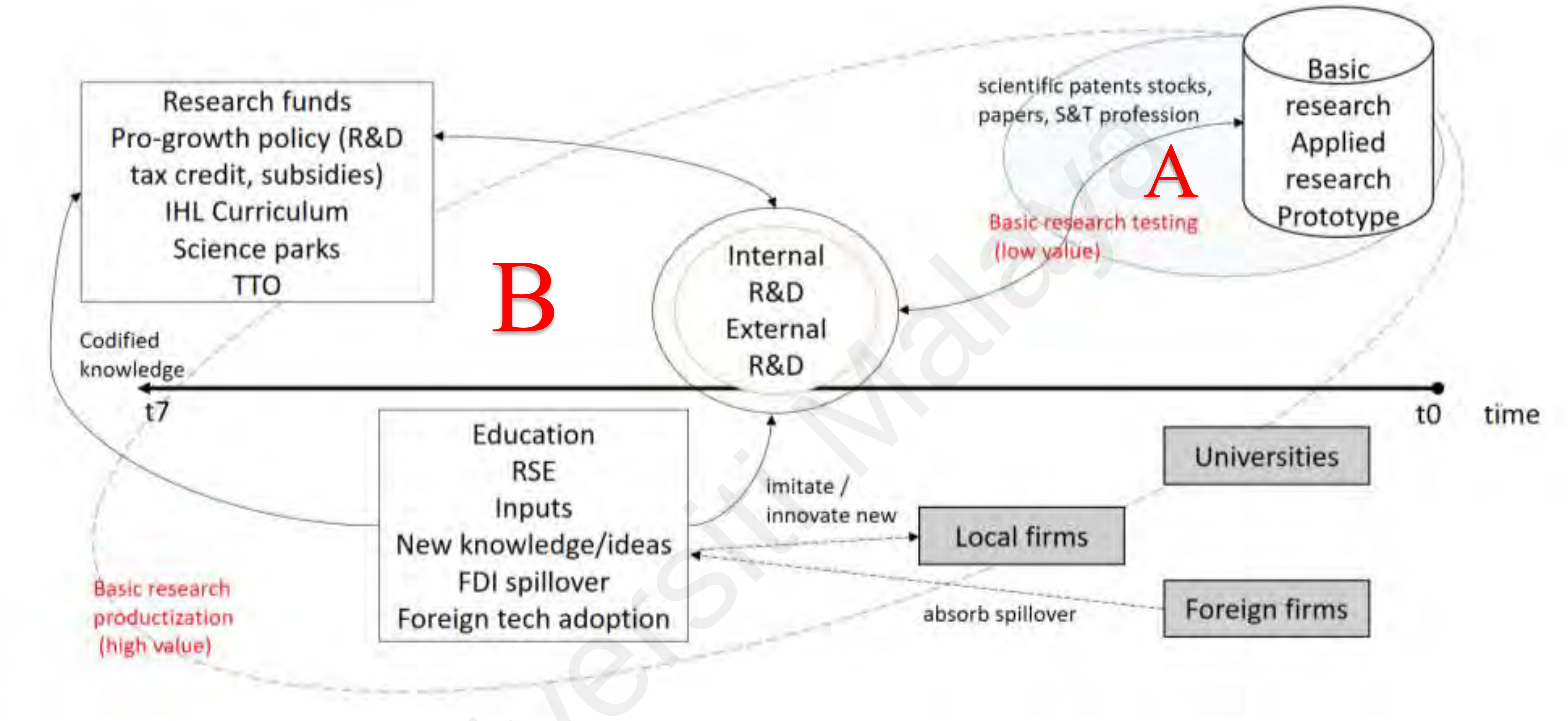


Figure 0.2: Analytic Framework

Source: Author, 2020

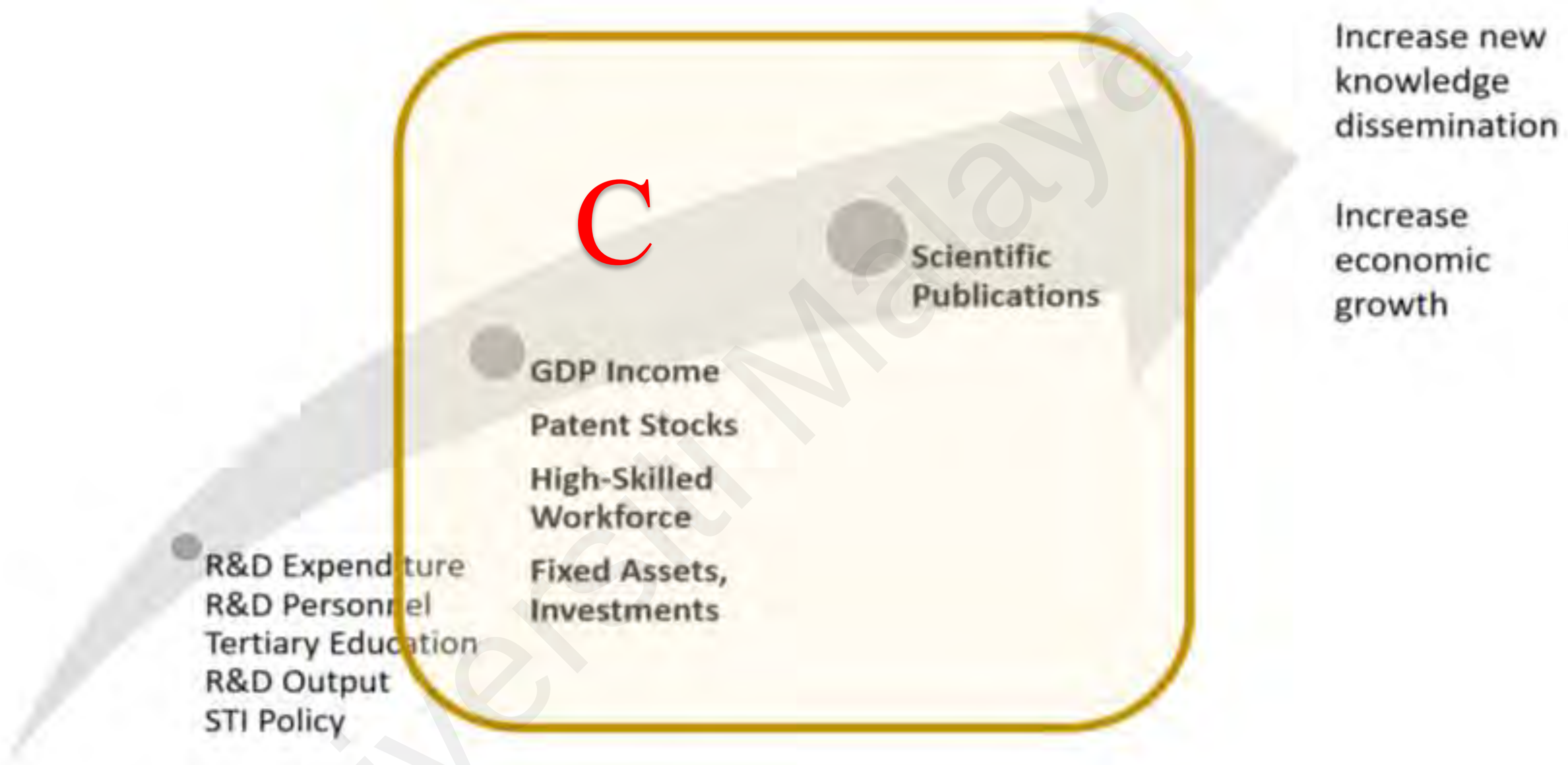


Figure 0.3: Conceptual Framework

Source: Author, 2020

Both patents and publications are the outcome of R&D or a research process, which are critical drivers of sustained growth. Mansfield, Griliches and Rosenbloom et al. (2014) pioneered the strand of basic research R&D which would not exist without the spillovers from academic research excellence. Thus, knowledge production function was set as the preliminary framework in the thesis and the relationship between the variables of interest can be expressed using a generic specification in Equation (5 to 7):

$$y_t = f\{x_t, x_{t-1}, \dots . x_{t-k}\} \quad (5)$$

$$y_t = f(A_t, L_{t-1}, R_{t-1}, \alpha) \quad (6)$$

$$y_t = \beta_0 + \beta_1 y_{t-1} + \cdots + \beta_p y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_q x_{t-q} + \varepsilon_t \quad (7)$$

where *t* denotes time period, L is labor input, R is research funding or R&D stock, and A is to capture technical changes that are common across universities at a point in time in Equation (6). $\beta_1 to\ \beta_p$ are the first-order to higher order autoregressive parameters describing the effect of a unit change on dependent variable y_t , and *t-1* denotes as the time period to reflect there is latency between input of resources and the commercialization and publication of research results.

The basic research R&D growth model presented in this study illustrates that real GDP is regressed over time on the variables of interest below which are central to our analysis: *GDP = f {past GDP, GERD, GFCF, ID, PAT, EMPHC}*. The scope of the research is on Malaysia basic research development. The country has experienced a series of economic transformation while R&D advancement has been a vital part of the twelve National Key Economics Area (NKEA) program to ensure it will not be left behind in advancing any potential innovative activities related to S&T. On data sources, we gather annual patents, GDP, fixed capital, and employment data sets collected from the Academy of Sciences Malaysia, MOSTI, DOSM, MOHE, WBG World Development Indicators, UNESCO, EPU, ILO, WIPO and USPTO over the period 1996 to 2016 in our analysis. We also cross check the numerical data between various sources to ensure consistency within the data collected, for example UNESCO / WDI / USPTO / ASM. We will employ these data to address the research questions.

Pakes and Griliches (1980) and Hall, Griliches, and Hausman (1986) researched the time lag effect of R&D investment on patenting activity. They found that, despite the limitation of data availability, the contemporaneous and lagged effects of R&D on patenting are significantly positive. Therefore, we need to conceptually quantify the time lags arises during translation process of the objects (see Figure 3.3); for instance, in patent stocks, the lags are required from patent application to timely patent realization including the knowledge diffusion process are completed and translated into actual product or new codified knowledge. Some lagged years examples are the cardiovascular research took an average of 17 years, cancer research took an average of 10 years, and nanotechnology took an average 5 to 6 years.

A quantitative analysis is carried out empirically to test the significance on the Malaysia GDP growth using 22 data points from 1996 to 2017 observations. The years of financial crisis are also included so that effect of changes (shocks) between those periods, if any, can be assessed in our analysis. The start year of 1996 was chosen in the analysis as Malaysia higher education system had just embarked on internalization and many R&D reforms activities took part to transform the RUs and domestic firms' technology capabilities in generating basic research. Any period prior to that is either lack of complete data or too few to examine in depth.

In the proposed conceptual model, we identified these variables of interest such as GDP income, R&D expenditure, patents stocks, high-skilled S&T workers, fixed capital, scientific publications are assumed to be a function of their own and past values of other variables in an autoregressive mode. The issue of spurious correlation also does not exist when we first perform differencing to the data set collected prior to regression estimation as mentioned above in Section 3.3. We intend to accommodate for only short lags of between 1 to 3 years as might be plausible because the data collected is in annual frequency. In addition, WIPO suggested a one-year lag from patent applications to R&D investment to measure R&D productivity realistically (WIPO, 2011). Therefore, we assume that a minimum time lag of one year exists between conducting R&D and the application of the patents.

The functional form of Equation (7) can be rewritten as in Equation (8):

$$\Delta lnDGDP_t = \alpha + \sum_{k=1}^{k_1} \beta_{1k}\, \Delta lnDGDP_{t-k} + \sum_{k=1}^{k_2} \beta_{2k}\, \Delta lnDPAT_{t-k} + \sum_{k=1}^{k_3} \beta_{3k}\, \Delta lnDID_{t-k} + \sum_{k=1}^{k_4} \beta_{4k}\, \Delta lnDGERD_{t-k} + \sum_{k=1}^{k_5} \beta_{5k}\, \Delta lnDEMPHC_{t-k} + \sum_{k=1}^{k_6} \beta_{6k}\, \Delta lnDGFCF_{t-k} + \varepsilon_t$$

Eq. (8)

where

$\Delta lnGDP_t$ represents the first difference of series on logarithm value of annual real GDP growth rate in Malaysia, *t* is time or number of observations for time series model, *t-k* is to consider the influence of time lag between inputs to generate revenue and β_0 (α) is a constant term. $\beta_1 - \beta_6$ are explanatory variables in first-order to higher order autoregressive parameters or elasticities obtained from the result of ARDL regression estimation and these long run parameters are expected to carry a positive sign. The variables on the right-hand side of the equation are $\beta_1 \Delta lnDGDP_{t-k}$ variable is k lagged years logarithm value of annual real GDP growth in Malaysia upon first difference of the series, $\beta_2 \Delta lnDPAT_{t-k}$ variable is k lagged years logarithm value of total number of patents granted in Malaysia at time *t* upon first difference of the series, $\beta_3 \Delta lnDID_{t-k}$ variable is k lagged years logarithm value of total industrial designs in Malaysia, $\beta_4 \Delta lnDGERD_{t-k}$ variable is k lagged years logarithm of gross expenditure on research and development to GDP in Malaysia, $\beta_5 \Delta lnDEMPHC_{t-k}$ variable is k lagged years logarithm of total employment with tertiary level education, $\beta_6 \Delta lnDGFCF_{t-k}$ variable is k lagged years logarithm of gross fixed capital formation to GDP in Malaysia (represent value of durable tangible and intangible goods), and ε_t is the unexplained residual (white noise error term or any possible factors not captured in the explanatory variables of our model estimation) for Malaysia data over twenty-two years.

The process of ARDL estimation method is carried out in Eviews statistical package for each of the regression model as illustrated in Figure 3.4(i) and (ii). Eviews provides several alternative estimation methods for multivariate time series regression either using original observed variables or transformed variables. We can also expand the functional form in Eq. (8) to consider for additional explanatory variables that may affect the dependent variable. The extension allows us to identify which is the best predictor among the independent variables based on the present Malaysia situation when no multicollinearity issue exists among the estimators and also minimizes the sum of squared estimated variances between the observed and predicted responses by the linear approximation.

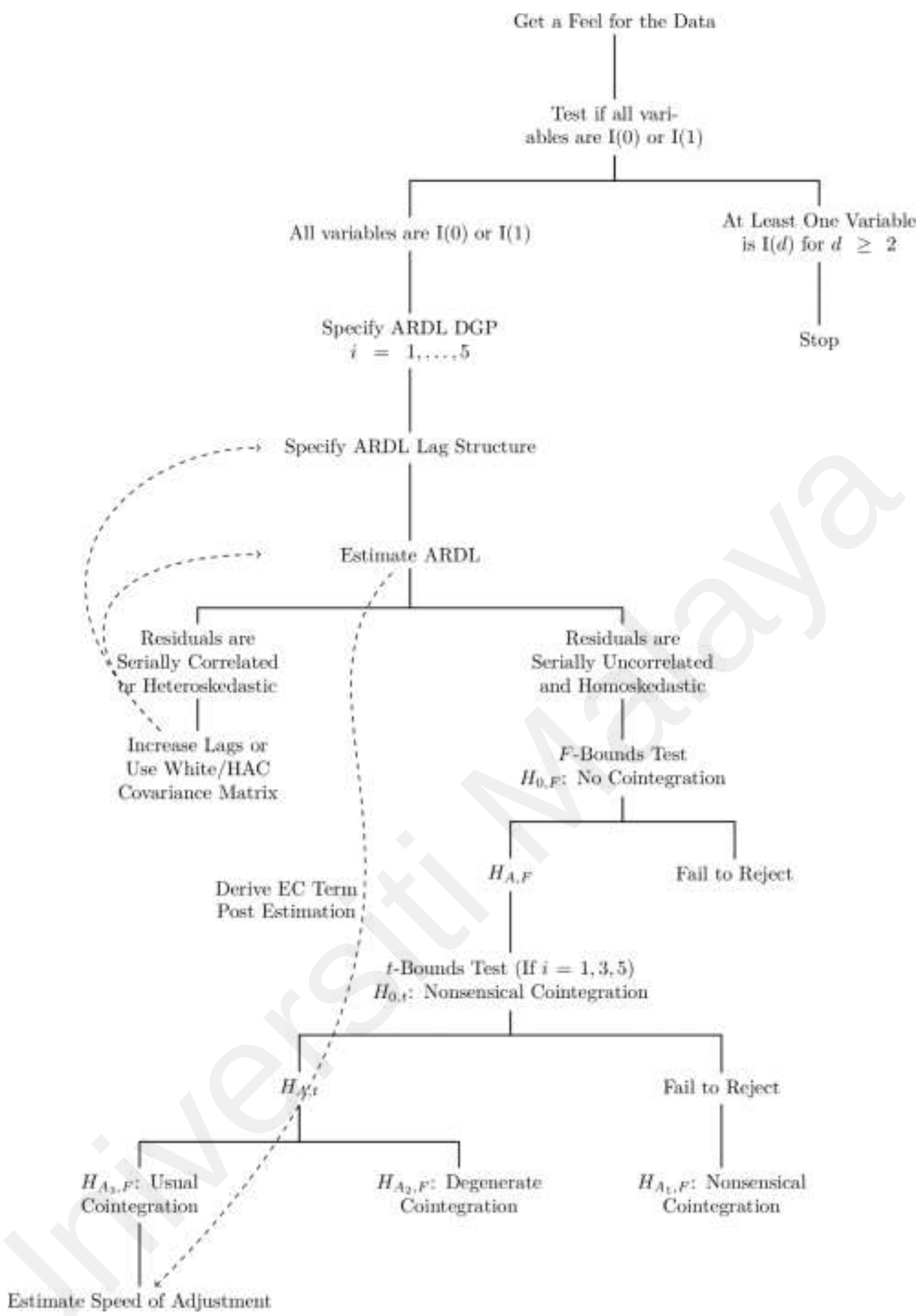


Figure 0.4a: Estimation Process

Source: Author, 2018; Eviews, 2017

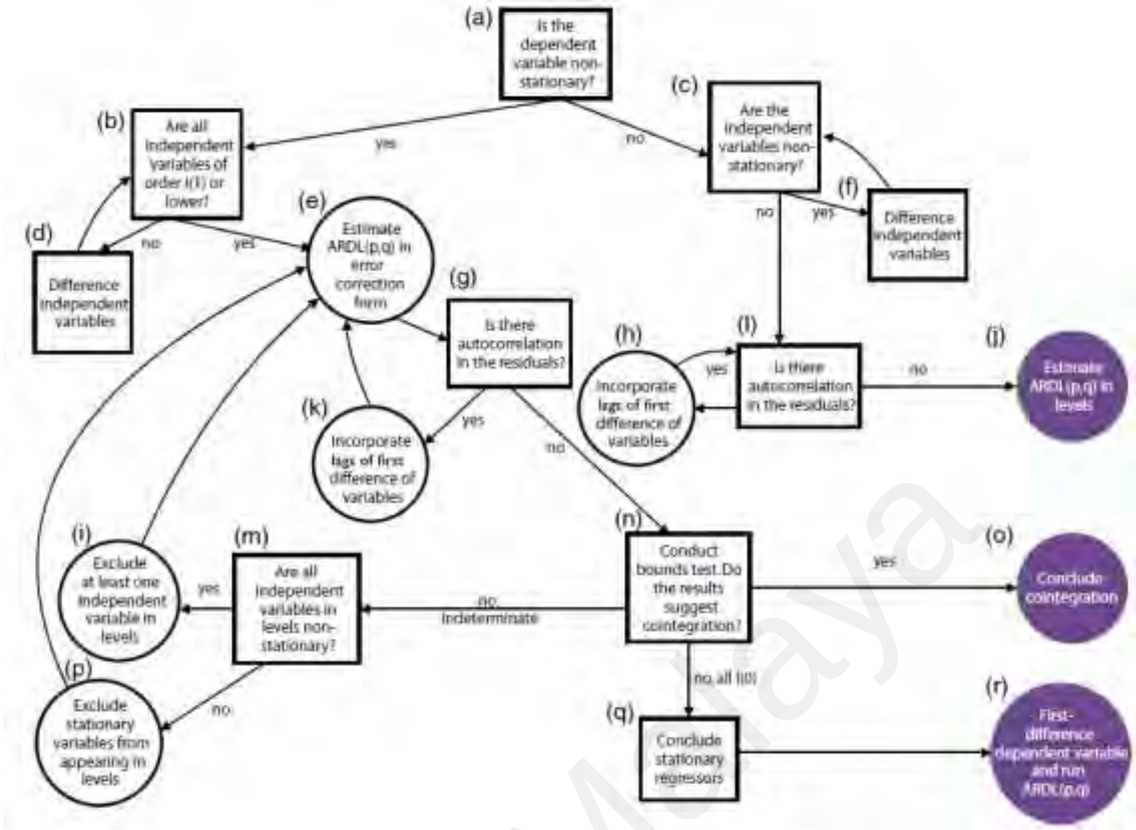


Figure 0.4b: ARDL Bounds Procedure

Source: Adapted from Philips (2018)

3.4 Diagnostic Tests

First before we conduct the econometric estimation, we check the statistical properties of descriptive statistics to ensure we have the correct data. The descriptive statistics of the variables, correlation matrix, and CUSUM plots are summarize in the Table 3.1. We use SPSS to analyze the multicollinearity test for the group of variables to be considered in our model estimation. The Pearson correlations should be below 0.7 between each of the predictors to ensure no collinearity problem. The calculated Pearson correlation coefficient *r* magnitude in Table 3.2 is between -0.390 to +0.459. Some explanatory variables have positive association such as R&D expenditure and scientific workforce while some have inverse association such as patents and R&D expenditure but overall no strong correlation between the explanatory variables which is good for the estimation procedure to avoid almost similar variables being use ended up with duplication or misinterpretation. Next, we check on the histogram and line graphs between the actual, fitted and residual plots in Eviews as a measure of heteroskedasticity test (see Figure 3.7). The Obs R-squared and probability of higher than 5% (67% or 0.6710 > 0.05) confirms that heteroskedasticity is not present in the model estimation. From Table 3.1, we can also check if the histogram distribution of the residual is symmetrical; if yes, we can assume that the data are normally distributed. The value of skewness is 0.2445 and reflects the existence of right symmetry. Jacque-Bera statistics and probability of higher than 5% (91.3% or 0.9134 > 0.05) confirms the residuals are normally distributed. The kurtosis value of 3.3567 exceeds 3 indicated has a peak (leptokurtic) relative to the normal distribution. We also check on the presence of outliers using critical value, and as a general rule of thumb the Variance Inflation Factor (VIF) should be above 1 and below 10 and tolerance factor should be above 0.2 to demonstrate no collinearity issue. We can use Coefficient Diagnostics in Eviews > VIF option with a constant to derive the variables VIF. It can be seen in Table 3.1 below the variables centered VIF results on the proposed model are all above 1 and less than 4 indicating no multicollinearity problem in the data set. In addition, we go to Stability Diagnostics in Eviews and run CUSUM test to show whether the coefficients in the ARDL model is stable and suitable for our decision making in the remaining chapters. The CUSUM and CUSUM-Square plots fall within the 5% critical bound indicate no any structural instability during the sample period (see Table 3.1).

Table 3.1: Summary Statistics and Stability Plots, Selected Variables, 1996-2017
(i) Descriptive Statistics

Sample: 1996 2017

	DEMPHC	DGDP	DGERD	DGFCF	DID	DPAT
Mean	0.028874	0.034621	0.073346	0.011143	0.149503	0.021636
Median	0.029864	0.038534	0.063799	0.020322	0.000000	0.024338
Maximum	0.060581	0.073713	0.183567	0.101814	2.448706	0.559862
Minimum	0.004767	-0.033460	0.027030	-0.243866	-0.214407	-0.493406
Std. Dev.	0.014347	0.024903	0.037855	0.064984	0.554187	0.234966
Skewness	0.410630	-0.952680	1.266784	-2.900600	3.623888	0.040566
Kurtosis	2.576014	3.985074	4.545590	12.71900	15.58765	3.675074
Jarque-Bera	0.747453	4.025671	7.706841	112.0987	184.6067	0.404519
Probability	0.688165	0.133609	0.021207	0.000000	0.000000	0.816883
Sum	0.606353	0.727051	1.540273	0.234011	3.139564	0.454350
Sum Sq. Dev.	0.004117	0.012403	0.028660	0.084458	6.142472	1.104181
Observations	21	21	21	21	21	21

Sample: 1996 2017

	DGERD	DID	DPAT	DPUB	DRSE	DGDP
Mean	0.073346	0.149503	0.021636	0.084707	0.062412	0.034621
Median	0.063799	0.000000	0.024338	0.064338	0.055796	0.038534
Maximum	0.183567	2.448706	0.559862	0.423542	0.201699	0.073713
Minimum	0.027030	-0.214407	-0.493406	-0.063541	-0.066933	-0.033460
Std. Dev.	0.037855	0.554187	0.234966	0.097773	0.064312	0.024903
Skewness	1.266784	3.623888	0.040566	1.950572	-0.048430	-0.952680
Kurtosis	4.545590	15.58765	3.675074	8.051541	3.044545	3.985074
Jarque-Bera	7.706841	184.6067	0.404519	35.64487	0.009945	4.025671
Probability	0.021207	0.000000	0.816883	0.000000	0.995040	0.133609
Sum	1.540273	3.139564	0.454350	1.778851	1.310647	0.727051
Sum Sq. Dev.	0.028660	6.142472	1.104181	0.191189	0.082721	0.012403
Observations	21	21	21	21	21	21

(ii) Jarque-Bera Normality Test for ARDL (1,2,1,3) and (2,2,2,2,1,2) is in Appendix 3.

(iii) VIF multicollinearity test for ARDL (1,2,1,3) and (2,2,2,2,1,2):

Variance Inflation Factors
Sample: 1996 2017
Included observations: 21

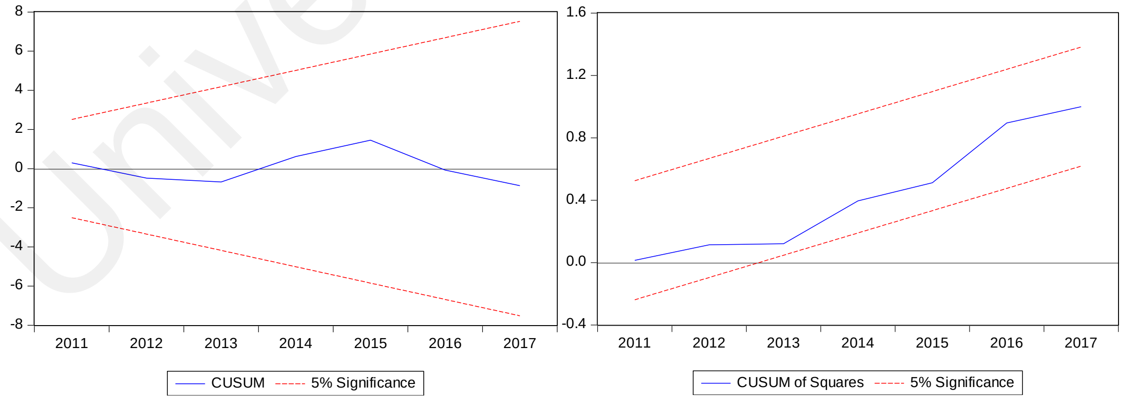
Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	0.000184	10.78938	NA
DPAT	0.000406	1.262578	1.251437
DID	7.74E-05	1.427231	1.325912
DGERD	0.017061	6.738948	1.363656
DGFCF	0.005595	1.358552	1.317862
DEMPHC	0.124529	7.509773	1.429596

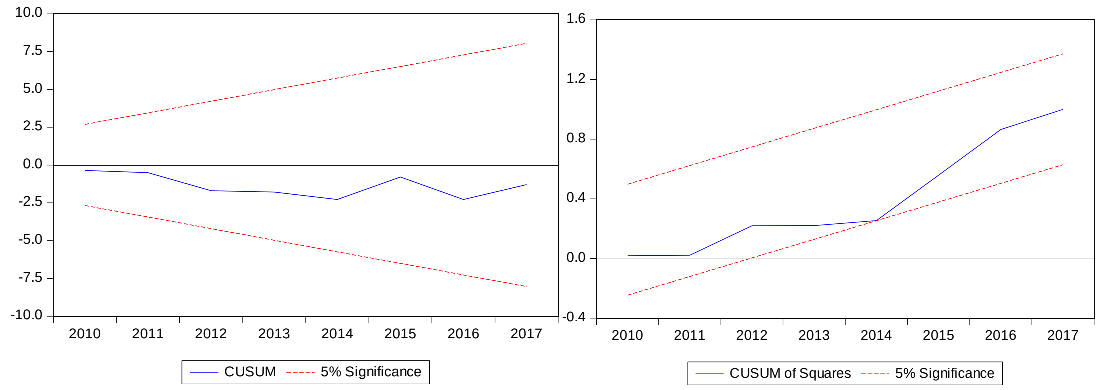
Variance Inflation Factors
Date: 08/16/18 Time: 12:28
Sample: 1996 2017
Included observations: 20

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	0.002075	19.08657	NA
DPAT	0.007120	3.232651	3.125062
DGERD	0.176657	8.770256	1.292264
DRSE	0.045868	3.272684	1.718777
DGDP	0.348346	5.687803	1.967177
DID	0.000412	1.253640	1.160195
DPUB(-1)	0.021010	3.295364	1.816518

Table 3.1 (continue)

(iv) CUSUM and CUSUMSQ Test for ARDL(1,2,1,3) and (2,2,2,2,1,2):





Source: Author, 2018

Table 3.2: Correlation between the Selected Explanatory Variables

Correlations

		DGERD	DID	DPAT	DEMPHC	DGFCF
DGERD	Pearson Correlation	1	-.003	-.390	.088	-.280
	Sig. (2-tailed)		.989	.089	.711	.232
	N	20	20	20	20	20
DID	Pearson Correlation	-.003	1	-.083	.459*	.310
	Sig. (2-tailed)	.989		.729	.042	.184
	N	20	20	20	20	20
DPAT	Pearson Correlation	-.390	-.083	1	-.195	-.035
	Sig. (2-tailed)	.089	.729		.411	.884
	N	20	20	20	20	20
DEMPHC	Pearson Correlation	.088	.459*	-.195	1	.342
	Sig. (2-tailed)	.711	.042	.411		.140
	N	20	20	20	20	20
DGFCF	Pearson Correlation	-.280	.310	-.035	.342	1
	Sig. (2-tailed)	.232	.184	.884	.140	
	N	20	20	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		DGERD	DID	DPAT	DRSE	DGDP
DGERD	Pearson Correlation	1	.014	-.404	.261	-.068
	Sig. (2-tailed)		.951	.069	.253	.770
	N	21	21	21	21	21
DID	Pearson Correlation	.014	1	-.100	.029	.250
	Sig. (2-tailed)	.951		.667	.902	.274
	N	21	21	21	21	21
DPAT	Pearson Correlation	-.404	-.100	1	-.374	-.489*
	Sig. (2-tailed)	.069	.667		.095	.024
	N	21	21	21	21	21
DRSE	Pearson Correlation	.261	.029	-.374	1	-.160
	Sig. (2-tailed)	.253	.902	.095		.488
	N	21	21	21	21	21
DGDP	Pearson Correlation	-.068	.250	-.489*	-.160	1
	Sig. (2-tailed)	.770	.274	.024	.488	
	N	21	21	21	21	21

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Author, 2018

From the Figure 3.5, it is obvious that most of the selected series is not stationary since it is increasing upward as time changes. We found evidence of unit roots using the Augmented Dickey-Fuller (ADF) testing process in Eviews (under Unit Root Test type we can select from menu either to run ADF or KPSS) and our observed series is non-stationary with a deterministic trend. The results from ADF test at a 5% significance level indicated having unit roots when probabilities are higher than 5% below except for LNID which is an I(0). We will verify the stationary test with Kwiatkowski-Phillips-Schmidt-Shin (KPSS) to confirm the consistency in the stationary test as reported in Table 3.3a and 3.3b.

Table 3.3a: ADF Unit Root Test

Variable	*Critical value*	*t-stat*	*Probability*
LNGDP	-3.658	-3.403	0.079
LNPAT	-3.658	-2.557	0.301
LNID	-3.710	-20.349	0.000
LNGERD	-3.710	-2.373	0.378
LNEMPHC	-3.674	-2.865	0.194
LNGFCF	-3.658	-2.968	0.165
LNPUB	-3.733	-2.361	0.383
LNEDUEXP	-3.658	-2.899	0.183
LNRSE	-3.030	-0.639	0.839

Table 3.3b: KPSS Unit Root Test

Variable	*Critical value*	*t-stat*	
LNGDP	0.463	0.624	Nonstationary
LNPAT	0.463	0.383	Stationary
LNID	0.463	0.448	Stationary
LNGERD	0.463	0.642	Nonstationary
LNEMPHC	0.463	0.635	Nonstationary
LNGFCF	0.463	0.499	Nonstationary
LNPUB	0.463	0.625	Nonstationary
LNEDUEXP	0.463	0.433	Stationary
LNRSE	0.463	0.648	Nonstationary

Source: Author, 2018

We use the first-differencing technique as in Equation (9) to estimate the equation to avoid spurious result or misleading inferences; the variables took the first order differences X_t – X_{t-1} to remove the non-stationary property of the variables. First differencing ΔX_t does not depend on strict exogeneity of the explanatory variables. The method is useful to avoid the problem of spurious regressions in the case where explanatory variables have a unit root (Wooldridge, 2012). So, as a result from our first procedure above, the stationarity of the data is completed and concluded with no unit roots by transforming it into stationary I(0) series (refer to Table 3.4a where column B p-value is smaller than column A critical value).

$$\Delta X_t = X_t - X_{t-1} \tag{9}$$

Then, all variables which become stationary I(0) after taking first order differences were applied to the series because the p-values were less than 0.05 and Durbin-Watson test between 1.5 to 2.5 (see Table 3.4a column C and D). Figure 3.6 displays the random trends upon visual inspection. We re-run the regression estimation to ensure $|\beta_1 - \beta_6| < 1$ and their probabilities are lower than 5% significance level before we proceed to the ARDL test to eliminate any non-stationary variables being used and generated inconsistent estimates. The DGDP result on ADF t-stats -3.9986 is smaller than critical value -3.0403 at 5% level with DW 2.1678, so we conclude that DGDP has no unit root, is stationary and no autocorrelation. A variable of concern to us is the gross fixed capital formation (GFCF)[46]. Since the research aims to investigate on basic research R&D activities, we find that this variable is suitable to measure the effect on intangible investment in the long-term i.e. competency development to absorb codified knowledge and spillover, environment, upgrading of standards and systems, acquisition costs to stimulate production and promote sales, etc (OECD, 1998). We detected the DW statistics for DGFCF is lower than the desirable minimum 1.5. So, to resolve the potential of autocorrelation in DGFCF, we adjusted the variable with two-lagged years instead of one. The new DW result is 1.5183* with p-value 0.0000 indicated it no longer has autocorrelation, but we will lose one observation from this series. For the dependent and explanatory variables to be cointegrated, ε_t must be I(0) to avoid spurious regression. So, we perform least squares regression on Equation (8) and save the residual estimates as '*resid01*'. After that, we apply the ADF unit root test on ε_t and confirmed that ε_t has no unit root and is stationary t-stats -6.1874 is smaller than critical value -1.9614 and probability is 0.0000 at 5% level. We can verify if the *resid01* suffer from autocorrelation or not by checking on the Durbin-Watson result. If the saved residual is stationary and

[46] OECD (1998) reported that intangible investment comprised of 31% to 49% of industrial GFCF in manufacturing sector such as electronics, machinery, chemical industries. The intangible investment also grew higher when number of personnel increases seems to indicate that the proportion of intangible investment as a % of GFCF will grow in tandem too.

CUSUM test indicated the model appears to be stable within 5% critical bound, we can proceed next to check their cointegrating relationship between the analyzed variables. The remaining ADF and KPSS results on other variables we obtained on the differentiated series are shown in Table 3.4a and 3.4b.

Table 3.3a: ADF Unit Root Test

Variable	*Critical value*	*t-stat*	*Probability*
LNGDP	-3.658	-3.403	0.079
LNPAT	-3.658	-2.557	0.301
LNID	-3.710	-20.349	0.000
LNGERD	-3.710	-2.373	0.378
LNEMPHC	-3.674	-2.865	0.194
LNGFCF	-3.658	-2.968	0.165
LNPUB	-3.733	-2.361	0.383
LNEDUEXP	-3.658	-2.899	0.183
LNRSE	-3.030	-0.639	0.839

Table 3.3b: KPSS Unit Root Test

Variable	*Critical value*	*t-stat*	
LNGDP	0.463	0.624	Nonstationary
LNPAT	0.463	0.383	Stationary
LNID	0.463	0.448	Stationary
LNGERD	0.463	0.642	Nonstationary
LNEMPHC	0.463	0.635	Nonstationary
LNGFCF	0.463	0.499	Nonstationary
LNPUB	0.463	0.625	Nonstationary
LNEDUEXP	0.463	0.433	Stationary
LNRSE	0.463	0.648	Nonstationary

Source: Author, 2018

Table 3.4a: ADF Unit Root Test – First Order Difference

Variable	*Critical value (A)*	*t-stat (B)*	*Probability (C)*	*Durbin-Watson (D)*
DGDP (LNGDP)	-3.040	-3.999	0.008	2.168
DPAT (LNPAT)	-3.030	-5.631	0.000	2.166
DID (LNID)	-3.081	-4.911	0.002	1.832
DGERD (LNGERD)	-3.030	-3.710	0.013	1.991
DEMPHC (LNEMPHC)	-3.030	-3.709	0.013	1.688
DGFCF (LNGFCF)	-3.030	-4.080	0.006	1.046 (1.518)*
DPUB (LNPUB)	-3.030	-4.965	0.001	2.066
DEDUEXP (LNEDUEXP)	-3.030	-5.429	0.000	1.966
DRSE (LNRSE)	-1.959	-2.088	0.038	1.848
RESID01	-1.961	-6.187	0.000	2.136

Table 3.4b: KPSS Unit Root Test – First Order Difference

Variable	*Critical value*	*t-stat*	
DGDP (LNGDP)	0.463	0.159	Stationary
DPAT (LNPAT)	0.463	0.105	Stationary
DID (LNID)	0.463	0.233	Stationary
DGERD (LNGERD)	0.463	0.381	Stationary
DEMPHC (LNEMPHC)	0.463	0.161	Stationary
DGFCF (LNGFCF)	0.463	0.338	Stationary
DPUB (LNPUB)	0.463	0.117	Stationary
DEDUEXP (LNEDUEXP)	0.463	0.155	Stationary
DRSE (LNRSE)	0.463	0.117	Stationary

Source: Author, 2018

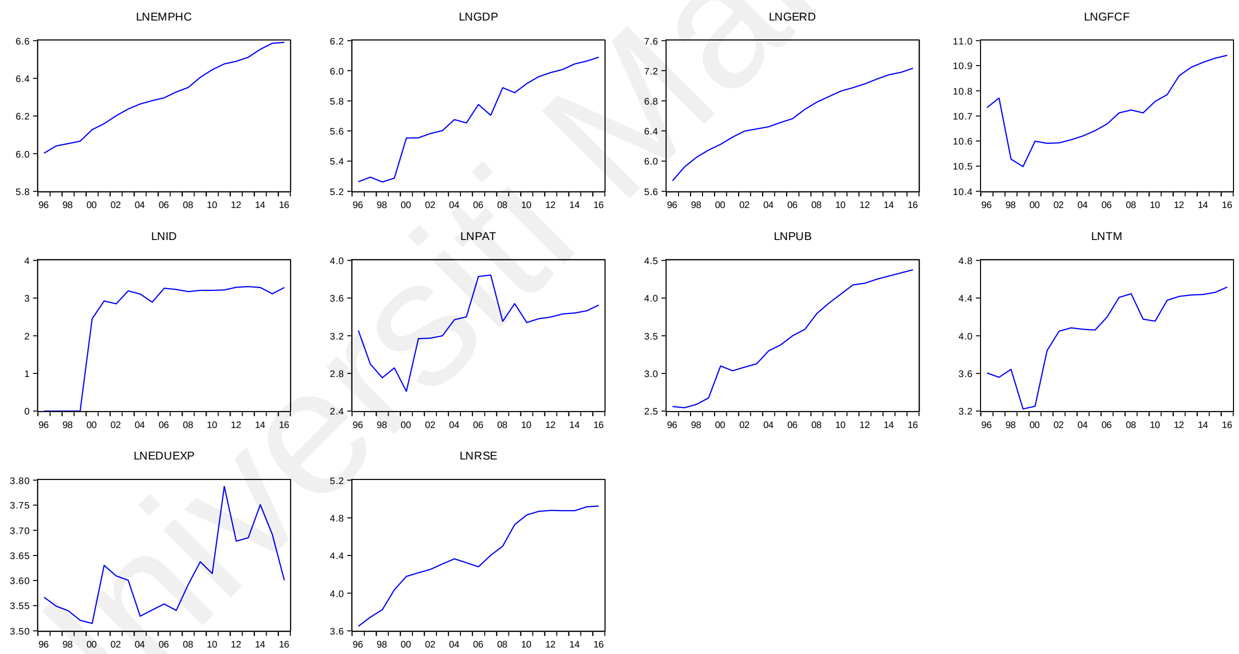


Figure 0.5: Selected R&D Variables

Source: Author, 2018

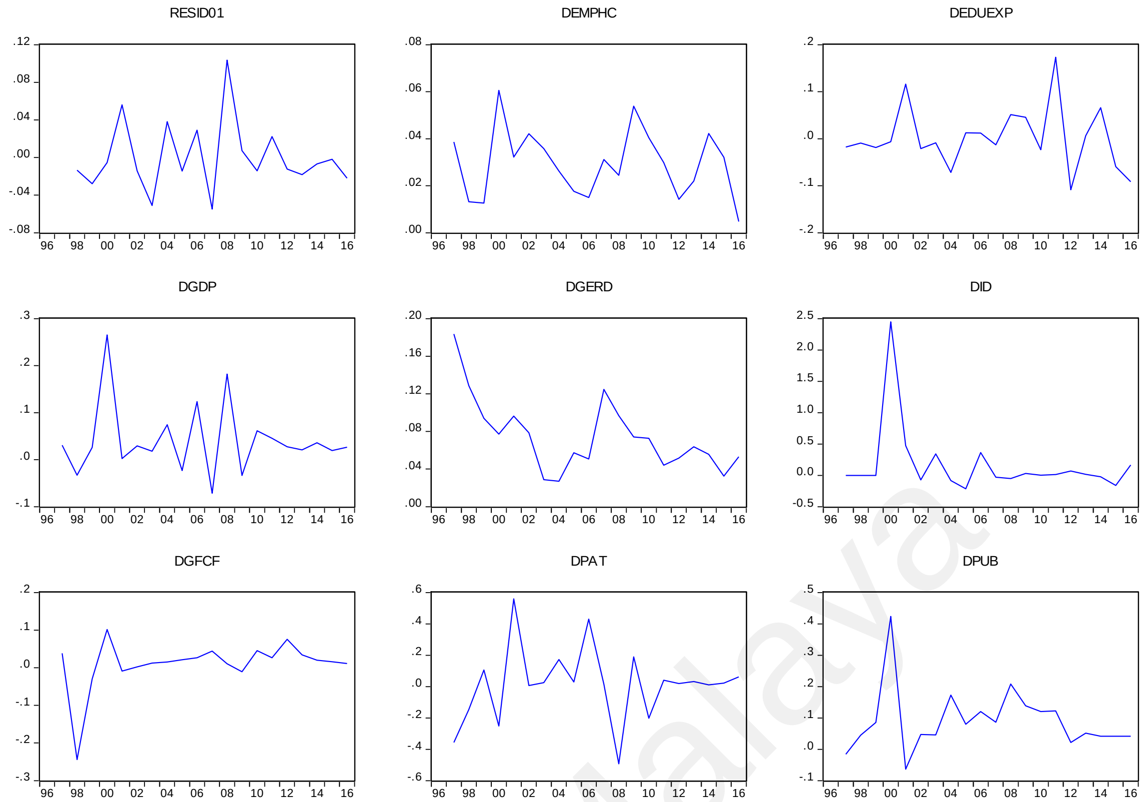


Figure 0.6: Selected R&D Variables – First Difference

Source: Author, 2018

Figure 0.7: Residual Plots on Selected R&D Variables – First Difference

Source: Author, 2018

After the pretest diagnostic checks above are satisfactory and both series is I(0) stationary integrated of the same order, we ensure that no explanatory variables are of higher than I(1) order of integration to proceed with ARDL estimation. All variables in this model are in natural logarithms. We ran the least squares regression again to derive indicative regression estimation result.

Since we are testing four to six variables in each model, it is likely we find some insignificant variables or parameters that allow us to consider re-parameterize the model by removing any insignificant variables that are potentially redundant or less impactful to align with theories examined in Chapter 2 using Redundant Variable Test in Eviews, such as Trademarks. We believed the reduced model can give clearly picture on how some inventive efforts accelerate or slow down. The coefficients of these variables can be biased and potentially underestimate the contribution of the other variables in our model estimation.

The reduced model set to become the basic structure of the equation for estimation from one chapter to another. Then we continue with the ARDL specifications (including ADF unit root test, bound test, cointegration test and CUSUM/CUSUMSQ stability test) as a second procedure to determine which ARDL model to choose from and to find out whether there is a long-run equilibrium relationship between scientific patents and publications on economic growth in Malaysia. The bound test on cointegration has advantage to examine long-run relationship of the underlying variables irrespective whether I(0) or I(1) series.

To establish the long-run relationships, we regressed the stationarized $|\beta_1 - \beta_6|$ with the usual least square method in Eviews using time series data from 1996 to 2017. ARDL modelling is one form of least squares regressions using lags of the dependent and independent variables as regressors. They can be estimated in Eviews using an equation object with the Least Squares estimation method with a specialized estimator for handling ARDL models. This estimator offers built-in lag-length selection methods as well as post-estimation views. To begin using the ARDL estimator, open the equation dialog by selecting Estimate Equation, specify the list of regressors followed by number of lags for all variables, then select ARDL from the Method dropdown menu and AIC as preferred lag structure.

Since change in patents and knowledge diffusion takes time to be commercialized, it will be a good practice to understand Granger representation whether a unidirectional or bidirectional causes among the variables of interest and the latency it faces as they unfold over time. We can use select Group Statistics > Granger causality test in Eviews to see if explanatory variable X_t Granger cause time series Y_t or otherwise, and to see if the past values (lagged) of X_t did help to improve or worsen the forecast of Y_t.

Since both series are integrated of the same order, we start estimating for cointegration as a necessary step by specifying the error correction model (ECM) in a single model equation. Keele and De Boef (2008, 2004) believed that ECM is a powerful mechanism to allow an analyst to estimate both short term and long run effects of explanatory time series variables. Both said the combination of Y_{t-1} and X_{t-1} must not be a unit root series to ensure no spurious or misleading inferences that undermine the overall outcome of the analysis. The cointegration procedure followed by estimation of error correction rate is flexible to pair relevant long run relationship of the considered variables in Eviews for a more meaningful forecasting and policy implementation to meet the research objectives especially when the data is found to be cointegrated. We can go to Coefficient Diagnostics to select ARDL-Bound Test menu option for unrestricted constant with no trend, and manually check Pesaran and Narayan's critical values against the F-test result generated by ARDL test to check whether cointegration exists among the explanatory variables or not with the dependent variables identified to answer the research questions.

If the two series are cointegrated and causally related to Y_t, we can estimate the short- and long-run coefficients by using ECM option in Eviews. Since the research is using yearly data set, we will proceed to estimate the knowledge production function in an ECM framework with a one-year lag structure to capture the relationship and speed of adjustment between the explanatory variables on the number of patents created and economic growth upon created *resid01* earlier. Since *resid01* is the lagged residual from the cointegration between Y_t and X_t, we expected it to be negative and statistically significant to detect whether the two series are cointegrated when paired together and eventually converges over time in the long run equilibrium. It also shows how much of the disequilibrium in the previous period is being corrected in Y_t. For example, if the *resid01* series had a negative coefficient value of -0.5363, this suggested that 54% of the adjustment takes place each year to correct for the past period patents performance back to long-run equilibrium. A typical adjustment takes place between 0 to 1, however rapid adjustment can stretch up to 2.

Next, we focus construct the functional model for variables GDP, PAT, DID, GERD, EMPHC, GFCF, PUB, EDUEXP corresponding to Equation (8) to estimate the relationship between the first order difference of dependent variable and the first order difference of explanatory variables and proceed with hypothesis testing using a Wald or F-test to determine whether we should accept or reject the hypotheses tested. For example, GDP with 6-lags where $|\alpha_0 - \alpha_6|$ are parameters to be estimated in Equation (10). Since the interest is on long-run response, the effect of lags is essential in the current setting when the current GDP income or patents and publications are more likely to be influenced by the GDP income or patents and publications of preceding periods due to speed of adjustment from initiating ideas to revenue generation. All the empirical test results from hypotheses testing and discussion points for each first differenced series and its possible explanation will be further describe in Sections 4 to 6.

3.5 Summary

This chapter found that the lack of technological progress has undermined in Malaysia's economic growth. The ARDL model along with the ECM model and the cointegration test were used to identify the causes behind Malaysia's lack of success in becoming a high income economy by the mid-2010s. Consequently, we propose a conceptual framework that is reliant on a pro-growth policy to speed up R&D productively so that its financing is realized within the UIG so that the evolving will not be wasteful. Although many studies use patent and R&D expenditure, and publication citation as proxies to show a positive relationship between these proxies and GDO growth in the long run, our framework and empirical results extended this framework by separating the different types of intellectual properties (IP), such as patents, industrial designs and trademarks to demonstrate their associations over the long run. We have also showed evidence on the need to raise the speed of IP creation in domestic ownership as more important than simply seeking to attract more foreign direct investment into the country.

Following our profound review, some variables, such as patents and industrial designs indicate stronger explanatory power of the value of patent. Among these variables, some explanatory variables have positive association, such as R&D expenditure, while some show an inverse association with scientific workforce, such as patents with R&D expenditure. The approach of disentangling the innovation outcome variables matched our purpose as the newly patented innovations take time to be produced, diffused to the related industry and to acquire the desired inputs with calculated risks and least wasteful activity. The knowledge translation and patenting activity are subjected to lags while the time may reflect different levels of propensity to patent and overall ideas-to-output production before being superseded by new innovations. If we strengthen the innovation processes on academic patenting and industrial patenting, we should expect better R&D performance outcomes.

CHAPTER 4

R&D EXPENDITURE AND INNOVATION OUTPUT

4.1 Introduction

Basic research is primarily an exploration task conducted to discover new knowledge or the impact of adapted existing stocks of knowledge across different fields. Basic research will essentially be the fundamental to deploy mission-oriented innovation in a problem-solving approach which benefit the entire innovation value chain. The stream of basic research is critical when firms target to reach the technology frontier, follow by the applied research where the firms invest on R&D to increase patent quality. Schumpeter (1943) saw this important to initiate new business cycles and a consensus that R&D is the spark of innovation and key driver of long-term productivity growth although it could vary with industry type and the stage of development. Ultimately, countries that possess high technological capabilities and output are capable of commercializing them to fuel GDP growth.

Since the road to rapid economic development is driven by scientific and technological progress, eventually developing countries will have to invest in R&D to close the productivity gap with high income economies. However, it is not enough for developing countries to invest in R&D and expect that it alone will guarantee rapid economic growth. In this chapter seeks to examine the impact of R&D on particular innovation output. Hence, we examine the relationship between R&D expenditure and innovation outputs such as patents, industrial designs, and scientific publications.

4.2 Critical Issues

Malaysia can establish and develop various NIS based on learning-by-doing and by-by-imitating (or learning-by-exporting). This managed to integrate Malaysia as part of untapped Asia emerging market in science and promoted higher means of technology-based exports, somewhat supported by the nearby technology powerhouses South Korea, China and India. It also engage Malaysian firms into higher technological content during this process and move away from the technologically lagging firms.

The high value products and patents are now primarily concentrated at North America and North Asia i.e. US, Japan, South Korea, Taiwan, Hong Kong and lately in China. We also observed that the technology inflows are diverting away from the stagnating Scandinavian and European innovation countries as Asia picks up. But in recent decades, the question arises on whether the productivity of developing countries to stimulate more innovation can propagate the catch-up since more Asian firms and universities from Malaysia, China, Hong Kong, Japan and South Korea are all making good progress in terms of ranking and scientific publication (assuming this publication comes with technological content) but actual patent commercialization actually diminishes.

Despite the NIS establishment have quantified among countries, we also observed that the competition intensifies when the latter put many developing countries into such bandwagon effect to target high growth in innovation output, be the producer themselves by transforming from a low-cost manufacturing hub to an economy emphasize in high-tech industries and high-impact research, and provisioning of these basic- to high-tech infrastructure and less of being a typical consumer of high-tech of other countries' products. The strategic actions was aim at economies of scale in these targeted patenting activities must be achieved to strengthen growth in the entire industry not just in infrastructure alone but also specialization, innovation-on-innovation, and lobby groups.

Essentially this means the Asian firms and their governments wanting to reinvent itself to stay ahead of competition, improve competitiveness, be the testing ground for latest advance technologies or techniques, to reduce technologically barrier that hinder their

R&D capabilities or impact their bottom line. So, this requirement fosters the developing countries to invest basic research in various fields is part of the responsive action and speed up the knowledge acquisition to catch-up with the frontiers at the developed countries and foster new discoveries of their own. But the quantitative measures related to efficiency of R&D spending and their scientific endeavor could differ substantially in terms of strategies and development on basic research, not just on the R&D spending allocated to basic research which we had observed the R&D spending has increased but not the actual output in the previous chapters. The question makes us wonder where the gaps was and is there any possible ways to fill in these gaps before we proceed to econometric estimation results for developing country like Malaysia discussed in the later chapters.

For effective R&D to happen, the end incentives are patents to gain a temporary monopoly rents while solving the social needs for economic development at developing countries. Basic research is an expensive activity when the unknown serves no commercial value until practical application is successfully developed after multiple attempts. With the establishment of research universities, the country can heavily tapped into the research university labs and use it aggressively to path commercial innovation and give the inventors a platform to learn and develop more valuable intellectual property over time. In this regard, the government or firms would have to step in to assist and raise support on the principal costs and benefits of basic research patents or inventions to be develop, and further change when applied research can be used to solve immediate needs of the country through the basic research findings. For instance, Malaysia as a developing nation still relatively focus on evading poverty, bringing affordable homes and healthcare over the years rather than building basic scientific capacity. But evading poverty, giving quality education, building affordable homes and healthcare, and building interest in basic science are all complementary factors to mechanize and change the ability of research universities capacities to active patenting activity. Another fundamental problem remain challenging is to grow basic research R&D which largely has been relying on government funding and to ensures transparency and effective use with regard to R&D funding allocated is even another bigger problem. Taking into account, none of these should be neglected or less prioritize in the innovation stage and economic development as part of larger phenomenon.

The lack of successful NIS can slow down to develop new industry and fail to transfer new knowledge from universities to the firms. This directly reflects then the needs of suitable fiscal policy to attract to business investors and had to open up to massive foreign investments mainly serve as an alternative source of money to improve the country's poor infrastructure back then for industrialization purpose and to improve the business environment opportunities to the local firms or to finance high-risk startup companies in the case of Malaysia. But since linkages are weak between universities and firms and the country entered into deindustrialization since 2000, the reciprocal effect on Malaysia still remains technologically lagging behind as no avenue to capture the basic research spillovers effectively, except the semiconductor industries that created some high-tech products and growth prospects for other sectors remain slow i.e. biotech.

Apart from targeted patents and the needs to increase inventors, strengthening the selected universities contesting for survival and building new first-tier cities to fit to the industry to promote innovation would further bring local improvements into economies or societies, stimulate higher technological progress, and align national strategies to promote domestic capabilities in the long term. The public and private universities ranking had improved and many developing countries such as Malaysia do benefit being free riders not to spend huge budgets to seek the outcomes of these basic research. Today, these challenges remain in place for the Malaysian universities to instill upward interest in STEM studies since it is more like applied culture than being a true creator of new observations, knowledge, or products. The students found uninteresting in the local scene whom they can emulate of their success will only make the country continue to depend heavily on foreign resources.[47] For Malaysia to disrupt innovation, the economic agents must be strong to capture both closed and open innovations known as patent intelligence.

In practice, to blindly have influx of patents would not help to strengthen the specialization. It is difficult to make a clear-cut separation of patents between basic and applied research for every situation as it needs to adapt to the local needs and capabilities. As a matter of fact, such basic research activity is at most time being monopolized either in some form of patents therefore enabling the rent capture mainly by the monopoly which then resulted in poor participation of others and very low volume of such intermediary knowledge towards product development. The foundation in basic research seems bleak when multiple sources i.e. Academy Sciences of Malaysia (2012) has reported the inadequate infrastructure support for basic and fundamental R&D health sciences activity in Malaysia, low grade medical sciences and publishing poor quality with lack of novelty publications have left the country even further behind against their regional competitors. We still do not see much improvement in recent years to close the gap in this sector. Laboratories infrastructure is still not properly maintained and very poor governance on the expensive and high-end lab equipment resulted in double- to triple-digit million-ringgit losses. A few examples are some of the public universities such as Universiti Malaya, Universiti Pertahanan and Universiti Teknologi Malaysia, Universiti Sains Malaysia are found with underutilized research center, poor financial management and unsatisfactory projects delivery performance again resulted the university required to pay additional cost unnecessarily. So, this has urged that proper basic research infrastructure

[47] Read more at https://www.nst.com.my/opinion/letters/2018/06/379105/malaysia-needs-nobel-prize

must be well taken care and keeping a close eye that the project deliver within schedule and systemic approach must be embed into the profession before the country can create any breakthrough in this industry. It would not entice any existing and potential researchers (including the university own students) to produce any good research with such limited or poorly managed facilities[48]. Thus, transformation is required to commercialize these patents into meaningful insights to discover new knowledge, new capital source, or even change market demands in Malaysia and the developing countries.

This relative disparity is not just the infrastructure alone. The debate on structural issue is also due to the participation rate of public and private institutions and researchers in developing countries are less prominent compared to the participation rate across developed countries. A common situation encounter by the developing countries are limited resources and lack of interfaces between research bodies and local community's needs could thwart the career of international scientists and researchers and their scientific publications. Such barriers at times makes them to leave the country preferring the developed countries to their origin especially to those who felt new knowledge is being isolated to them or slow to assess this information even though way of communication has technically improved. The developed countries need to promote transfer of technology to developing countries and not just using low value added production hubs by setting or investing their money to gain control in decision-making process. This ensure foreign R&D efforts are focused on the economic and social development needs of developing countries rather than just capital injection which benefit the short-term but detrimental to long-term.

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[48] Effective asset management is as important as producing good research in a well accredited laboratory. Read more at https://www.thestar.com.my/news/nation/2015/06/16/no-account-of-rm13mil-um-lab-equipment/, https://www.thestar.com.my/news/nation/2014/12/15/usm-not-living-up-to-status-varsity-does-not-meet-apex-expectations-despite-getting-grants/, https://www.thestar.com.my/news/nation/2015/06/16/pac-wants-financial-controller-to-explain/

If we assume the patentable rents are available in Malaysia, a researcher's publication should correlate with their view of their individual incentives. Institution responds to positive incentives and bibliometric measures. However, many of the developing countries including Malaysia are inadequate to produce innovative technological breakthroughs so this implied the high profitable patent-based rent on patenting activity still reside largely at the developed countries. The amount and speed of reward are necessary as a catch-up tool to refurbish the labs or hire more personal research assistants in the developing countries to close the learning gaps among the local research institutes and foster international collaboration to support the expansion of basic research absorptive capacity in the country.

In this regard, the changing landscape for universities to embed research and publication into their universities KPI is no longer a new thing. High incentives are given for the publications in Science Citation Index Journals as a long-standing tradition in Malaysia after the post-internationalization period of higher education in 1996. The researchers in Malaysia expect a big payday when they publish especially as the first author. To list a few examples, universities have developed publication incentives scheme ranging from a minimum of RM200 per citation received, Q4 journal RM500 times impact factor or by number of chapters or RM2,500 for Q1 journal up to a maximum of RM25,000 or generous cash incentives of RM300,000 as lifetime achievement. Citation in scientific publication can become another source of income growth for the researchers to grow their funding and global presence.

Beside publication rewards and gain access to knowledge and technology of the developed countries, the Malaysian government had also forged partnership collaboration with these countries to establish local and international funds and the researchers could receive between RM200,000 to RM3mil on their new innovative inventions or concepts for 2 to 3 years such as the long-term research grant or Newton Ungku Omar fund, to name a few.

Fundamentally, when we examined MASTIC's findings, we still found a huge need to make radical change on the private firms and universities in Malaysia. It is presumed that the level of basic research R&D conducted in Malaysia is lower after post-internationalization which should not be the case as among the high FDI recipient country in Asia. The cultural dimension remain in teaching on open ready-made knowledge did not create higher added value to create new scientific breakthroughs again in basic research. No teaching is sustainable without allowing basic science with labs research activities. The country was faced with skills deficit and remain stuck in the imitation stage (unlike South Korea and Taiwan which moved into innovation stage). Coupled with the lack of expertise especially in basic research, the Malaysian government had launched returning expert programme under TalentCorp to arrange the homecoming benefits for the supposed group but infeasible to help much to raise the commercialization of basic research R&D and rely heavily on foreign patents although domestic firms had taken advantage of the spillovers from these MNCs or available foreign technologies in Malaysia.

Although tax incentives have been a good push incentives forward to stimulate higher R&D spending on private firms in Malaysia year-to-year on natural sciences, biotech and agricultural industries with the inception of Malaysian Industry-Government Group for High-Technology (MIGHT), we found the needs to also create the pull incentives for basic research to spark local innovation such as creating markets for example vaccine development or new product development when they are absent to replace with a more cost effective solution which is much needed for the developing countries such as solution to the dengue problems or any viral disease. The country is fourth richest bio-resources in medicinal herbs and plants after India, China and Indonesia. It has the ability to raise its skill in life sciences i.e. Professor Sandy[49] is one good example to start off to demonstrate the Malaysian capability on plant-based medicinal products. This provides ample opportunity for greater diversification in basic research R&D and constitutes a source of valuable foreign exchange to other developing countries to establish a better medicinal practice to come. But there can shortcomings in Malaysia if similar case of Prof Sandy is not given a chance to expand the opportunity and develop it into a commercial sector remain invisible and the scientific manpower such as engineers think there is lack of promotion prospect to the premier grade and any chance of being mid-management decision makers especially if working for the government. The engineers are stuck behind the scene added with a very low fresh-graduate starting pay of RM2,300. Most of this role and high pay are given to diplomatic officers instead[50].

High incentives for publications in Science Citation Index Journals (which might exceed a month's salary in institutions in China he refers to) might promote bad scientific practice or natural sciences have been plagued by prominent cases of fraud or faking of data.

For basic research R&D to happen, the R&D outcomes must be managed on the basis of building / upgrading the domestic production capabilities and capacity of local firms in a non-discriminatory manner or using open licensing terms although generic competition is an important task. ensure that products/technologies emerging from R&D will be licensed to promote generic competition with the aim of increasing supply and

[49] Cheaper and more patient-friendly using edible plants to develop dengue and influenza vaccine that is consumable in a capsule form rather than needing special equipment like needles. Read more https://www.nst.com.my/education/2018/06/379483/using-plants-produce-dengue-vaccine

[50] Engineers is among the prime mover for economic development. Read more at https://www.thestar.com.my/news/nation/2016/03/21/engineers-seek-better-terms-in-govt-the-professionals-want-to-become-decision-makers/

reducing the price of the products/technologies. It was found mainly there are predatory practices or the industry licenses being monopolized such as the pharmaceutical issue found lately in Malaysia.

4.3 Methodology and Data

We theorized earlier that basic research R&D should be the central research activity conducted at university level. A strong knowledge inflow and outflow should be initiated at this level and anticipated larger impact with government funding if we have productized the knowledge creation into a patent activity to the impact of scientific publication. When patenting activity is more successful, it became a relevant output indicator of innovation and directly link to its R&D efforts particularly when comes to revenue generation or productivity and significance of new knowledge or innovation creation. Since there is different role and level of appropriation to R&D, we will recommend using different resources of evidences related to the patent data comparison beside the existing ones collected in Chapter 5 and 6. There are essential differences between developed and developing country when it comes to the actual commercialization and uses to increase the quality of research output.

For the purpose of this section, we obtained national statistics on utility and design patents of the chosen different countries and look at the structure of these data related to basic research and patents granted from USPTO, World Bank and OECD for the period 2002 to 2015. USPTO database is preferred due to OECD's finding that United States remain the top destination for Malaysian applicants and inventors in patent filings abroad. From our analysis, the preference is likely due to the lower USPTO patent fees (US$1,600) compared to EPO higher fees (US$3,540) and the perceived value of international market.

Based on the selected countries, we will map out those excel in basic research R&D policies and execution and those whom emerge as potential catch-up to these frontiers. The available data is in time series format but in this section, we will be running queries to perform data visualization and trend estimation in SAP Analytics Cloud, and shall not be doing any differencing since we are not dealing with regression analysis or lagged terms to prevent autocorrelation or spurious regression problem. We shall create graphical displays to map an initial understanding of the interactions between patents and publications. First, full patents information are collected from the USPTO and World Bank databases. This involved repeated processes to devise a set of intended query on this patents and publications and subsequently uploaded to SAP Analytics Cloud for analysis purpose within the indicated year limits and use visual analysis to derive the characteristics of the selected countries. We filtered undesired patents category such as firm-level as we are interested to devise academic patents generated by the university as an indicator of basic research. We further segment it into public and private university. Among the filtered university patents, we fetch patents by technology class. We want to observe the evidences on patenting in new business by choosing to see active patenting activity which normally last for 20 years or less. It will provide a chain of significance evidences to strengthen our regression analysis and results discussion on Malaysia to be described in Chapter 5.

4.4 Results and Discussion

We acknowledged that R&D input such as GERD is one of the most important component to steer forward research output such as patent. However, measuring patent-to-GDP is much logical and fair take-off measure since we can avoid of issue of country size i.e. large and small economies endogenic with population growth rather than innovation growth. Angus et al (2020) found that patent can transition a stagnant economy to a more sustainable economic growth to close the gap with the technology frontiers in the long run only if the market size is large enough. In their findings, when the market size is weak it will create insufficient or unattractive incentives to develop new product or improve existing product and reduce the patent breadth. Hence, we investigate the variations between developed and developing countries in the extent of scientific patents from their R&D investment, and see if the universities have been accelerator or enabler towards the end goal.

At this stage, we selected six countries from our database analysis (three developed countries: US, Japan, South Korea, three developing countries: China, India, Malaysia). The reason for selecting these countries are based on their top-5 performance in the 2019 Global Innovation Index by WIPO as innovation economies. USA is the regional leader for North America, while Japan, South Korea and China lead in the South East Asia/Oceania region and India leads in the Central/Southern Asia region. We also assume there is no restriction in free entry or exit in the selected countries.

There are few possible explanations to the observed variations. First, investment of GERD by the developing countries are still far below compared to the developed countries. For example, Figure 4.1 shows a map to denote the investment amount made by the selected countries. The darker the blue color corresponds to the country with higher investment in R&D spending (typically the incumbent of science heavyweights) compared to the lighter blue color (emerging).

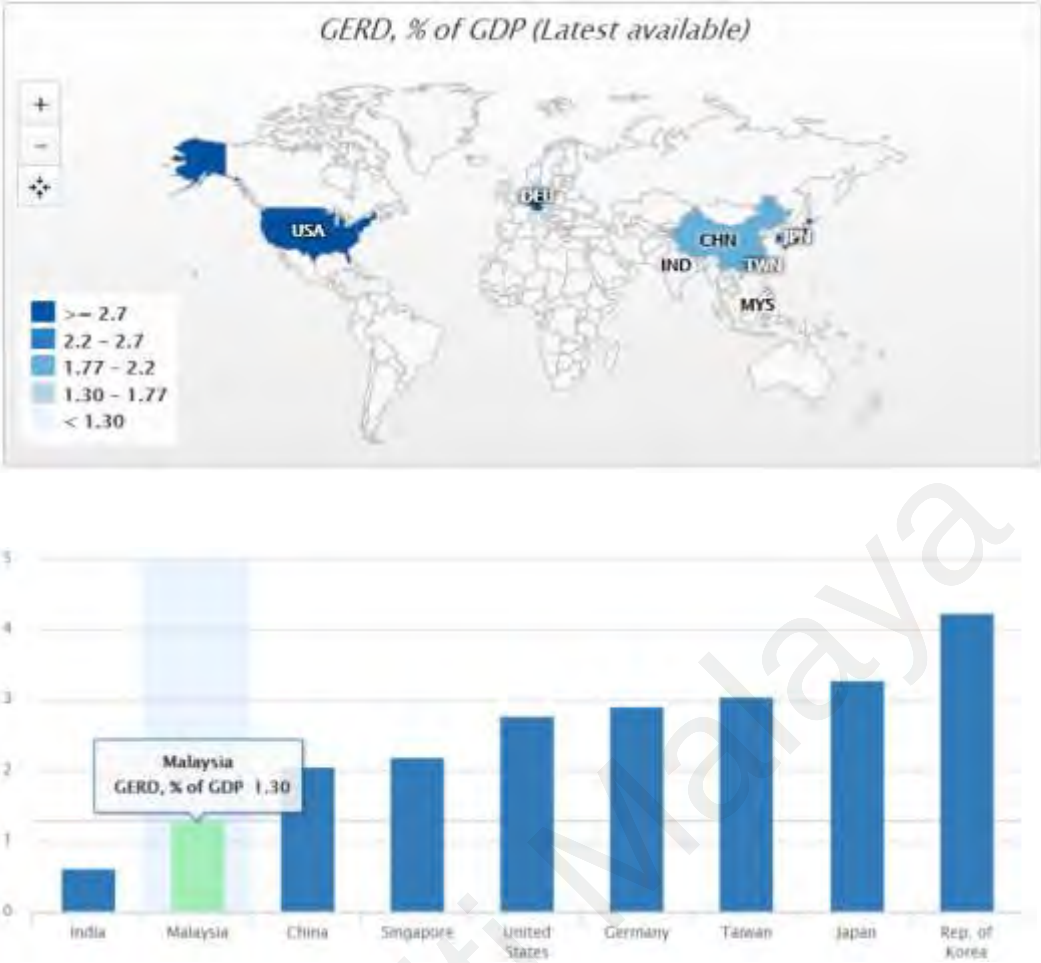


Figure 4.1: GERD as Percent of GDP for Selected Countries
Source: Author, 2018

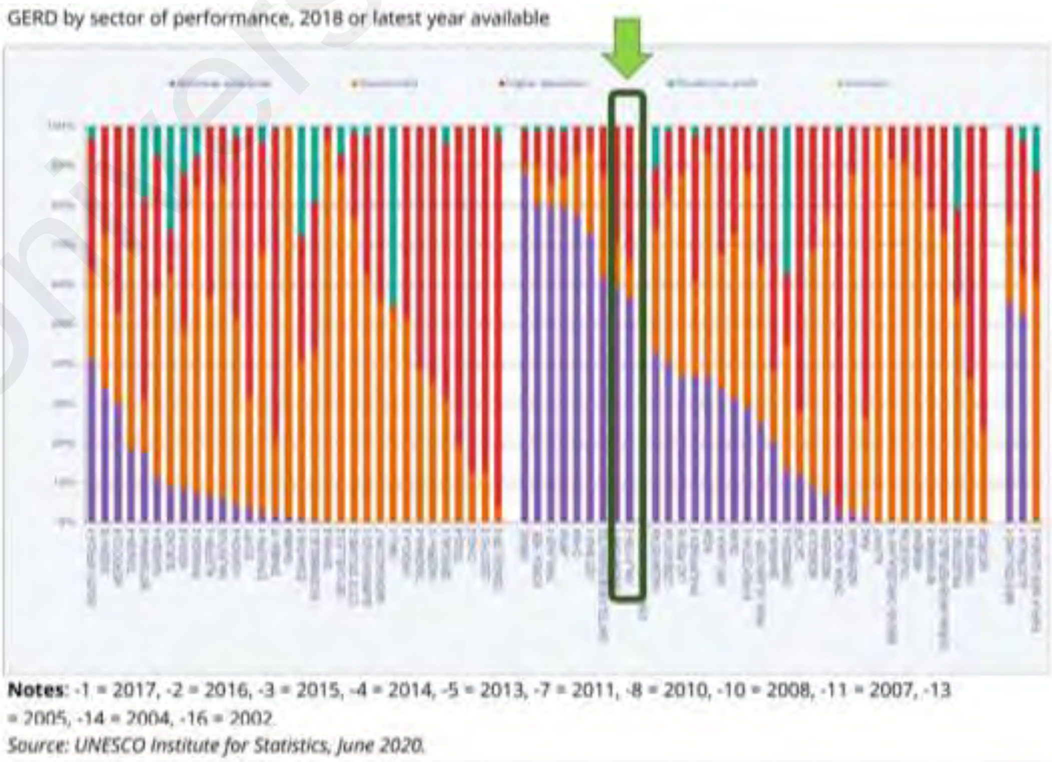


Figure 4.2: GERD Investment in Asia by Sector

Source: UNESCO UIS, 2020

From our Figure 4.1 result and Figure 4.2 supporting figure, two critical gaps on the GERD investment are found which potentially undermine the performance of basic research translation to innovation in Malaysia. The two gaps found from the two figures above are Malaysia's 1.3% GERD as percentage of GDP is still way below the World-average R&D intensity (2018) at 2.2% and OECD-average R&D intensity (2019) at 2.5%. Malaysia as a developing country at present spent a small proportion of its GDP to R&D i.e. 1.3%, is anticipated to spend more on R&D activity by increasing GERD to 2% by 2020 respectively. With the 12th Malaysia Plan (2022), the GERD has yet to grow at faster growth rate 2.5% than the GDP growth rate of Malaysia in Q1/2022 of 5%. This can hamper real growth when GERD is still below the GDP growth rate. Second, Figure 4.2 also show that business enterprise (purple color) and higher education (red color), which accounted for over two-third of the GERD investment but underperform to produce useful and competitive patents. The need to commit to R&D spending to productive innovation output, recover, catch up and protect STI post-Covid19 have to be step up in Malaysia and across other developing countries. This result is consistent with the fact that the two category of countries experienced different stages of innovation and economic development where US and Japan have earlier take-off while take-off in South Korea, China, India, and Malaysia were much later. So post-Covid, when radical changes on the GERD and R&D policy in South Korea and China (from 6.09% to 8% by 2025) have speed up the entire innovation value chain, we found that it would be extremely challenging for Malaysia to catch-up with the developed countries at this pace for a given level of GDP and lack of engagement to understand certain phenomena due to lack of basic research. To derive the same quality growth rate, the developing countries have to find ways to close the gap with science heavyweights such as US, Japan and Germany, whom are all investing way above 2% almost 30 years ago since 1996, while South Korea over 4% a decade ago to successfully catchup and leapfrog over the said incumbents.

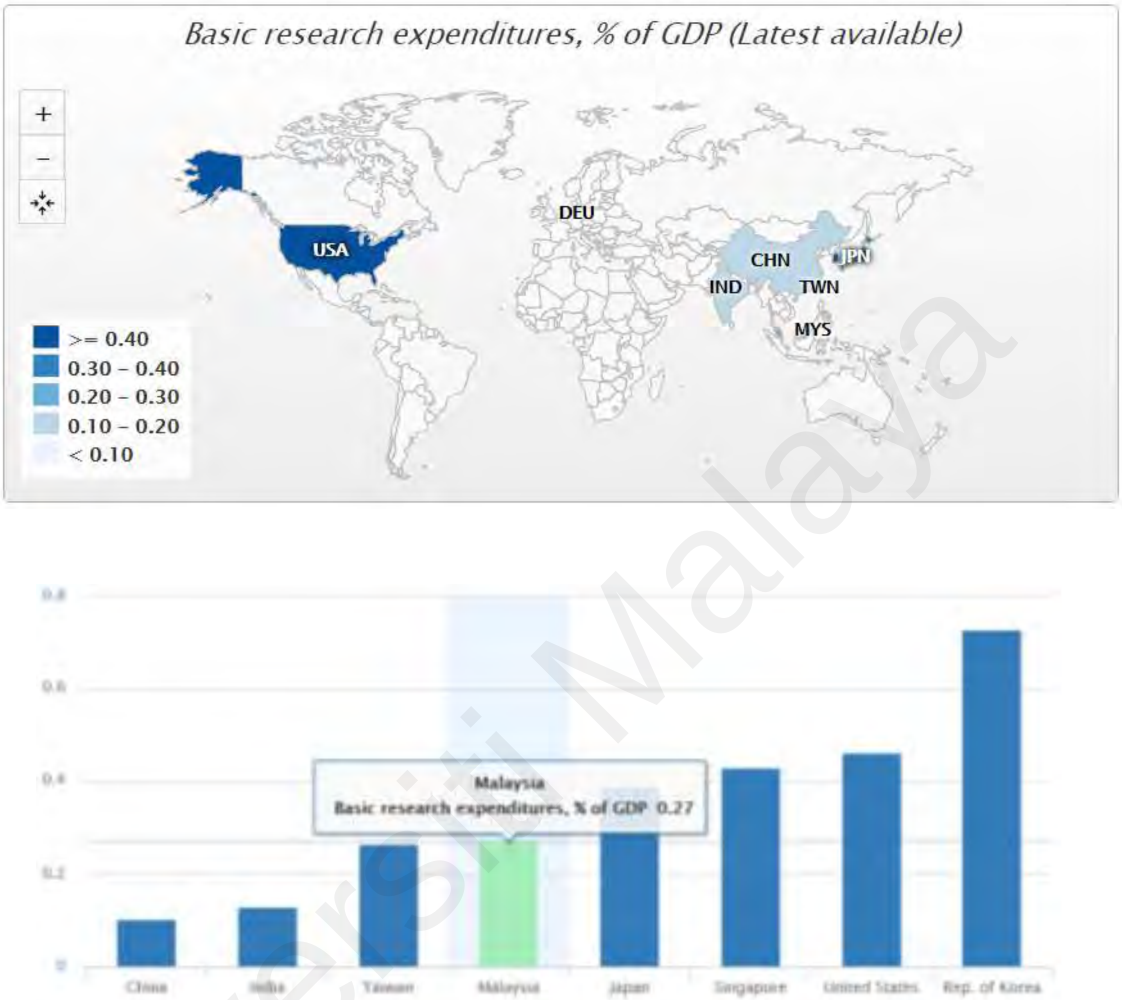


Figure 4.3: Basic Research as Percent of GDP for Selected Countries
Source: Author, 2018

Hence, developing country like Malaysia need to cross the first threshold of 2.5% GERD-to-GDP to stay focus on improving the basic research and expand their overall innovation. Basic science can allow to understand more phenomena in-depth and improve standard of living of the country and the Malaysian economy. So, our second observation is it will remain challenging for Malaysia not just the smaller proportion R&D but smaller proportion GERD spending also means smaller allocation to basic research spending. Over RM400million is set in Budget 2022 to channel to MOSTI and MOHE but as aligned to our predicted outcome in Figure 4.3, it still demonstrated that the developing countries including Malaysia spent relatively smaller proportion on basic research i.e. 27% compared to developed countries spent minimum 40% (eg. US spent 41% in 2019) or more than have of its GERD ensuring their basic research activity would eventually be successful in either creating new knowledge or prototype into a new product. For example, improving the clinical trials in human research can improve the public health, knowledge and skills of their citizen in developing country to shift towards producing higher value-added goods, rather than at present becomes the production hubs to developed country on low-value added goods and not upgrading the skills on this low-skilled labor would only diminish the position of Malaysia to be competitive and creative in the long run. This second threshold must exceed to improve the quality of innovation as part of the transition path.

Third, we found that over the past fourteen years the huge gap in terms of the annual growth rate of patents successfully granted between developed and developing countries can varies according to the size of country as shown in Table 4.3 below. There are signs that the science heavyweights are slowing down in terms of patents generation and much of these basic research inventions are shifting towards Asian countries as the emerging scientific hubs. We observed the Asia's share of scientific patents are rising rapidly with larger populous country like China has an annual growth rate of 22.27% while smaller country like South Korea and Malaysia both experienced 11% growth rate during the same period. This could be due to the expiring of patents from the incumbents which set to benefit the emerging Asian scientific hubs to invest heavily in basic research R&D to speed up their innovation to sustain competition. The results are consistent with the fact that selected countries' infrastructure, quality of universities, scientific policies execution, and exchange of scientific knowledge between universities to foreign universities and foreign government research institutes have strengthen over the years[51] but the inefficiency of government agencies without a good and effective central planning to oversee this development would slow down translational research as well as the patentable output in these Asian hubs if not executed cautiously.

Table 1: Compounded Annual Growth Rate of Scientific Patents, Selected Countries, 2002 - 2015

Country	Population (in million)	CAGR %
US	328	3.51
Japan	127	2.96
Germany	82	2.78
South Korea	51	11.75
Malaysia	32	11.61
China	1415	22.27
Taiwan	23	5.63
Singapore	5	6.31

Source: Author's estimates (2019)

The CAGR show in Table 1 above is self-calculated by the author based on selected countries. The reason is to compare Malaysia and selected countries on the CAGR patents growth rate within said period. Although growth rate seems promising for Asian peers, our analysis further indicate that gaps remain wide when absolute number of scientific patents, publications and licensing income are taken into comparison instead which further deliberated in Figure 4.4 and Figure 4.5 below.

Figure 4.4 shows that the developing countries is only slightly above half the size of developed countries over last fourteen years of knowledge flows and invention progress and primarily driven by the growth in China. Furthermore, Malaysia (MYS) remain a low in generating utility and design patents 2,156 and 202 respectively (see blue and green bar chart indicators in Figure 4.4), compared to their developing peers India or China and far worse than their scientific heavyweight peers. Malaysia used to be a prominent

[51] Based on Global Innovation Index 2018 ranking has improved for the selected countries but low patentable output and translational research. In particularly, two important indicators were weak performer i.e. business sophistication on firms exposure to innovative activity and knowledge and technology outputs or inventions.

manufacturing exporter back before 2000s, this growth starts to decline when institutional and structural environment has evolved but competencies remain ineffective.

At the same time, Malaysia has increased the international co-authorship of articles over the last two decades with internationalization of research and higher education, however the same underperformance could be seen as the country produces relatively very low number of scientific articles 140,333 compared to South Korea 663,345 as a form of knowledge diffusion (see orange bar chart indicator in Figure 4.4). This deteriorating productivity on patenting which is part of upgrading the industrial structure to higher value-added industries would fail and worst still caught by other developing countries who have catch-up and leapfrog over Malaysia. In Figure 4.5, we also show you that developing country like Malaysia will face with new challenges as the technological progress gap widen as much as 372% could potentially limit the speed for the exporting country to catch-up and leapfrog over the emerging scientific countries like South Korea and China and far worst if compared with existing innovators like Japan and Taiwan in the Asian region, although Malaysia still can achieve fairly positive economic growth rates.

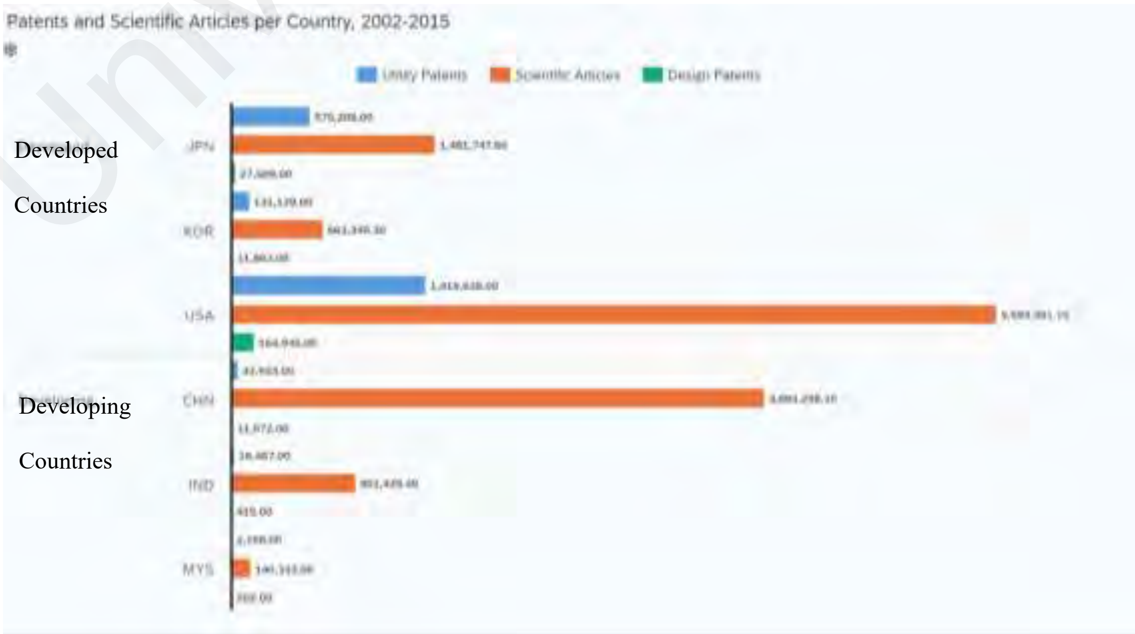


Figure 4.4: Scientific Patents and Publications for Selected Countries

Source: Author, 2018

Figure 4.5: Comparison on Malaysia and South Korea Scientific Articles Performance
Source: Author, 2018

We reiterated the dominant contribution of basic research remain as the cornerstone of broad base knowledge to provide solution to practical problems. The sophistication of exports become a new measure in examining exporting of modern industrial products or capital-intensive industries will allow transform in the innovation ladder. Thus, universities retain the core knowledge institutions on basic research which had considerable impact in economic development in the long term to reduce Malaysia dependency on purely manufacturing lower value-added products with no radical changes over years which also weaken the transformation factor endowments and industrial structure upgrading.

The integrated basic- to applied research evidence that we show above seems to reflect our fourth observation that developed countries are primarily driven by private firms or large multinationals with patents granted to large firms, such as IBM, Intel, GE, Canon, Samsung, though most of this projects are government funded. Patenting support from the government in new business development is common at the developed countries that gain positive licensing income. While in contrast to the developing countries, majority faces negative licensing income, insignificant knowledge or technology spillover and worst still have to find new funding to acquire new scientific knowledge from foreign markets but does not mean that they are not useful to support patenting or invention activity (see Figure 4.6).

Overall, firm's productivity can be overestimated when the actual number of scientific output is indeed low despite increasing R&D inputs over the years show that weak translation and appropriation of knowledge remain unresolved can be due to bureaucratic process and planning. Existing NIS hubs at the developing countries are inadequate when lack sophistication to compete ended up licensing payments is larger than their licensing income as shown in Figure 4.7. In the case of Malaysia, the country is not lack of innovation policies but largely fragmented on the establishment of scientific strategic agenda are cut across too many ministries and state governments resulted in duplicate efforts (23 federal ministries and 14 state governments). Weak integration in the NIS is stem from this short-lived coordination, though Malaysia is not at the lowest nor least productive when comes to basic research spending but the key challenges on low (9%) commercialization rate of basic research investment and deficit on high-skilled workers are not ideal to convert the basic research into any form of high quality translational research or output weaken the entire innovation system altogether.

So, it has implied that developing countries have suffered from actual research output gap versus their full estimates on unexploited potential output, streamlining their innovation policies and questionable mandates when licensing deficit continue to multiply with negative IP licensing income. Poor coordination has deterred other developed countries raising their criteria to be selective in choosing the correct developing countries or even considering doing it back in their Home country. Selected stakeholders can be skeptical on raising more monetarily and physical investment at the non-performing developing country accumulated specific know-how such as Malaysia when the poor coordination, corruption in between the R&D processes and output gap continues even though the country has developed their specialization area such as FELDA, FGV, RISDA, MARDI, and others. R&D corruption in unnecessary public procurement or misuse of R&D grant possibly undermine the entire country NIS system again ended up with limited income resources and effective returns to invest back to commercialize their basic research activity. Consequently, this also leads to research universities possibly fail to obtain new outputs further weaken the existing knowledge flows and stocks.

After such experience, the developed country will look for more productive country's choices these days to invest in widening the gap of these laggards developing countries. Existing specialized NIS clusters including the RUs will weaken like the case of Malaysia. In contrast, the developed countries remain attractive location and far better off in this aspect to gain positive net licensing income from their inventions and re-invest in another new breakthrough research continuously though we are not implying is zero corruption or full efficiency. Such R&D investment and partnerships are worst off during uncertain times such as the current coronavirus pandemic.

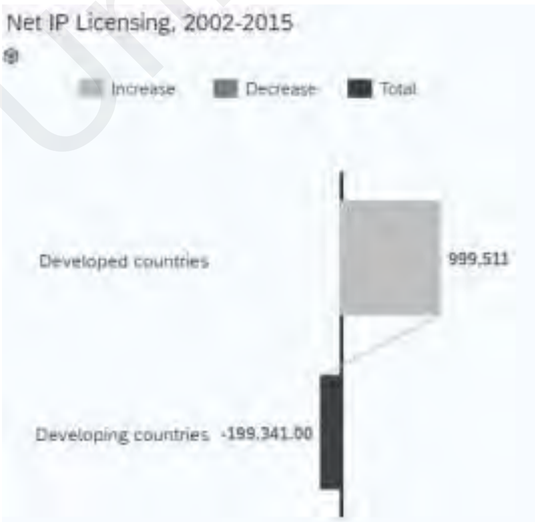


Figure 4.6: Comparison of IP Licensing in Developed and Developing Countries
Source: Author, 2018

Figure 4.7: Licensing Income and Payments for Selected Countries
Source: Author, 2018

In the meantime, our findings in Figure 4.8 below suggested that S&T activities in developed countries are relatively more well balanced measuring the relative importance of patents income and publications over the last fourteen years, while developing countries are more concentrated on publications rather than increasing stagnant patenting income in terms of utilizing the economic resources spent on basic R&D. We reiterate that publication is a by-product of patent with intangible value and should not constitute as the core product with can generate tangible income in the long run beside sustaining competitiveness.

Furthermore, it has implied that developing countries are at the early stage of improving their S&T activities by raising their tertiary graduates in engineering and science and increasing their country's scientific manpower as a pre-requisite for co-authorship, attracting foreign collaboration, and preparing their domestic resident capability for patenting activity thereafter. Changes on patent is a game changer to country who seek targeted technological progress at a speed. The short-term alternative can be to push up scientific publication just like how China did it. They publish four times more than India holding the size of the country constant. So was clearly the scientific superpower of the developing countries when comes to scientific articles surpassed US in 2015 and Malaysia's gap is significantly low and far away to catchup with China or even South Korea. Malaysia's speed on publication is too slow as the 2015 scientific publication output is South Korea's performance fifteen years ago.

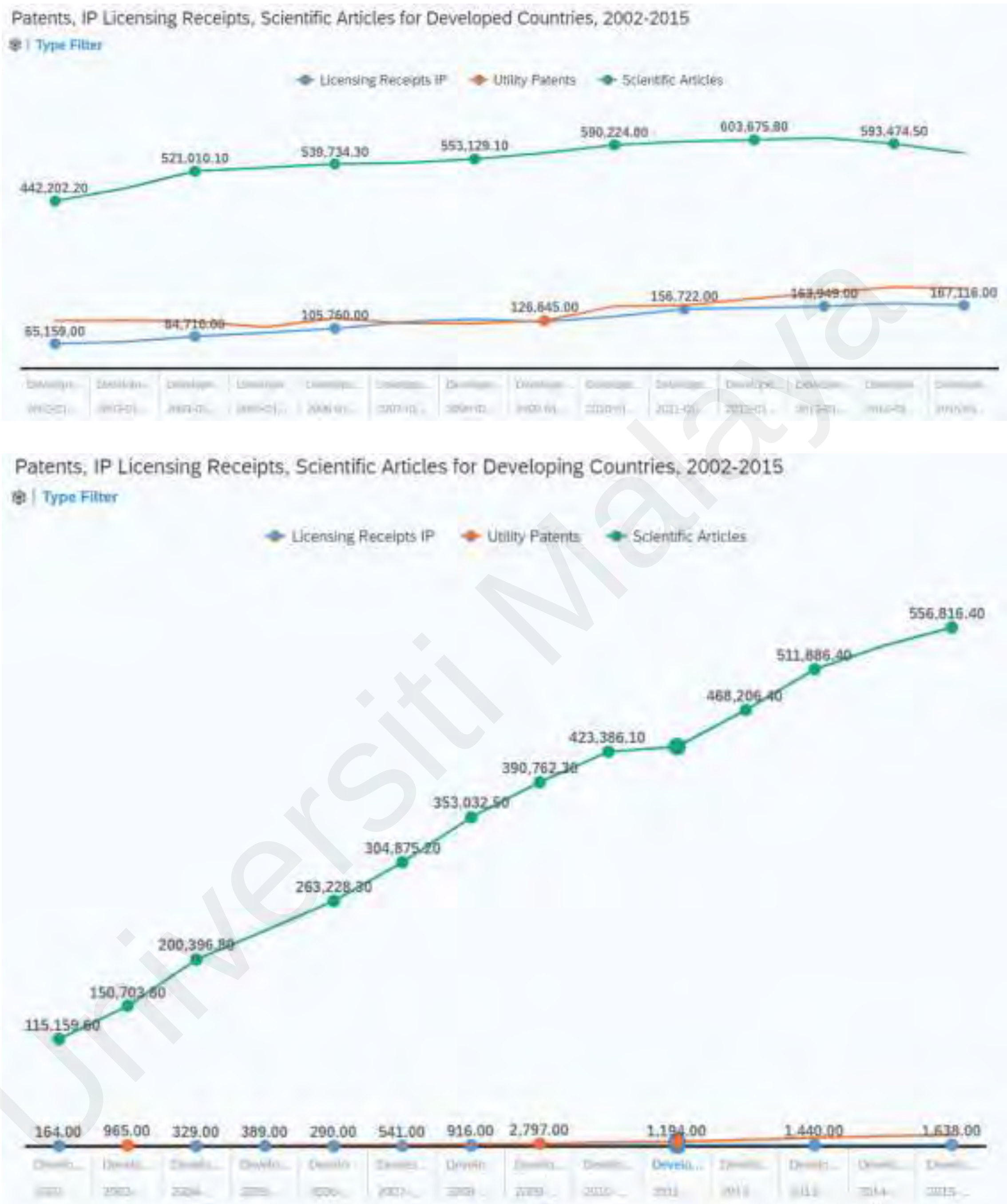


Figure 4.8: Comparison between Scientific Production in Developed and Developing Countries
Source: Author, 2018

In this section, we are interested in the patents claim by universities, much of these increase in patents were achieved after educational reforms. Universities must consider the needs to develop new knowledge stocks alongside creation of academic patents. By having such mindset, universities at the developed countries had the competitive advantage to develop appropriate innovation and educational policies that are capable to produce the desired research output. The trend shows that the positive existence of knowledge transfer activity at university level when the high number of patents claim by productive universities and a positive trend on university patenting.

In contrast, when we observed the academic patent trend at the developing countries, only few universities with such high research productive prospect can achieve such result and mainly perform in a specific country China. By and large, most of the developing countries weak interaction among agents in NIS including university-industry partnerships have also undermine the research output at the universities. These universities no longer carry the prestige but merely communicating an open knowledge without new invention or open up new opportunity for the country or invention team. The developed countries can produce more than 6,000 patents granted in a single year 2015, but developing countries only represent 6% of the combined selected developed countries. This implied not just financial resources gap widen and practically weaken to provide high-skilled resources to the industry. Failing so, led to the disorientation of domestic firms to produce valuable patents and industrial designs.

Based on the above rationale, it is proven that both Malaysia and India are highly disadvantaged in their R&D investment process despite high R&D spending invested and high degree of attention effort done since they are unsuccessful in raising the domestic university utility patents (also means lack of ability to extract tacit knowledge and prototype it for new development) including skills and licensing deficit in the future except for co-authorship scientific publications (see Figure 4.9). In fact, Malaysia can be worst off when the country's polytechnics and TVET are not performing as well which involve most of the psychomotor to shape and speed up the patenting activity.

We went further to examine the above findings and corroborated that one of the contributors to the developed countries performance is also the existence of strong growth of individual inventor's owned patent that dominate the patenting landscape plays a crucial role. We found that the top performers in scientific studies and research concentration remain strong in the West compared to Asia regions in Figure 4.10 and have evolved differently between the developed and developing countries. Therefore, the sharp increase in US's individual owned active patents and high number of alumni patents and research foundation over the last fourteen years raises the university patent and make the country sustain as scientific superpower to dominate the licensing income many times fold, while both Japan and Korea have reaped from successful central planning system on scientific activities.

Such results supported our literature analysis in Chapter 2 on why the research universities are important to speed up patenting derived from the past experience of Japan, South Korea and China. In 2004, Japan had reform their higher education and university research system to conceptualize a *national university corporation* concept while South Korea had conceptualized an *industry-academic cooperation foundation* concept to perform aggressive authorized testing and prototypes had successfully develop a visible trend of rising patents in East Asia ever since in scientific competitiveness against the US. These two countries do not just produce patents but also act as the backbone to regional innovation cluster promotion project align with the national development plan. As a result, it was ranked highly among the top innovators research universities upon strengthening their local scientific community and the economy. Yet, incentive system on university patent is weaker in developing countries.

We foresee the large gap continue to exist if reliant solely on China as front-runner when we benchmark against the two largest economies in developing countries i.e. China and India remained low, and Malaysia domestic capacity are nowhere to catch up due to unproductive universities when compared to the selected countries which are academically- and scientifically well driven. The performance of the Malaysian universities can be compared when we examined the three highest patenting technology class within a five years period from 2011 to 2015, namely class 257 Active Solid-State Devices, class 438 Semiconductor Device Manufacturing, and class 424 Drug, Bio-Affecting and Body Treating Compositions, class 426 Food and Edible Material. According to our own estimates, the developed countries represent over 60% of the above said patents classes, and again China had on average 20% of those patents respectively. Only Universiti Putra Malaysia had successfully produce 7 units of drug related international patents. The rest are mainly produced by individual or private firms which indicate the weakness in Malaysian research universities capability to administer international patents to stay ahead of competition. Resident patent activity in the case of Malaysia will be described in Chapter 5 when MyIPO patent fees (US$332) is much lower than USPTO to see if higher patent fees had constraint the Malaysian applicants to file patents abroad or has it been equally low R&D output performance at the domestic level as we found in this section.

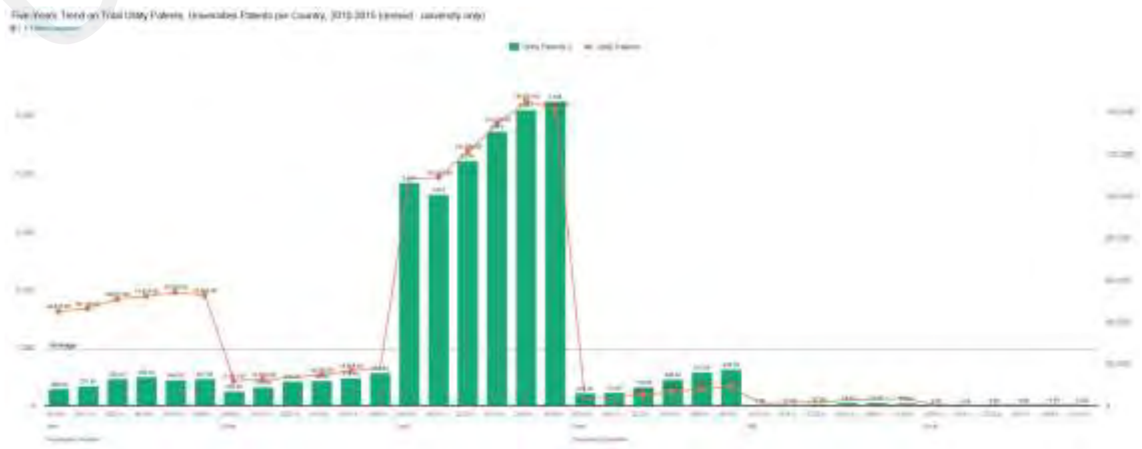


Figure 4.9: Trend in University Patent Granted in Developed and Developing Countries
Source: Author, 2018

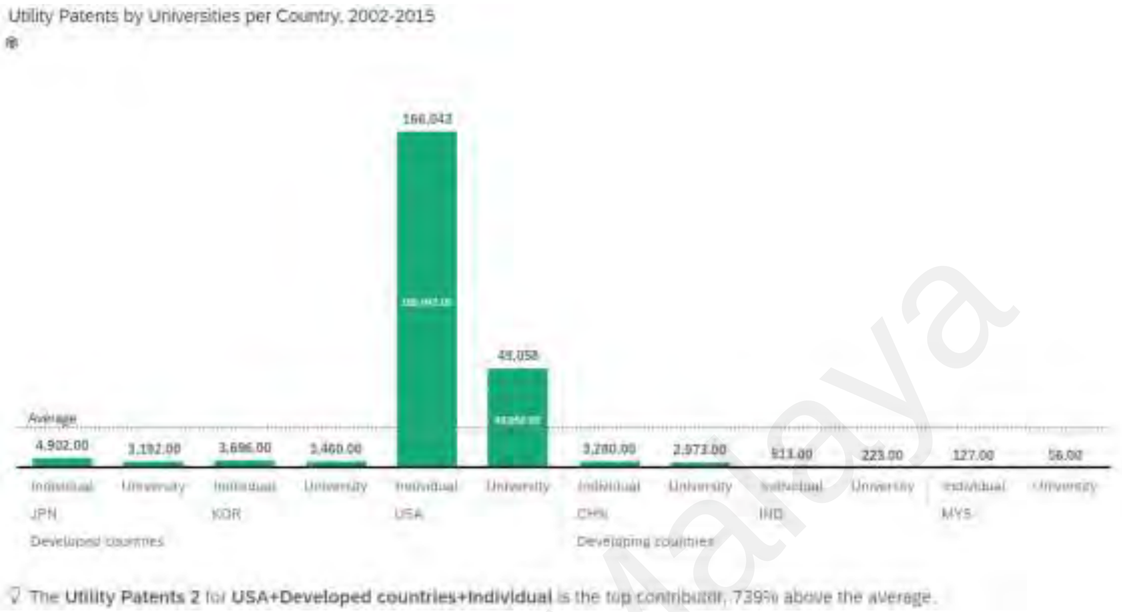


Figure 4.10: Trend in Inventor-Owned and University Utility Patents

Source: Author, 2018

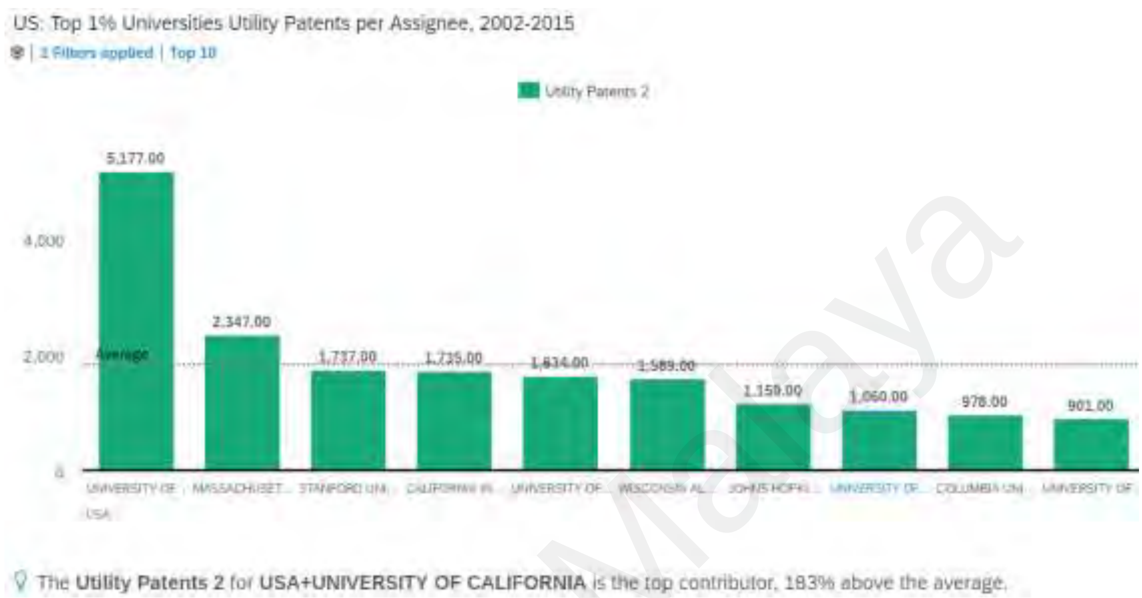
The top performers in scientific studies and research concentration also clearly seen to be concentrated at a few institutions which had been upgraded to research university status after internationalization and educational reforms effort. Figures 4.11 presented the result split by different countries allow us to understand that developed countries on average have more than one university, while developing countries lack alumni patents or national university corporation concept mostly is reliant on one prime university to carry the scientific research stewardship could be a risky strategy for development growth. The large populous countries such as China and India were riskiest among our selected developing countries as in India two institutions i.e. Indian Institute of Technology and Indian Institute of Science have dominated 78% of the top 1% performers, and similar trends in Republic of China dominated by Tsinghua University and Peking University (64%) for such a large populous country should have the ability to create more credible research university than the current status.

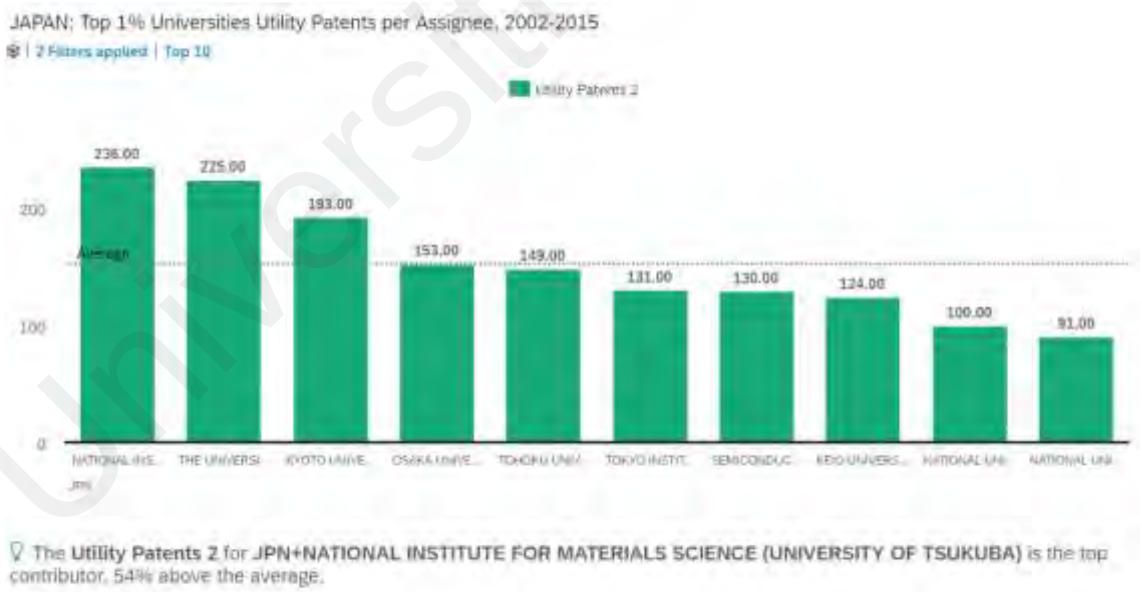
From the top 1 percent academic institutions, we zoomed into top 5 as a matter whether public or private research universities matter in terms of research performance variations. The US had a well-balanced patent portfolio between private and public universities; University of California and University of Texas (public RUs) with a leading Wisconsin Alumni Research Foundation which manages the discovery and licensing revenue for University of Wisconsin-Madison, Massachusetts Institute of Technology, Stanford University, Caltech (private RUs).

In the case of Japan and South Korea, the top 1 percent research activity are centrally plan thus a high degree of patent portfolios concentrated at mostly state-owned public universities under their ministry of education, science and technology, namely MEXT in Japan and MEST in Korea, S&T oriented roadmap are expected since 17 out of the top 20 Asia's Most Innovative Universities reside at this two locations; Japan - University of Tsukuba, University of Tokyo, Kyoto University, Osaka University, Tohoku University, Nagoya University and Hokkaido University; Korea – KIST, KAIST, Gwangju Institute of Science and Technology, Seoul National University, Kyungpook National University.

The alumni research foundation or industry-academic cooperation foundation act as a technology transfer office (TTO) has been successful incentive to improve faculty's productivity, to retain staff and reward them with higher salary, as well as support their research work and giving scholarship and depend less on tuition fees alone. So back in 2004, Japan and South Korea had educational reforms (including Basic S&T Plan and Program 577) to transition these established universities into specializing TTO commercialization. Using this method, we see the incentive to commercialize these patents are pass on to TTO office i.e. national university corporation so the inventor-owned patent will be lower unlike in US with a more balanced ratio of patents owned by the institution when government funds were used rather than on the inventor can elevate competition between different states in the country to monitor the return on investment in science towns or parks. The private universities in South Korea such as Sungkyunkwan University, Hanyang University, Yonsei University, Pohang University, Korea University have established industry-academic cooperation foundation as part of their responsibilities to induce active patenting activity and entrepreneurship collaboration on these research universities to promote new knowledge and technological advances. Most of the scientific reforms in 2004 till today is to expand investment in basic and fundamental research. The effort stems positive results when the universities gain large operating profit through firm's research order and profit from IP rights upon utilizing the government research funding since the patent ownership is solely owned by the university (for example, 99% of such foundation patents are solely own by the universities).

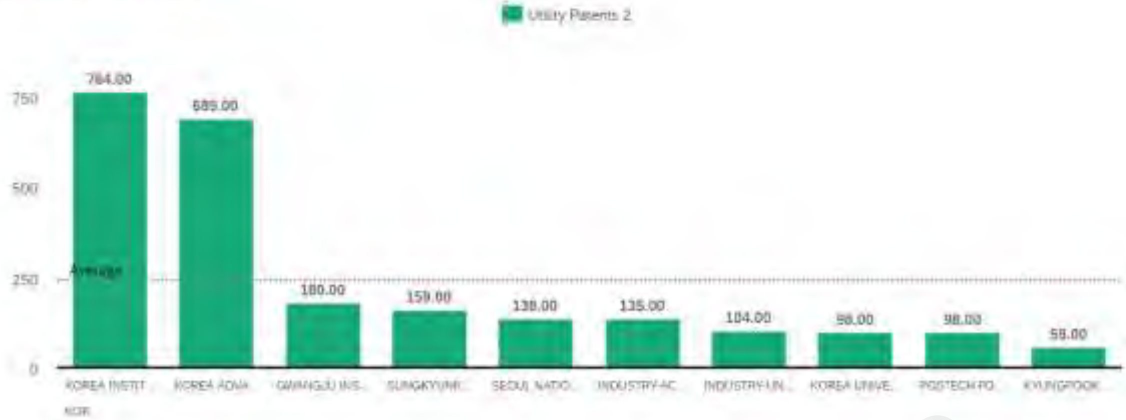
In terms of science education curriculum revolution, Malaysia, Japan and South Korea shared similar progression path to incentivize more potential graduates to pursue S&T as their early careers to embark into innovation economy. The Ministry of Education at respective countries allow science students to incorporate learnings from both areas to understand certain scientific phenomenon and use it to spark their analytical and creative mindset. However, at current state challenges remain high in Malaysia due to the divisive of roles and responsibilities to make basic research even to happen. The many divisive ministries i.e. Ministry of Education, Ministry of Higher Education, ASM, MOSTI, KETTHA, etc coupled with very few TTO being established by the established public and private universities can give weak signal to incentivize whether what should they patent and whom should administer this patents. Japan and South Korea were successful because this initiate to shape their R&D output is kept lean and MEXT and MEST as the sole ministry to revolutionize their universities to become entrepreneurial had less intervention and bureaucracies and in general the patent is solely owned by the university.





SOUTH KOREA: Top 1% Universities Utility Patents per Assignee, 2002-2015

2 Filters applied | Top 10



The **Utility Patents 2** for **KOR+KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY** is the top contributor, 215% above the average.

China: Top 1% Universities Utility Patents per Assignee, 2002-2015

2 Filters applied | Top 10

The **Utility Patents 2** for **CHN+TSINGHUA UNIVERSITY** is the top contributor, 362% above the average.

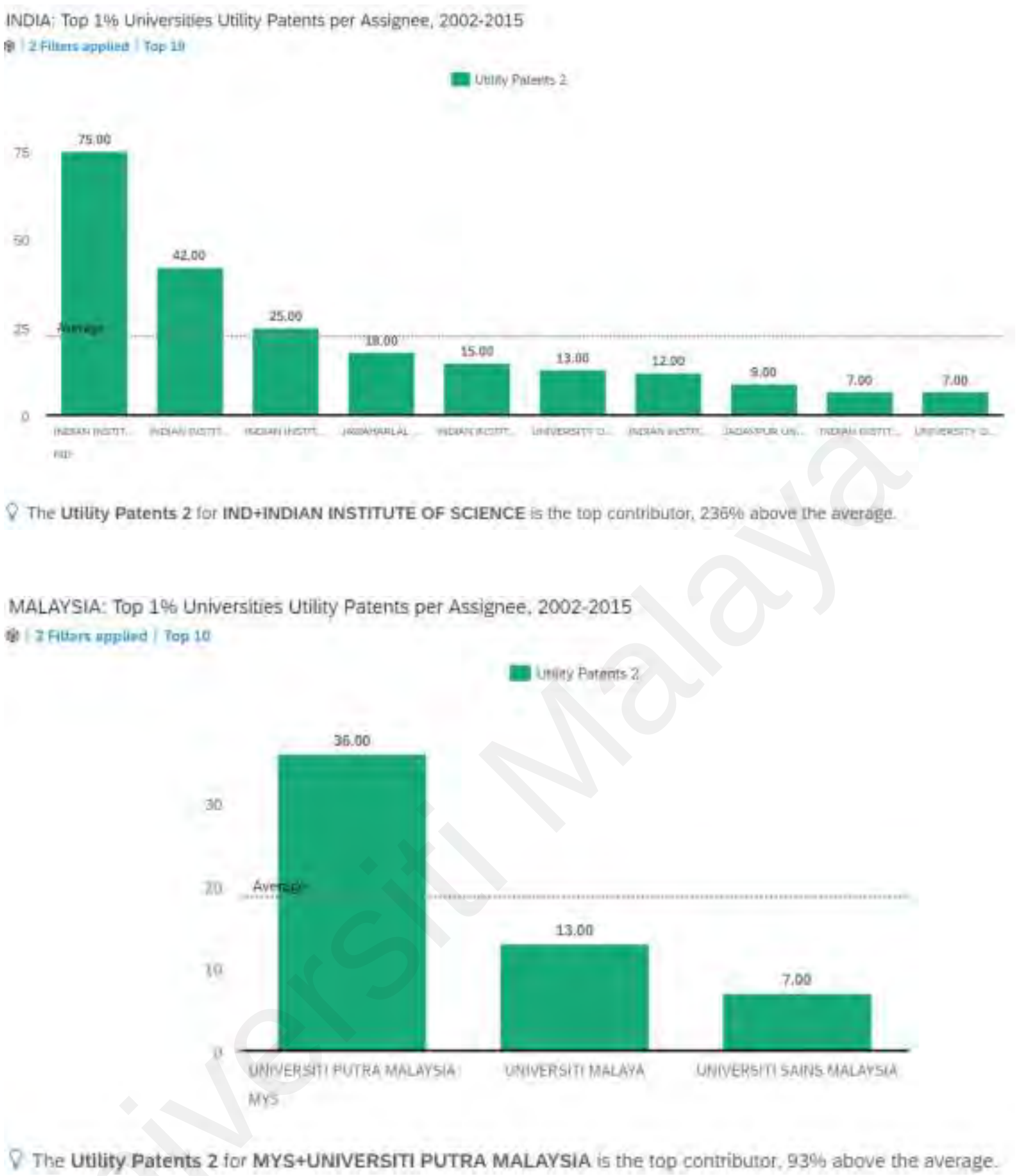


Figure 4.11: Contribution of Top 1 Percent University Utility Patents by Country, 2002-2015

Source: Author, 2018

4.5 Summary

The evidence shows that the successful developers to high income status, such as the United States, Japan, Germany, South Korea and Taiwan have filed massive numbers of patents among their innovation outputs. These countries have also recorded a sharp increase in scientific publications. China also has also performed well, which explains its rapid economic growth and structural change even have continuously increasing plan in basic research upon post-Covid. However, while Malaysia has managed to record an impressive growth in scientific publications, its record on patent filing has been dismal. The Budget 2022 and 12th Malaysia Plan also clearly lack of detailed implementation plan to catch up on the basic research and achieve real growth in innovation value chain. Although Malaysia has also enjoyed rapid expansion in scientific publications, its deficiency in generating patents as an innovation output is drawback that has slowed down its economic growth. The overwhelming focus among universities on scientific publications has created a knowledge gap that has denied firms the applied innovation output in the form of patents to stimulate rapid economic growth.

Even among patents filed, most of them are by foreign individuals and firms, which are either reproduced nationally to protect their intellectual property or filed from domestic research will tend to produce little spillover nationally. The widening gap in patenting by ownership in other words offer national firms little access to knowledge spillover from the R&D expenditure, which is likely to be why no manufacturing firm in Malaysia in the critical industries of electronics and automotive products are at the technology frontier. In addition to bureaucratic problems in the filing of patents, the focus of incentives to universities towards scientific publications have discouraged the targeting of R&D grants for producing patents. Consequently, R&D grants allocated to universities have largely gone to producing scientific publications rather than patents. We examine the relationship between resident patent and economic growth in the next chapter.

CHAPTER 5

PATENTS AND ECONOMIC GROWTH

5.1 Introduction

The lessons learnt from previous chapter highlighted how incentives have impacted on patent filing in economic growth when assessed empirically between developed and developing countries. In this chapter, we focus on the patenting activity using patent-to-GDP, patent performance between resident and foreign patent on Malaysia's economic growth, utility and design patents performance compared to industrial designs.

Apparently, patent is a form of endowment and competitiveness progress to the university or nation and closely related to the supply of scientific human capital. Market access and intellectual property, (such as academic and industrial patents), are important to move countries away from the middle-income trap and knowledge stagnation. While it is not necessarily enable such countries to leapfrog existing frontier countries, it can surely improve the standard of living of the latecomer countries, which akin to saying that education is a pathway to reduce poverty and innovation deprivation.

Developing countries, such as Malaysia have to work hard to raise their scientific publication and patenting capabilities. While the establishment of the NIS impressively raised the ranking of Malaysian universities, they have lacked the support required to stimulate firm-level innovations to the point of support catching up technologically and economically. In the case of US, China and South Korea, the universities have been that starting point to spur such resident patents. Even during Covid time, we have observed developing country like India have reduced their patenting fee on their education institutions to encourage more local innovation patent creation.

Hence, in this section we use an econometric model to examine how the different types of patents, in particularly resident patent have impacted on economic growth with a focus on Malaysia. Universities became the largest supplier and most complex institutions to strengthen the country NIS and sustain competitive advantage on their own by generating various sources of income by encouraging knowledge transfer, new scientific discovery and set high provision of quality scientific workforce as the fundamental of economic and social growth. Weak patenting will act as failing the keystone enabler or accelerator to improve education and innovation activities in the country with damaging effect to future R&D output.

We expect the more patent, the more innovation, the more attractive the market is to investors and opportunity to access new market, therefore the more jobs created. It would be useful for university to continue this inspiring path to facilitate new employment, strengthen university-industry alliances, and incubation labs on new products and services or even start-up (and spin-off company from the university) connecting both government and industry.

5.2 Critical Issues

Malaysia is a small country is an existing member of the World Intellectual Property Organization (WIPO). One key advantage of Malaysia is the country has some fundamental setup of IPR system from MyIPO and the Patent Cooperation Treaty that came in force since 2006 which make it more economical and globally connected than ever connecting to over 130 members countries to spur patenting activity in the business and manufacturing sectors. From the past experiences, we have seen the success of several small countries such as Sweden, The Netherlands, Switzerland, Singapore and Taiwan. Perhaps the key missing link is to quickly establish the dynamic learning curve to leapfrog the small country in producing innovative patents.

It is also evidenced that many Asian countries including Malaysia has been actively attracting foreign investments and collaboration with MNCs on high-tech exports and establishing foreign universities to turn itself into a global education hub. The research activity has been increasing to reinforce their plan to support R&D technological hubs. The universities do not just teach and publish, however aim to produce more tertiary-educated to become skilled workforce assimilating the success of US and European models. To align to their resources to R&D strategy, the S&T human resources are needed to support this development primarily concentrated in Malaysia, Singapore, Thailand and of late in Vietnam in the Southeast Asia region. Although Malaysia has the second highest researcher densities among ASEAN countries: 1,780 after Singapore 6,440 per million population, and four out of five researchers are employed in the higher education sector, this still failed to address the research output mission. In McCann and Mudambi (2004) findings, normally this knowledge-intensive production concentrated in the NIS are specialized, and the small countries can be successful only when sufficient scale (sizeable markets) is attained to capture the positive externalities exceeding the size of the small country alone, which is much needed in the case of Malaysia.

As of 2018, we observed that not just universities ranking have improved, however patenting also has increased as a result of higher adult literacy rate (95.1%), lower unemployed labor force (504,800 compared to 507,500 in 2017; unemployment rate has remained below 4% is a good sign comparative to South Korea and Japan) but some structural problems are not easy to resolve such as to upskill the country's basic research activity due to low proportion of skilled workers (23.5%). The targeted R&D intensity can increase to 2.0% by 2020 with 1.2 million students among which 150,000 are international students but tertiary-educated students should not constitute the ability to produce and commercialize patents. Since 2002, the CAGR and number of tertiary-educated S&T graduates have been growing faster from 37,948 to 117,240 in 2017

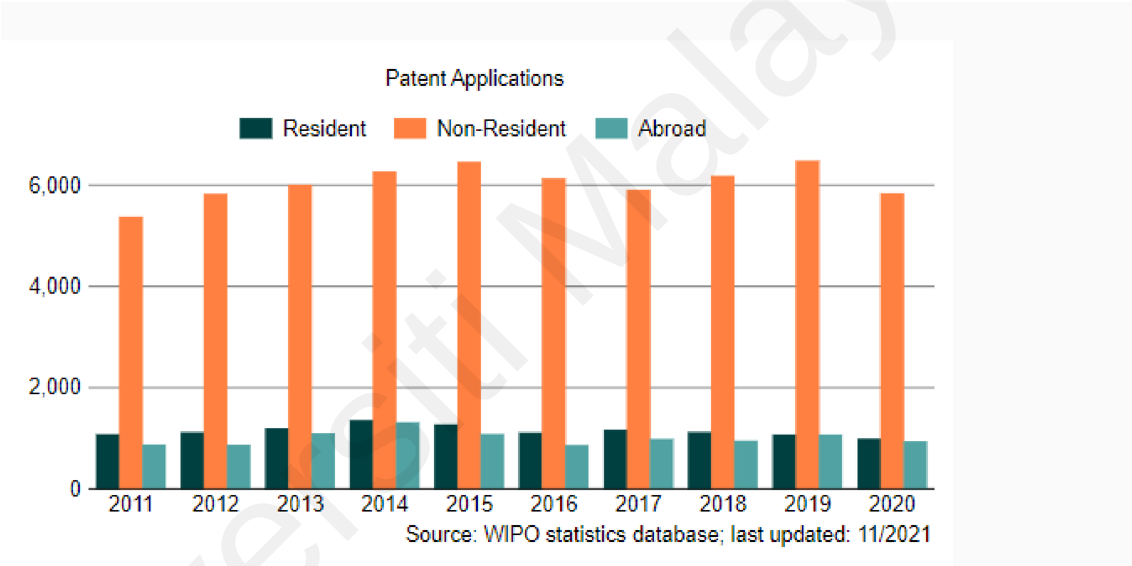
(DOSM 2017, MOHE 2017) than patent CAGR and research output can conclude the low performing rates of patent commercialization due to shortage to develop correct resources.

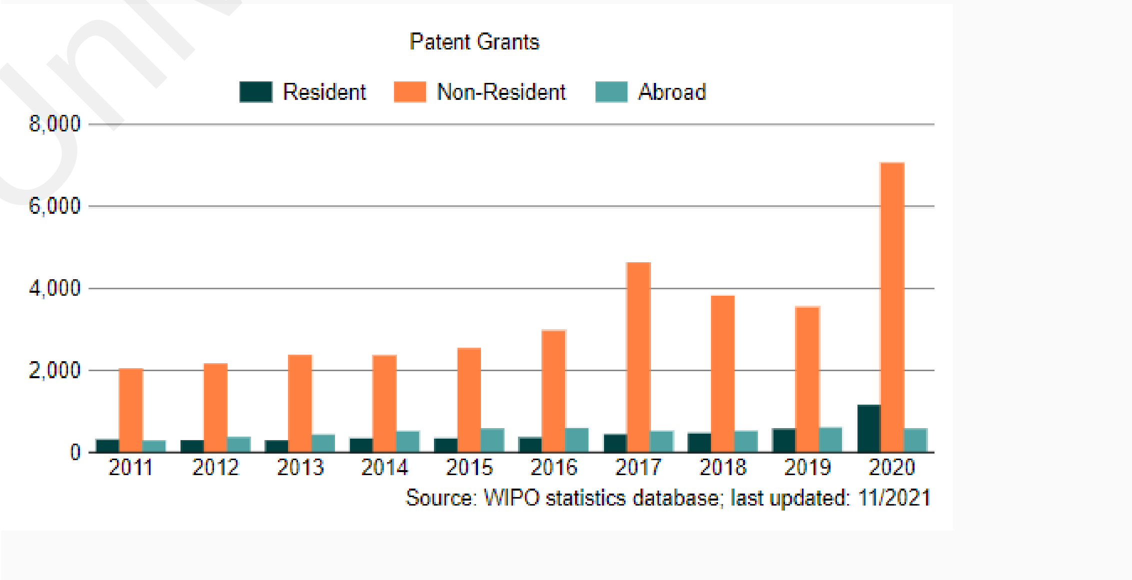
Even though Malaysia gain momentum to be the fourth[52] largest patents producer, second largest ASEAN GERD's spender[53], and ranked second (after Singapore) in terms of high-technology exports, but the changes on investment in basic research were insignificant and has declined in recent years stem from the inability to compete with South Korea, Taiwan, and China.

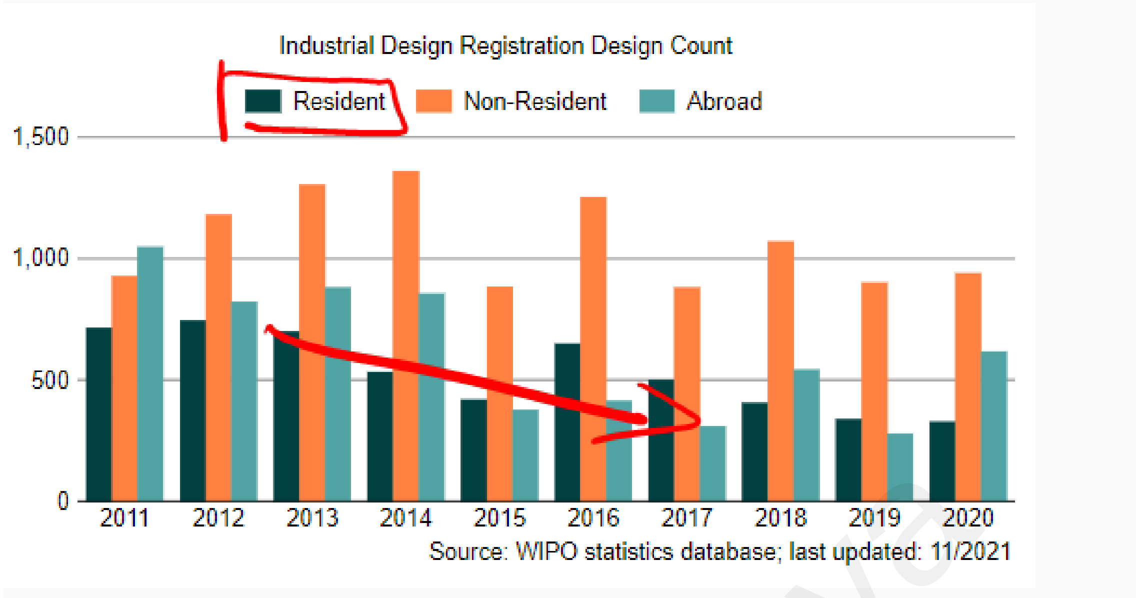
Back then, the country was technologically lagging and constraint with limited R&D infrastructure hence became dependent on foreign technological capability to mature their economy similarly in the case of China and South Korea. The strong presence of MNCs in Malaysia since 1980s were due to the tremendous effort of the Malaysian government to increase trade openness and invited high quality foreign investment into the country. Malaysia stood out in terms of massive production activity back then and contributed to a higher business expenditure on R&D (BERD) compared to Philippines (UNESCO, 2016). It is not surprising as these MNCs ran their operation locally, the more patenting activity also took place at the same time with the higher BERD invested. As it turned out and supported by Figure 5.1 below, foreign patent application and patent granted have been consistently lower over the last ten years even after Malaysia have joined the Patent Cooperation Treaty 2006. Malaysia has become highly dependent on foreign technological capability including the preference on foreign products and foreign education perceived as better quality than local produced. The inferiority continues to inflate when the rate of manufacturing foreign products in Malaysia by the non-residents

[52] Accounts for 95% of ASEAN patents together with Singapore, Australia and New Zealand, and the second largest ASEAN spender in research expenditure (1.13% of GDP and 1.26% research intensity) after Singapore (2.02% of GDP and 2.18% research intensity) and among the top five OIC countries.
[53] 37% of the Malaysian education budget is spent on investment in tertiary education (Sharma, 2015).

is growing faster than the manufacturing of local products along with skills and IP licensing deficit. On the same Figure 5.1, we observed that industrial design patent fell doubled over the last ten years while utility patents grew doubled. Over the years, not just the the gap widen to innovate its own indigenous technology or products, but exhibits misses opportunity to engage and spur local innovation or creative imitation all in all weaken the knowledge appropriation and creation on basic research and basic science disabling the optimal level of R&D output environment barrier to catch up with other leaders.







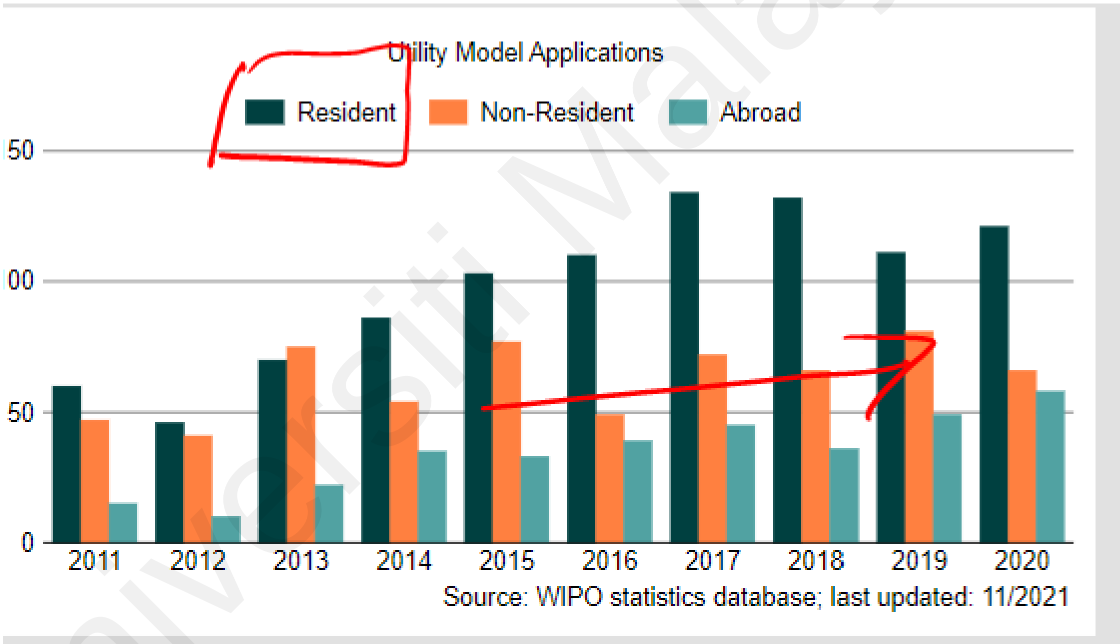


Figure 5.1: Malaysia's progress in patent application to patent grated, utility patent versus industrial design patent

Source: WIPO, 2022

Other than tertiary graduates, they need a capable pool of scientific human capital and well-functioning universities as institution to reflect the quality in basic research to compete with the leaders. But patenting activity is still consider very low (and not much increase from the universities either with an increased budget allocated[54]) and even lower if compared with those of non-residents patent although having to safeguard these activities through the Patents Act 1983 and Patents Regulations 1986 in compliance to WTO's Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) as S&T increasingly became the nation strategic agenda.

The increasing role played by the various ministries from the then Science & Technology, Higher Education, and the homegrown universities in shaping the innovation economy in Malaysia going forward have attracted attention for future changes. The universities were no longer to conduct mainstream teaching, but set to calibrate research, publication, and internationalization among the criterion set for rewards i.e. hiring, promotion, getting R&D grant has become the rising catalyst to transform the universities to be entrepreneurial.

Technological frontiers like US, Japan, South Korea and Taiwan are less reliant on government grant or funding once the NIS take-off. In the case of Malaysia, the gradual shift was meager still highly depending on government grant such as National Science Technology Policy, pre-seed fund Multimedia Super Corridor Malaysia to research Science Fund and High Impact Research Fund to commercialization Industrial Technical Assistance Fund, but gradual shift to private funding still relative low failing the research outcomes to increase the resident (industrial) and academic patenting and growing at a slower pace than non-resident. Although it is a costly pursuit in the short-run but results are better off in the long-run. The selected local universities were also upgraded to research university concept as the Malaysian government learnt from the developed country especially the influences from successful American and European to enable not just the change in pedagogy on science education, rather it seek to transmit any knowledge

[54] R&D grants of RM400 mil is provision to public universities in Budget 2018 higher compared to previous year RM235 mil in 2017.

and collaboration not readily available in the local market including attracting international students or talents (in hope they will remain in the country and work) and enhancing the vocational and technical schools to increase the selected research universities educational and research experience, and there are many blueprints to transform some targeted sectors such as chemicals, electrical and electronics, machinery and equipment, aeronautics, healthcare and medical devices, and digital economy. It becomes the integral part of the mission of these selected universities to become entrepreneurial, respond to industrial needs, increase the country's economy and social growth, their productivity, endowment (less reliant on government funding), to produce a better quality of scientific education system and graduates to sustain the competition locally and globally (life-long learning). During this take-off, the change in country leadership also changes the rapidness of innovation-driven policy and projects to assimilate and speed up this catch-up with the global frontiers. Different leaders give attention to different trends that might erode the efforts put into expanding specialization.

There is a dire need to improve these adverse trends. Pesek from Nikkei Asia (2020) saw that weak internal demand and unstable political leadership poses Malaysia to fall behind these targeted innovation output and revival is just trailing behind others countries who have outperform Malaysia. These lost decades must be quantified to advance the Malaysian NIS on domestic patent capability or face with regressing outcome. As discussed later, we will analyze the properties of my model to quantify the impact on how has the supply of science & technology (S&T) human capital affected growth on GDP per capita. It is hypothesized that R&D has supported the Malaysia GDP growth for the past twenty-two years and the critical gaps in the supply of R&D produced by scientists and engineers in Malaysia are examined.

5.3 Methodology and Data

In Section 4, we argued that the inventive path comparison between developed and developing country is a distinct on their own. Although both the developed and developing countries displayed patenting activity is incremental in nature, the rate of local innovation differ substantially following this pattern analysis. Scientific publications have increased rapidly but not the licensing receipts and patents, widening the gap in the developing countries. In contrast to the growth of such objects in the developed countries, it is more stable and gap is maintain and minimized. Thus, we concluded in the last chapter that the Malaysian research universities failed to commercialize productive patents leads to a fall in new knowledge creation to advance innovation.

We shall further examine the gaps found in Section 4 through this chapter to provide a deeper conclusion. As shown in Section 4, we need to further examine the inventive efforts of Malaysia as a sample for our study. Rather than using bar or column charts analysis, we then turn to the use Malaysian patent granted analysis as an indicator of inventive output and check where the gaps are using regression model. In view of patent has proven to foster more invention and stimulate growth on innovative production capacity, we wish to show that different types of innovation will impact the Malaysian economic growth differently and would like to test the following null hypothesis for this case is *H1. Scientific R&D has supported Malaysia economic growth.* The country is in dire needs to increase its commercialization rate in particular the ability to generate indigenous knowledge or innovation.

For this section, the feature research method adopted is ARDL model (described in Section 3 on the selection method and compliance to the ARDL procedures and the right platform for detecting long-run cointegrating relationship and infer the speed of convergence to equilibrium using CECM-ARDL; see Figure 5.2) and compare our findings with economic theories and past literatures. Often, patent is a significant predictor but has time lag so we preferred to use patent being awarded or granted rather than patent application as a stronger indicator of actual volume on successful protection of its valuable R&D inventions and control for the overestimated time lag. The selection of indicators to measure the patent performance is based on the various types of patents in Malaysia to reflect the innovation activity related to basic research as a developing country. As a developing country, many technological breakthrough required rigorous amount of patenting on utility innovation to reflect their inventive productivity before they can compete over the leader or frontier.

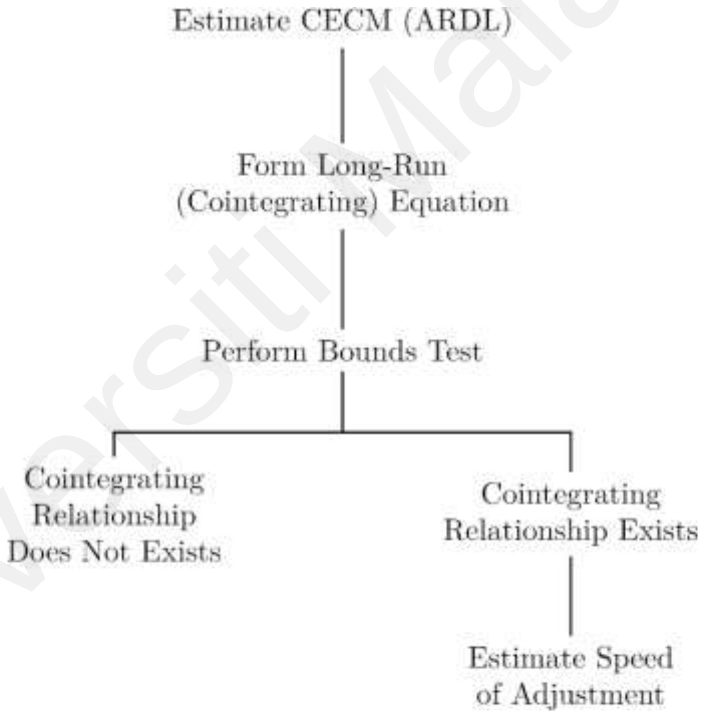


Figure 5.2: CECM-ARDL procedure fit the special case of Conditional Error Correction Model

Source: Eviews, 2017

First, we created 22 data points i.e. annual patents statistics, GDP, GERD, fixed capital, and employment data sets collected from the Malaysian Intellectual Property

Office (MyIPO), Academy of Sciences Malaysia, DOSM, MOHE, World Bank, UNESCO, ILO, WIPO and USPTO over the period of 1996 to 2017 (22 years) in our analysis based on available information up to-date except that availability of data on industrial design only start from 1999 onwards. The selected variables were used based on the economic theories and past literatures as mentioned in Section 2. Our sample period is sufficient to be indicative to which the patented inventions belong to in the database as R&D intensity rises rapidly from 0.21 to 1.30 resort to eight international patents classification (IPC): A-Human Necessities; B-Performing Operations or Transporting; C-Chemistry or Metallurgy; D-Textiles or Paper; E-Fixed Constructions; F-Mechanical Engineering; G-Physics; H-Electricity. Since patent is still the most reliable and direct proxy, we suggest to use the Malaysian patents statistics and will not sum up the patents, designs and trademarks which complicate and potentially leads to biases results when trademarks demonstrate little technological advancement especially in indigenous innovation.

In the case of Malaysia, the patent system (IPR) is categorized into four types – patent (exclusive invention rights), industrial design (pattern and ornamentation), trademark (exclusive sign), and geographical indications (exclusive sign of geographic origin). Among them, it would be interesting to observe the utility and design patents compared to the remaining two categories as it is a sign of technological learning on domestic applicants and improvement in local innovation. As for trademarks (TM), we excluded it as it is problematic to consider high level of trademark can correlate with the underlying quality of technological inventiveness and reveal little economic values in the long term since it does not attached to any technology. It is more for marketing purpose to differentiate the products or brand awareness in the market.

In order to investigate the relationships between R&D, economic growth and other selected R&D variables in Malaysian economy, the proposed basic model to be estimated is as follows. The GDP is regressed over time on the variables of interest, which are central to our analysis, i.e., GDP = f {past GDP, GERD, GFCF, ID, PAT, EMPHC} as explained in Section 3.4.

Long run equation:

$$lnDGDP_t = \alpha + \sum_{k=1}^{k_1} \beta_{1k}\, lnDGDP_{t-k} + \sum_{k=1}^{k_2} \beta_{2k}\, lnDPAT_{t-k} + \sum_{k=1}^{k_3} \beta_{3k}\, lnDID_{t-k} + \sum_{k=1}^{k_4} \beta_{4k}\, lnDGERD_{t-k} + \sum_{k=1}^{k_5} \beta_{5k}\, lnDEMPHC_{t-k} + \sum_{k=1}^{k_6} \beta_{6k}\, lnDGFCF_{t-k} + \varepsilon_t$$

Eq. (8)

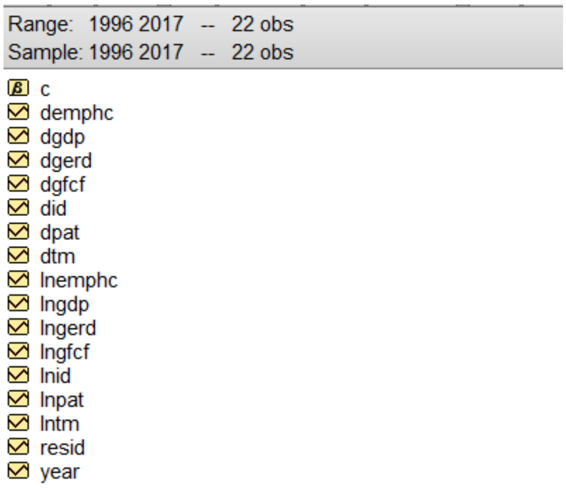
Short run equation:

$$\Delta lnDGDP_t = \alpha + \sum_{k=1}^{k_1} \beta_{1k}\, \Delta lnDGDP_{t-k} + \sum_{k=1}^{k_2} \beta_{2k}\, \Delta lnDPAT_{t-k} + \sum_{k=1}^{k_3} \beta_{3k}\, \Delta lnDID_{t-k} + \sum_{k=1}^{k_4} \beta_{4k}\, \Delta lnDGERD_{t-k} + \sum_{k=1}^{k_5} \beta_{5k}\, \Delta lnDEMPHC_{t-k} + \sum_{k=1}^{k_6} \beta_{6k}\, \Delta lnDGFCF_{t-k} + \delta ECT_{t-1} + \varepsilon_t$$

Eq. (9)

where $\Delta lnGDP_t$ represents the first difference of series on logarithm value of annual real GDP growth rate in Malaysia, *t* is time or number of observations for time series model, *t-k* is to consider the influence of time lag between inputs to generate output and β_0 (α) is a constant term. $|\beta_1 - \beta_6|$ are explanatory variables in first-order or higher order autoregressive parameter or elasticities obtained from the result of ARDL regression estimation and these long run parameters are expected to carry a positive sign. The variables on the right-hand side of the equation are $\beta_1 \Delta lnDGDP_{t-k}$ variable is k lagged years logarithm value of annual real GDP growth in Malaysia upon first difference of the series, $\beta_2 \Delta lnDPAT_{t-k}$ variable is k lagged years logarithm value of total number of patents granted in Malaysia at time *t* upon first difference of the series, $\beta_3 \Delta lnDID_{t-k}$ variable is k lagged years logarithm value of total industrial designs in Malaysia, $\beta_4 \Delta lnDGERD_{t-k}$ variable is k lagged years logarithm of gross expenditure on research and development to GDP in Malaysia, $\beta_5 \Delta lnDEMPHC_{t-k}$ variable is k lagged years logarithm of total employment with tertiary level education, $\beta_6 \Delta lnDGFCF_{t-k}$ variable is k lagged years logarithm of gross fixed capital formation to GDP in Malaysia (represent value of durable tangible and intangible goods), δECT is the speed of correction derived from lagged error correction term which is expected to be negative and statistically significant and ε_t is the unexplained residual (white noise error term or any possible factors not captured in the explanatory variables of our model estimation) for Malaysia data over twenty-two years.

For regression purposes we will take a total of the eight IPCs. Before proceeding to the econometric analysis, we sort the collected data and take a logarithm (including differencing) on these statistics using Excel. Once the dataset is cleanse and prepare according to the format, we will begin to upload the dataset into Eviews 10 to establish the abovementioned Equation (8) seven-variable regression model as shown below. We will conduct diagnostic test for goodness-of-fit on the proposed model estimation. Under Test Type, we select either ADF or KPSS to proceed with the unit root test. Subsequently, we generate the descriptive statistics and regression estimates by inserting the selected variables into Equation Specification. Subsequently we establish the cointegration relationship and finally we use MLE for robustness check to ensure stability of the model using a different technique. A more detailed discussion of the MyIPO data is describe in Section 5.3.



5.4 Results and Discussion

Upon dataset uploaded, we observed that they are not stationary using line graphs. All the seven variables exhibit positive trends. We see a stable incremental growth on R&D inputs such as national income (GDP), R&D expenditure (GERD) and productive stock of tertiary human capital (LNEMPHC), however R&D output such as patent shows an unsteady growth in the series; a visible dip in tangible and intangible assets could be associated to financial market instability i.e. 1998 to 2000 and 2008 to 2010 (see Figure 5.3 below).

5.4.1 Diagnostic Check

For regression purpose, we normalized the data by taking differencing on the non-stationary property of variables and results on ADF and KPSS unit root tests to avoid spurious or biased result. Prior differencing, both ADF and KPSS test results show that all the series are non-stationary at a 5% significance level and integrated of order one I(1) consistently having the occurrence of unit roots when probabilities are higher than 5% except for LNID which is stationary and integrated of order zero I(0) as reported in Section 3.4 Table 3.3a and 3.3b. After performing first-order differencing, the re-test ADF and KPSS results on non-stationary series became stationary as shown in Table 3.4a and 3.4b below (see Figure 5.4; adopted from Section 3). To kick start our analysis, we proceed to run an AR(1) estimation with the following estimated equation: DGDP = C(1) + C(2)*DPAT + C(3)*DID + C(4)*DGERD + C(5)*DGFCF + C(6)*DEMPHC + C(7)*DGDP(-1)

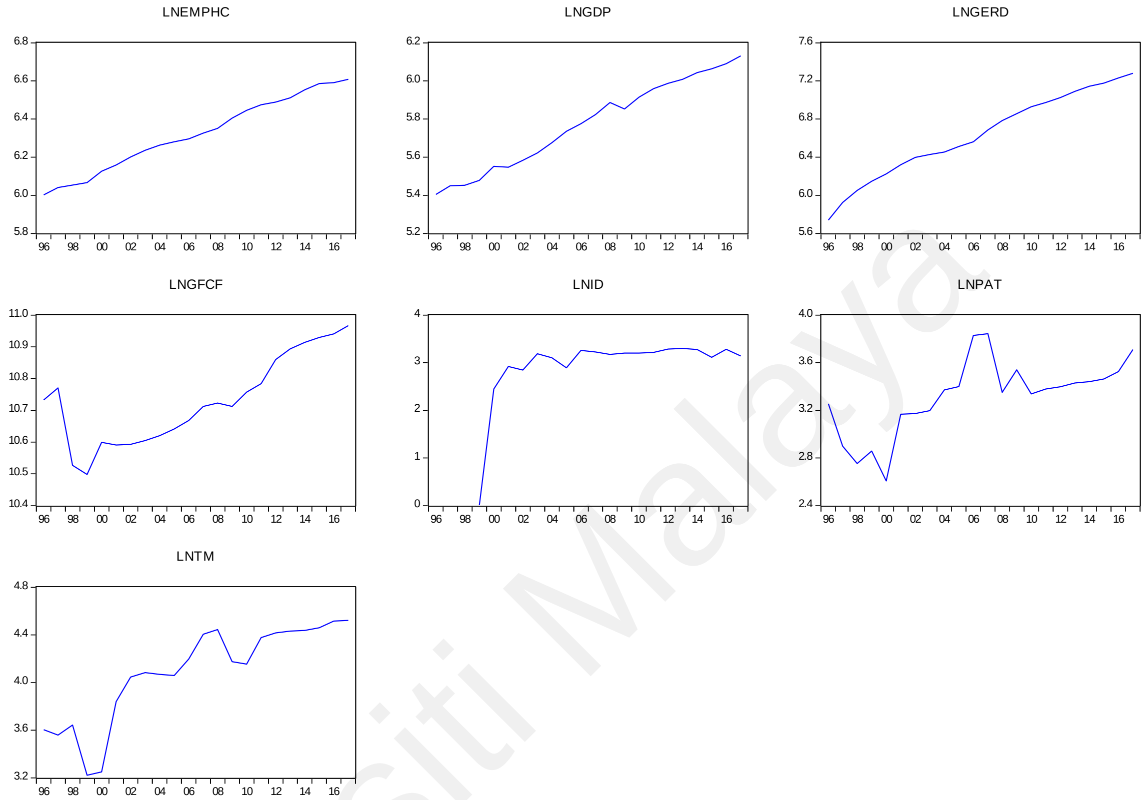


Figure 5.3: Stable Growth on Non-stationary of Selected Variables Except for Patent

Source: Author, 2018

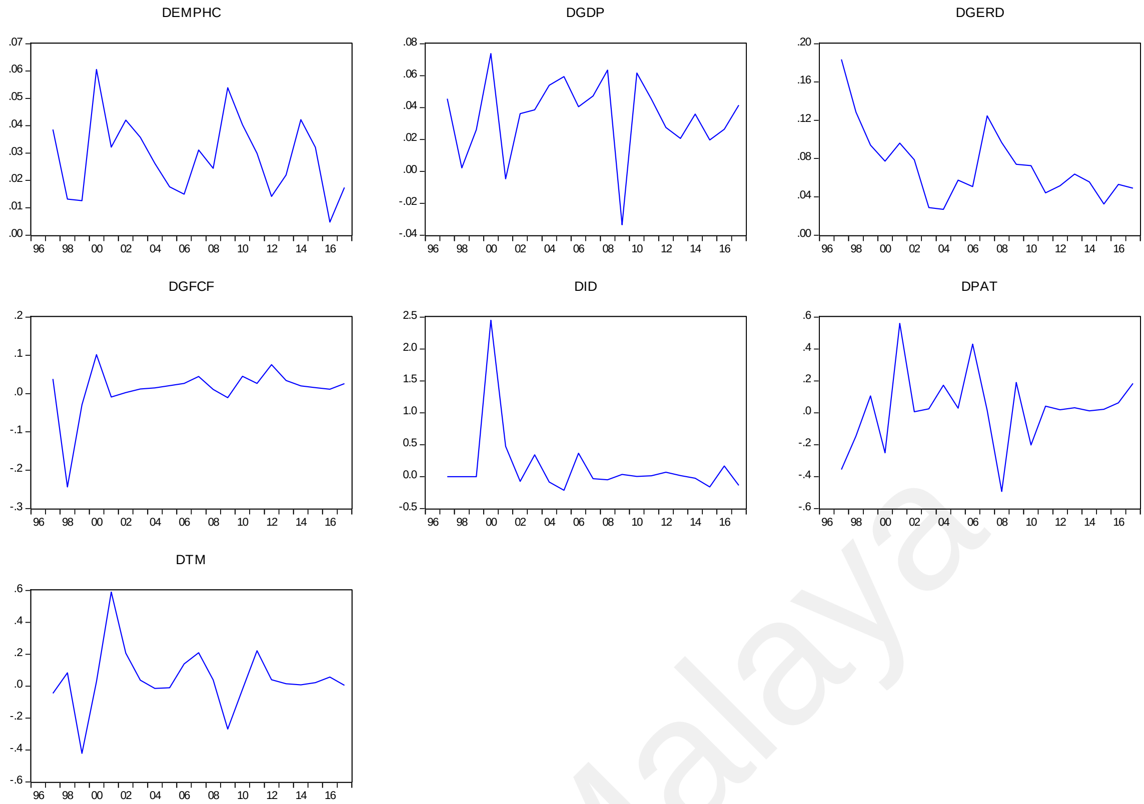


Figure 5.4: Stationary Series of Selected Variables (Author, 2018)

Source: Author, 2018

Table 3.4a: ADF Unit Root Test – First Order Difference

Variable	*Critical value (A)*	*t-stat (B)*	*Probability (C)*	*Durbin-Watson (D)*
DGDP (LNGDP)	-3.040	-3.999	0.008	2.168
DPAT (LNPAT)	-3.003	-5.631	0.000	2.166
DID (LNID)	-3.081	-4.911	0.002	1.832
DGERD (LNGERD)	-3.030	-3.710	0.013	1.991
DEMPHC (LNEMPHC)	-3.030	-3.709	0.013	1.688
DGFCF (LNGFCF)	-3.030	-4.080	0.006	1.046 (1.518)*
RESID01	-1.961	-6.187	0.000	2.136

Table 3.4b: KPSS Unit Root Test – First Order Difference

Variable	*Critical value*	*t-stat*	
DGDP (LNGDP)	0.463	0.159	Stationary
DPAT (LNPAT)	0.463	0.105	Stationary
DID (LNID)	0.463	0.233	Stationary
DGERD (LNGERD)	0.463	0.381	Stationary
DEMPHC (LNEMPHC)	0.463	0.161	Stationary
DGFCF (LNGFCF)	0.463	0.338	Stationary

Source: Author, 2018

5.4.2 Results and Discussion

According to AR(1) model, the patenting model is statistically significant at 5% significance level (p-value 0.0471; no serial correlation LM test probability 23.6% is more than 5% at up to 2 lags) and able to predict 57% of patenting impact to the Malaysian economic growth. Such significance was similar to the effect of tertiary education in Malaysia. The many uses of scientific knowledge and scientific R&D initiated since 1990s have considerably supported Malaysia economic growth and more range of research activities were undertaken to solve national needs. We expect all variables to have positive coefficients except for DGERD variable which is expected to be negative since it is a spending to the economy and exhaustible resources. This strongly suggests that the the larger the GERD is good for R&D but returns on appropriation must be well compensated with continuous knowledge flow and flow of R&D income to recover the R&D costs or otherwise becomes a burden to the economy in the long run. Our model estimation also shows that some of the predictors have positive relationships while some had negative impact the Malaysian GDP.

Although resident patents application and granted have been increasing gradually over the 22 years range, we found that more than two third of the Malaysian residents applications failed to get patent approval (an average 80%) had little improvement, while the non-residents applications were much improved to reduce their rejection rate to only 49% on average based on our own calculation (see Table 5.4). The increase on patent applications not accompanied with the increase on patent approved can signifies quality impact. It is evident that utility patent and innovation, past one-year GDP, R&D expenditure, and employed tertiary human capital stock (potential RSE) have negatively impact on the country's economic growth over the last 22 years range, in particular utility patents coefficient is negative and statistically significant at 5% (p-value 0.0335) indicating insufficient resident patents or quality of the indigenous innovation pose a big question due to high rejection rate over the past two decades and the unproductive research universities to generate sufficient basic research patents altogether leading to a state of unable to generate positive returns from these R&D investment despite many reforms done after 2008 in science and engineering education, expanding the Electrical and Electronics manufacturing market, or as rewarding career path for the locals.

There may be concerns from our analysis was the negative coefficients of employed tertiary human capital stock to produce and commercialize research output. The negative result although it is slightly insignificant at 10% level (p-value 0.1511 or alternatively 0.1317) with a large effect of 0.56 to 0.57 interpretated the possibility that tertiary educated workforce spillovers effect on patent creation had less influence on the economic growth in the Malaysia case when there are stagnation to employed these skilled workers from the demand side is slow or existing prospect for R&D industry remain flat over years in Malaysia when other countries start to overtake Malaysia as the preferred Asia best performer. Although the supply of these tertiary educated workers can increase but is constraint by fruitful retention on this group in productive sector and merely to fulfill existing employment opportunities. There is no new growth opportunity for these workers to be new high-tech industry or new capital-intensive industry. Thus, the lack of market sophistication on exports failed to maintain and improve any high-quality growth on researchers and inventors. The inefficiency is an obstacle can only be addressed when the demand side manage to stimulate the growth on the supply side not just on supply of human capital but also on patenting activity as a form of incentive to increase market sophistication.

In contrast, we observed a significant decline in absolute value of fixed capital formation between 1998 to 2009. Although the estimation result shows that fixed capital formation is statistically significant at 10% (p-value 0.0624; and statistically significance at 5% level in our alternative model with p-value 0.0171) suggested many aesthetical related progress made is promising to the country when industrial design and fixed capital have gain positive increment of 18% to 20% over the years, however not in advancing the new design knowledge or further build a new comparative advantage. This can be a lost decade for Malaysia due to the paying wrong attention in the S&T pursuit. Perhaps aesthetical can be a short-run quick gain but learning curve is less productive, unsustainable to compete in the long run. Furthermore, in spite of the significant FDI investments since 1990s, the innovative capacity of Malaysian firms is still relatively low although high level of manufacturing activities have created masses of knowledge spillovers resulted in increasing fixed capital formation and business confidence over the years for the foreign firms to do their business in Malaysia.

On one hand, we observed that Malaysia was struggling to compete and innovate on the global market. Mega-projects were often politicized, dominated by large GLCs or GLICs, and lack of quality control. Industrial design was also insignificant with a very small magnitude of less than 1% at this point has less impact to innovative activity in Malaysia. As a result, when most R&D works were allocated to the aesthetical aspect could have somewhat neglected the country ability to improve their productivity on basic research and domestic capability building to catch-up over the latecomer scientific frontiers today such as South Korea and Taiwan, and emerging China[55]. For instance, we assume the utility patent and industrial design are the overall output from R&D spending allocation. It is also noticeable that the estimate of utility patent is statistically different from industrial design. From the magnitude of the effect, it seems that DPAT 5.5% negative effect is larger than DID 1% positive effect therefore leads to overall less

[55] China created extensive number of resident patents and has transformed their military sector from an initial state-run aviation into homegrown world-class maker of aviation jets have strengthen the performance of their military business not just selling aircraft but training expertise and electronic systems, and perhaps even psychological invasion threat to some countries. Read more at https://economictimes.indiatimes.com/markets/stocks/news/asias-hottest-stock-is-a-bet-on-chinas-military-expansion/articleshow/63694528.cms

innovative output and commercialization to catch-up against the frontiers despite high investment of basic and applied research. Worst still, the combined DPAT and DID effects also at the losing end when 1% increase in GERD or R&D output will reduce economic growth by 7.7% and 4.5% respectively. Thus due to the effect of fall in GERD is larger than fall in R&D output, it could indicate wasteful allocation to unproductive activity which must be addressed.

Table 5.4: Average Statistics for Utility Patent in Malaysia, 1988-2017

Year	Resident Application	Foreign Application	Resident Granted	Foreign Granted	Resident Rejection %	Foreign Rejection %
1988-1998	1705	37586	286	10380	83	72
1999-2008	4502	47803	928	25568	79	47
2009-2017	11407	52070	3010	24369	74	53

Source: Author's estimates (2018)

Nevertheless, we see another possible reason in our analysis worth mentioning although it is insignificance at this point of time. The said unproductive measure we can see from the model analysis is that although tertiary education is a widely used investment for developing countries like Malaysia and had contributed to the economic growth, would have utilize industrial design as part of the education strategy for creative imitation would lead to greater interest in scientific fields as a career but the low unemployment obviously did not help to improve the situation either; most likely suffer from unattractive incentives, tedious bureaucratic process and not providing progression into mid-management level as consultant or decision makers for the government.

On the other hand, tertiary education and universities ranking have improved significantly. The reliance of tertiary educated human capital and universities to create technological breakthrough did not materialize to promote catch-up and innovation to the intended R&D programs. As the country progress to compete with other regional scientific peers, the expectation that investment in any tertiary education is sufficient to leapfrog the country against the frontiers could be naïve or short-sighted. This reflection show that the country is partially lacking a pool of scientific-able RSE to produce invention patents (described further in Section 6) which stems from good foundation of technical or scientific education. Much of the incremental availability stock of tertiary graduated human capital were somewhat less useful in the catch-up process if not being employed or assigned to the targeted scientific sectors to improve the country economic growth. The less successful on the Malaysian R&D programs also implied that the RSE would have either change into a non-S&T career due to early career was uninteresting or migrated to developed country for better exposure to latest high-technology products. Furthermore, the country remain fruitless in attracting their own and foreign talents to work in the country on a long-term basis, thus slowing down the R&D output at the downstream level.

Much of the initial result above make practical sense in the case of Malaysia, alternatively we can also try to remove one insignificant predictor R&D expenditure (as R&D input) assuming this is spent on the breakdown of each predictors (to generate the R&D output) for both the short-run to long-run Equations (8) and (9) thus becoming a redundant variable in the model. But keep in mind that based on past experiences and to avoid underspecification the model relevance, we shall not omit industrial design as a useful proxy thereafter when lag effect arises. We shall isolate the impact generated by each of the indicator such as patent, industrial and fixed capital formation which we believed each has its own effect for us to understand deeper into the R&D catch-up process and policy related to proxy itself.

By doing so, the alternative AR(1) model is also overall statistically significant at 5% significance level (p-value 0.0229) and consistently able to predict 57% of patenting impact to the Malaysian economic growth similar to the initial proposed model. The sign of the coefficients are as expected and effects did not change much either; utility patents remain negative at between 5.3% to 5.5%, tertiary stock of human capital still contribute negatively to the country's economy across the two models between 57% to 57.8%, the losses impact from patent is larger than industrial design thus still net loss in terms of R&D investment, while last year GDP still had not contributed much to the R&D growth in Malaysia for the past one year.

We believed R&D takes time and is a long-term investment therefore required to know the extent of time lag to each variable lag to understand the actual value it can bring to the table from the R&D spending behavior from ideation, research, develop, testing to strengthen reform measures. The initial AR(1) results above only assume dependent lagged period (GDP) but holding other important R&D indicators constant without lag would reveal less of the true picture happening in Malaysia. We also anticipate the cost and tediousness in patenting process between the full patent or aesthetical part of it during the time lag could differ to indicate stages of technological change and innovation. Therefore we selected ARDL as our choice of testing procedures.

Next to support our correlation empirical analysis, we proceed with the ARDL procedures as it allows us to analyze the past lag responses to economic growth. Still, we begin by first selecting the optimal lag length using Akaike Info Criterion (AIC) as described in Section 3.4. Then we select the best ARDL model based on the smallest AIC and highest log-likelihood; the smallest AIC is -5.94 and highest log-likelihood value is 64.48 with maximum 3 lag order on dependent and explanatory variables were sufficient to confirm that the model is well-fit, reliable with practical implications. We also tested to see whether this is the best model selection using SIC and Adjusted R-squared (see Table 5.5). All the three tests indicated the same results selection of maximum 3 lag order.

Of course we prefer shorter lags, however if 1 or 2 lags were to be selected the AIC of -4.93 and -5.21 could be not at its optimal level, hence we prefer to select the model with the smallest AIC for our investigation purpose.

Table 5.5: ARDL Model Selection Criteria Table for Top 5 Model

Specification	LogL	AIC*	BIC	HQ	Adj R^2
ARDL(1,2,1,3)	**64.48**	**-5.94**	**-5.39**	**-5.86**	**0.822**
ARDL(3,3,1,3)	67.31	-5.92	-5.23	-5.82	0.772
ARDL(2,3,1,3)	66.26	-5.91	-5.27	-5.82	0.795
ARDL(2,2,1,3)	64.99	-5.88	-5.29	-5.80	0.804
ARDL(1,2,2,3)	64.57	-5.84	-5.24	-5.75	0.794

Source: Author’s estimates (2018)

From this estimated equation: DGDP = C(1)*DGDP(-1) + C(2)*DPAT + C(3)*DPAT(-1) + C(4)*DPAT(-2) + C(5)*DID + C(6)*DID(-1) + C(7)*DGFCF + C(8)*DGFCF(-1) + C(9)*DGFCF(-2) + C(10)*DGFCF(-3) + C(11), Eviews evaluated 192 models, and determined the optimal lags on selected the four variables ARDL model specification as (1,2,1,3) which satisfies the smallest AIC condition. From Criteria Graph results, we selected 3 as the maximum lag orders with Automatic Selection since we are using annual data and to keep a reasonable degree of freedom. But as we explored, there are different optimal lags of each variable in the model. Compared to the maximum 3 lags, the optimal lag order proposed for GDP (as dependent variables) and industrial design have mixed result ranges between 1 to 3 lags while patent has between 2 to 3 lags, and only fixed capital formation is consistent with three lags. As such, we observed that shorter lags are preferred for better estimation using AIC selection criteria. We did not select Fixed Selection of 3 lag order for all variables making the model less desirable model with a larger AIC and statistically insignificant to explain the phenomenon indicating not an optimal lag model and also is not within the top 10 AIC models presented.

Again, we checked the serial correlation from the ARDL(1,2,1,3) model result. We are satisfied with the model estimated results do not show any anomalies. Durbin-Watson statistic 2.0143 on the above specifications which is close to 2 indicated the model does not suffer from any serial correlation; same goes to Breusch-Godfrey LM test results reported the probabilities of 16.2% is more than 5%, so we will accept null hypothesis that no serial correlation at up to 2 lags and Q-statistics are insignificant at all lags (0.115 to 0.840) showed that there is no serial correlation in the residuals (Eviews, 2018). The Jarque-Bera statistic is 0.1809 with probability of 91.3% is more than 5%, so we confirmed the residuals are normally distributed, and the model is homoscedastic with probability 80.7% is more than 5% with the variance of residuals is homogenously spread across zero. Histogram error term shows that it is evenly distributed across 0 between -1 to +1. The results from explanatory centered VIF on this model estimation confirmed that it is not affected by any multicollinearity problem when all the results are above 1 and less than 2 as reported in Table 3.1. As noted in Table 5.6, we also perform a robustness check using Maximum Likelihood Estimation (MLE) to ensure the estimated regression coefficients above is robust, plausible and reliable causal effects of the associated regressors for valid inference to theory or policy. The signs and magnitudes of the regressors are consistent to the least square estimators indicate no specification problem to the model, while MLE inverted AR roots result of 0.33 is less than 1 indicated a stable (stationary) model.

Table 5.6: Robustness Check

	AR(1)		MLE	
Regressor	*Coefficient*	*Std Error*	*Coefficient*	*Std Error*
DPAT	-0.055** (-2.37)	0.023	-0.064** (-2.15)	0.030
DID	0.009 (1.00)	0.009	0.007 (0.46)	0.016
DGERD	-0.077 (-0.40)	0.190	-0.094 (-0.29)	0.322
DGFCF	0.179* (2.03)	0.087	0.173 (0.73)	0.235

DEMPHC	-0.569 (-1.52)	0.373	-0.503 (-1.59)	0.316
DGDP(-1)	-0.141 (-0.70)	0.199	-0.182 (-0.57)	0.316
Constant (c)	0.059*** (3.25)	0.018	0.060* (2.03)	0.029

Notes: 1. ***,**,* are significance at 1%,5%,10% level respectively. 2. Number inside the parenthesis is the t-ratio. 3. Both models estimated are statistically significant with close range of adjusted R-sq 57~58%, AIC -4.7.

Source: Author's estimates (2018)

Next we proceed to check on cointegration behavior of this model. Upon lag selection, we employ the proposed ARDL approach to cointegration to establish whether there is any long run relationship between the variables in Equation (8) since they are integrated of different orders. Based on our sample size, the ARDL-Bound test is suitable for a small size study (Pesaran et al., 2001). We proceed to re-parameterized the model by selecting Long Run Form and Bounds Test function in Eviews. The critical value tables are computed under an asymptotic regime (sample size equal to 1000) with referenced from PSS (2001), and for finite sample regimes (sample sizes running from 30 to 80 in increments of 5) is referenced from Narayan (2005). Following our sample size, we can examine the long run relationship using Wald test or F-statistics provided by Eviews. The critical value bounds for n=35 with four regressors were as follows: I(0) 2.618, I(1) 3.532 (at 10% level); I(0) 3.164, I(1) 4.194 (at 5% level); I(0) 4.428, I(1) 5.816 (at 1% level). The computed F-stats 10.209 is larger than both lower I(0) and higher I(1) critical bounds of finite samples at the 1% significance level, thus we can reject the null hypothesis of no cointegration and conclude there are long run relationships between patent, industrial design, fixed capital and economic growth (see Table 5.7 below). The single asterisk on lag of dependent variable is expected as a common output generated by Eviews (Eviews, 2018). We do not find any other variables with double asterisk so the model indicated the predictors we selected somewhat is associated with some lags and is not zero lag-free.

Table 5.7: Bounds Test Result

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	10.20963	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	18		Finite Sample: n=35	
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816
			Finite Sample: n=30	
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Source: Author's estimates (2018)

Since both series are cointegrated, Granger causality test is used as an approach to discover interesting causal relations between selected variables in different models. As suggested by Toda-Yamamoto, Helmut-Lutkepohl, Dave Giles, we proceed to determine the causality test to cross check if we can regress each variable on their lagged values. Overall the granger causality confirmed that PAT has causality direction and there is enough statistical evidence of causal relations between patent, GDP, publication and scientific manpower. The results revealed that patent, industrial design and scientific publication changed before RSE changed. At this point considering up to 5 lags, there is causal relations between patent and GDP and the bi-directional confirmed that patent is able to cause fundamental change in GDP, however longer lags revealed that changes in patent is likely to caused changes in GDP and not the reverse. It indicates the existence of causality is uni-directional (one-way) from patent to GDP as we reject null hypothesis of PAT does not granger GDP.

Besides, the results indicate the existence of causality from RSE to PUB is bi-directional causal when longer lags are applied i.e. 5 to 6 lags indicating fundamental change in place so required longer lags while shorter lags indicate no relationship to produce changed on good quality scientific publications if shorter time frame is set to this scientific manpower. Under most circumstances, it is normal the RSE allocate a portion of the granted R&D expenditure to promote scientific publications. While causality on patent is uni-directional and publication do granger cause patent at lower lag i.e. 1 lag suggested there is a temporary lag rather than fundamental change is present when the scientific manpower in Malaysia are learning-by-doing and studying this technical documents or absorb the technical know-how and turn it into productive use of incremental invention but not a breakthrough invention, and patent will granger cause publication at higher lags (4 to 5 lags), industrial design will granger cause publication between 2 to 4 lags. Since the causality exist, we hypothesized how best to measure this patent and RSE to economic growth particularly for developing countries like Malaysia.

Having established the selected series were cointegrated, we estimate the long-run and short-run elasticities. The long-run coefficients from the ARDL Long Run Form and Bounds Test of the model is reported in Table 5.8. The case of Malaysia shows that each of the explanatory variables in the proposed model ARDL(1,2,1,3) are statistically significant at 1% significance level (p-value 0.0042) and expected to have positive impact. The lagged dependent variable DGDP(-1) is statistically significant at 1% level (p-value 0.0272) with a negative coefficient -0.67. This indicated that a 1% increase in GDP lagged one period results in about 0.7% fall in GDP in the current period can be due to frequent reliant or importing of foreign technologies, licensing income deficit year-on-year, slow resident patent growth and other factors.

For the explanatory variables, the physical patent had the expected positive sign to contribute positively to economic growth, however for other R&D assets focus on outer appearance such fixed capital and industrial designs are expected to contribute negatively to economic growth in the long run. The coefficient on patent is positive and statistically significant at 1% level, while coefficients on industrial design and fixed capital are negative and statistically significant at 5% level. A 10% increase in patent results in a 0.8% increase in economic growth but a slow growth. One of the reason for slow growth could be attributed to a significant decline on approved projects since 2011 under basic and applied research grants. Five out of the six grant schemes were high number of declined approved projects such as Fundamental Research Grant Scheme (FGRS) declined in 2008, 2011, and 2015, Exploratory Research Grant Scheme (ERGS), Research Acculturation Grant Scheme (RAGS) since 2011 to name a few have generated a lot of instability on the Malaysian R&D performance.

On the other hand, a 10% increase in industrial design and fixed capital formation results in 0.5% and 4.8% fall in economic growth respectively; the fall is larger than patenting marginal growth so would drain off R&D resources easily in Malaysia. Malaysia NIS might not achieve the scale of R&D output against its target. Thus, it suggested that the past was dampen by the high rejection rate in resident patent (74% to 83%) and low technological progress especially on enterprise R&D described in Table 5.4 indicating overall R&D efficiency has fall, operating unproductive allocation of R&D activity and inefficient scientific policies to focus on the aesthetical area would widen up the gap in the country to catch up with the frontiers and also patenting intensity between resident and non-resident firms operating in Malaysia. In addition, one could take the explanation on the inefficiency arises in the filing process to file protection on design instead of the entire patent as a less costly approach when the Malaysian R&D had limited and lower budgets than their peers Singapore, Japan, South Korea, China, Germany, France and US. This can erode incentive to innovate actively because of lack protection to the whole patent.

With the respective long-run magnitude of the selected variables above, a lot R&D reforms have been done, yet in this context patents in Malaysia still has an important effect on economic growth although small at this point of time could be due to the lower patent intensity in-country and slow upgrading of patent-intensive industry as Malaysia still stuck with lower skilled export-manufacturing rather than high-tech higher value-add or business-driven. The six established science and technology parks (namely Malaysia Silicon Valley Cyberjaya, Technology Park Malaysia, Selangor Science Park, Subang Hi-Tech Industrial Park, Kulim Hi-Tech Park, Johor Technology Park) are typically filled with foreign companies would have monopolized the scientific products and services. Also, because we not are measuring the differences between patent-intensive and non-patent intensive industry (noted in Section 1.1) specifically in this study could have undermine the a priori higher expectations which can be enhance in future research.

South Korea was ranked as top number one from 2017-2018 on patent activity while both China (6^{th}) and Singapore (12^{th}) surpassed Malaysia low performance at 34^{th}. As Bloomberg Innovation Index 2018 and WIPO (including Global Innovation Index) clearly put it: the inefficiencies in the catch up process of Malaysia can be attributed to the poor performance on domestic capabilities i.e. an overall drop in innovation ranking, resident patenting activity (filings and granted), high-tech density (high-tech Malaysian companies) and less tertiary efficiency due to drop in science and engineering graduates has proven that the existing higher education policy were ineffective in growing just any types of graduates in the country. For example, both South Korea and Singapore produces 450 and 250 patents per million people respectively in 2008 compared to Malaysia only produces 12 patents per million people in the same period (WIPO, 2005, p.10). Clearly something was amiss tactically in the ASEAN region with such a wide gap despite Singapore is by far a smaller size country and Malaysia had more space for the development of scientific infrastructures or even number of universities, firms and tertiary resources. We opined such scientific policy needs to be very niche and tactical on the specific sectors or targeted group to be groom for future socioeconomic benefit. This suggests that less resident patenting activity reflected from the visualizations in Section 4 and empirical results and drop in innovation ranking from this section have proven less futile benefit to the Malaysian economy in the long run.

Table 5.8: Long-run Coefficients for ARDL (1,2,1,3) Model

Regressor	Coefficient	Std Error	t-Statistic	Prob
DGDP(-1)	-0.670**	0.240	-2.783	0.027
DPAT	-0.009	0.016	-0.585	0.577
DPAT(-1)	0.049**	0.018	2.671	0.032
DPAT(-2)	0.077**	0.024	3.102	0.017
DID	-0.043***	0.011	-3.643	0.008
DID(-1)	-0.047**	0.015	-3.144	0.016
DGFCF	0.314	0.217	1.446	0.191
DGFCF(-1)	-0.102	0.171	-0.596	0.570
DGFCF(-2)	-0.444***	0.109	-4.053	0.005
DGFCF(-3)	-0.477***	0.134	-3.561	0.009
Constant (c)	0.074***	0.011	6.359	0.000

Notes: 1. Dependent variable is GDP income (DGDP), 2. ***,**,* are significance at 1%,5%,10% level respectively.

Source: Author's estimates (2018)

The ARDL Error Correction short-run coefficients for Equation (9) is reported in Table 5.9, with the speed of adjustment CointEq(-1) (lagged one period error correction term; ECT(-1)). The CointEq(-1) result showed it will converge towards long-run equilibrium level since it is negative and highly significant (p-value 0.0000) but is smaller than -1. According to this estimation, since the magnitude of ECT(-1) is between -1 to -2 is within an acceptable range when we analyze macroeconomics data on annual basis (Narayan & Smyth, 2006; Shittu et al., 2012). The average speed of adjustment of -1.67 noted in Table 5.9 will mean that the lost year's opportunity can be corrected by 167% by the following years during the catch-up process. This implies that instead of monotonically converging to the equilibrium path directly, the selection of strategic S&T or emerging fields did not go through strict demarcation, the error correction process fluctuates around the long-run value in a dampening manner before convergence. When this process is completed, the converging to the equilibrium path is expected to be relatively rapid for the Malaysian case. Few important short run trends from the table below were patent does not have a significant effect in the short run but a significant effect given a longer period i.e. lagged one period, whereas both industrial design and fixed capital formation have significant impact in the short run for Malaysia, especially for fixed capital formation.

Table 5.9: Short-run Coefficients for ARDL (1,2,1,3) Model

Regressor	Coefficient	Std Error	t-Statistic	Prob
ΔDPAT	-0.009	0.010	-0.951	0.373
ΔDPAT(-1)	-0.077***	0.017	-4.310	0.004
ΔDID	-0.043***	0.007	-5.623	0.001
ΔDGFCF	0.314**	0.130	2.404	0.047
ΔDGFCF(-1)	0.922***	0.110	8.319	0.000
ΔDGFCF(-2)	0.477***	0.098	4.841	0.002
ECT(-1)	-1.670***	0.186	-8.956	0.000
Constant (c)	0.044***	0.004	9.610	0.000
	R2=0.974	Adj-R2=0.959		DW stat=2.01

	AIC=-6.387	Log-likelihood=64.483

Note: ***,**,* are significance at 1%,5%,10% level respectively.

Source: Author’s estimates (2018)

This section makes several important findings. This presented results suggest that innovation whether incremental or radical continue to be stimulant of economic growth as Schumpeter stressed in most of his studies. As we highlighted in Section 2 that typically latecomers have the ability to achieve higher catch-up rate than advanced or developed countries only when the magnitude in patenting surpass the intangibles in generating rapid economic growth. The Malaysian experience indicated the country had fail to speed up their catching up process as a latecomer over the last two decades after industrialization in 1988 when high-tech, heavy industries and ICT boom kick off in the country with changes and uncertainties during the transition period to improve their domestic science system. Taking 2016 as example, holding country size irrelevant, one critical gap we found from the World Bank data is the Malaysian exports of high-tech products was higher (42% of exports) than China (25% of exports), however patents per million inhabitants in Malaysia (232) was 1.5 times below ASEAN average (346), 4 times lower than China (970) and 8 times lower than Singapore (1958).

This implies that the speed of return to equilibrium after a deviation is rapid but face a lot of fluctuations in the case of Malaysia technological catch up progress have been far larger during the transition time especially when checks and balances are in place on R&D spending policy between public and private, the investment of large multinational companies reside in Malaysia to become a high-income and scientific-found country has enable the country to be pro patent regime regardless by resident or non-resident. This result is interesting and could reinforce the signal that for some developing country like

Malaysia S&T policy tends to favor immediate emphasis into industrial design building capability as the first crucial step in R&D to measure the R&D performance. While not all the industrial design (ID) leads to patentable item to be commercialized by the university or company, the ID sets as an important pre-trial stage for scientific and technical workforce to inquire a single or multiple embodiments into one concept before the patent application process to steer higher productivity in their capital and as the initial progression in promoting domestic innovation. For example, the US researchers from MIT and Harvard have been very successful in building soft robotics at lighter weight and lower cost with the invention of artificial muscles for the robots; a similar property to natural muscle. These AI robots were inspired by the creative design of origami folding technique provided higher level of flexibility, so it has less risk of rupture had become disruptive to replace the older generation of jerky robots and possibly fitting these muscles into human body [56].

Moreover, patent system becomes investor friendly, and being the top three strongest industrialized countries within ASEAN-core countries, poses a strong tendency to adjust their past disequilibrium by catching up the number of patents with their counterparts by seeking newer inward orientation scientific advancement before normalize between 0 to -1. Thus, capitalizing on this knowledge diffusion from foreign latest technological change poses an opportunity for the Malaysian government to undertake different reforms every 5 to 10 years in the national plan is theoretically plausible to spark incremental innovations. Hence such small improvements have rapidly grow in industrial design and high spending on basic research to cause economic growth has opened up the opportunity to use it on creative sectors in the domestic capability building including skills development and ideation will help improve patenting performance in the country in the

[56] A single muscle can be constructed within ten minutes with materials cost less than US$1. Read more at https://www.sciencedaily.com/releases/2017/11/171127152103.htm

future. Furthermore, the long-term influence is larger for patent compared to short-term indicating patent can influence an increasing economic growth while if focus on aesthetical or intangible asset will constrained economic growth instead.

For the developing country such as Malaysia and many others such as South Korea and Taiwan, design is the starting process to spark ideation and creative thinking, while openness to FDI-leveraging developing country can potentially leads to high growth rate in technological diffusion and adoption. However, as we conform to our findings in Section 4 earlier, the heavy reliant on foreign technologies and without creative imitation to produce new goods and services were not able to surpass and give edge to Malaysia to compete with the frontiers at this speed and unable to create any possible breakthrough that will transform lives of mankind to an entirely new level; similar to the case of India. At present the Malaysian government strategy fails to incentivize innovation ecosystem between universities and local businesses. The domestic economy industrial design (15 times) and patents (6 times) are relatively lower and relies more on the non-resident patents which deter our growth and continuously cause financial burden on the high charges (millions of US dollars per annum) for the use of foreign patents as compared to aggressive indigenous innovative campaign and megaprojects launched by the American, European, German, French, Japanese, Korean governments which encourage the development of resident patents growth instead to boost industrial policies and technology catch-up strategy. But we have witness through this empirical study that relying on domestic industrial design will never be able to raise the bar of domestic innovation.

Our results are in line with the obstacles mentioned here, we can conclude that we can reject our null hypothesis that R&D has a strong effect to support the country growth as a developing country and failing to upgrade the research universities and domestic firms’ capability in producing more resident patents, and poor science literacy since young age with ailing polytechnics or technical schools and unproductive universities in particular research universities will never be able to catch-up with the frontiers if we continue to allocate the R&D expenditure on the aesthetics area and not back to growing basic science on the patent-intensive industry. In this respect, we can investigate deeper into Malaysia phenomena, but nevertheless from the above analysis we can see clearly strongly for the needs to develop resident patents for developing country like Malaysia to increase income growth, and a strong reason for emerging scientific powerhouse like China (a strong contender in the developing country) had joined the rat race to rapidly over perform in their resident patent application and patent granted filed in-country as well as abroad within a short period of time (there are many WIPO reports in this regard although patent quality could differ so we would not want to re-mentioned but WIPO see the good start in China progressive patenting approval trend similar to the trajectory of Japan and South Korea back in 1980s as catch up strategy), reformed their basic science policies, globalized their platform on open knowledge, develop their indigenous innovation and upgrade their domestic firms capabilities to cope with latest technological change.

The elasticities suggest to invest in resident patent in the long run that will benefit positively to the Malaysian economic growth. Creativity and patenting matters when it comes to variation in productive basic research innovation as we have seen in the case of Germany, Japan, South Korea and Taiwan which had done well in this aspect to grow their industrial designs and also indigenous innovation. As for policy implications, we suggest the Malaysian government should be investing more in resident patenting including retaining local RSEs, and paying more attention to develop the domestic firms' capabilities and both public and private domestic research universities to assist in creating more resident patent with the funding allocation. Given this proposition, it means that the Malaysian government and their potential innovation agents i.e. domestic universities and firms (especially those with higher endowment) should keep pace on with the increase of approved utility patents in order to catch up and leapfrog over the frontiers in the long run should the government decided to invest more in R&D. This shall highly support our theoretical conclusion in Section 7.

5.5 Summary

The results show that the relationship between the filing of resident patents and industrial designs, and GDP growth is significant both in the pooled sample and in Malaysia. Whereas Germany, Japan, South Korea and Taiwan have appropriated significant growth synergies from resident patents granted, Malaysia has lacked such a rapid growth effect owing to a lack of resident patenting. It is also a consequence of Malaysia failure to grow basic science with the selected eight IPCs in the patent- and industrial-design intensive industries in which Malaysia has potential competitive advantage which supported by Figure 5.1 why industrial design has been a weak linkage to enable Malaysia commercialize their R&D output.

Unlike other past studies that solely measure GERD-to-GDP effects without differentiating the "hardware" issue from innovation output that take the form of knowledge output, such as patents and industrial designs, this chapter showed the critical importance of such output in eventually supporting commercialization and economic growth. This evidence shows that the government's efforts to transform Malaysia into an innovative knowledge-based economy have yet to materialize. It also shows that a significant volume of incentives and grants allocated to firms and universities have not succeeded in yielding the requisite patents and industrial designs to support rapid economic growth in the country. While the Malaysian universities have successfully raised the volume of scientific publications from Malaysia, it is simply not enough to give the country the fillip to become a high income economy. This shortcoming can be observed in the slow rate of growth in resident industrial designs and patents compared to those filed by foreign individuals and firms.

The rapid expansion in scientific publications demonstrates that localized knowledge spillover exists in Malaysia but they have largely leaked out, or not realized owing to a disconnect between the knowledge producers and users (firms), or that they have been allocated in areas that offer little spillover. Although countries demonstrate different strategies in the trajectory of development, (which is defined by developmental stages), the lack of synergy between patent take up and economic growth in Malaysia demonstrates a lack of policy connect between incentives and grants allocated to stimulate R&D and economic growth. The evidence confirms that patents and industrial designs are among the most feasible means to measure the impact of R&D since they offer significant effect on economic growth in the long run, while industrial design and fixed capital formation have significant impact in the short run to pilot the Malaysia innovation system.

The findings show that Malaysia must focus on resident patent filing and industrial design building capability as the first crucial steps to appropriate economic synergies from R&D. While not all the industrial designs and patents end up being commercialized, they extend a particular path for scientific and technical progress that will be necessary to direct innovations through new paths. The investment in resident patents and industrial designs in the long run will also strengthen basic science and benefit positively Malaysian economic growth.

CHAPTER 6

SCIENTIFIC PUBLICATIONS AND PATENTS

6.1 Introduction

While the evidence produced in chapter five showed a weak relationship between R&D expenditure and patenting, and the latter and GDP, in this chapter we examine the relationship between scientific publications and patents. We also wish to examine how far does the increasing trend of scientific publication have actually impact on the patent performance in Malaysia. Typically, governments look to scientists and researchers to play the dual function of generating knowledge that can be published as well as that can yield patents and other intellectual properties. The latter with the hope that they show a high intensity of commercialization to support economic growth. While some individuals at firms and organizations do publish the bulk of scientific publications come from universities, especially those equipped with strong R&D facilities.

Different forms of legislations have promoted patenting and several successful countries (Rasiah, 2019). The Bayh Dole Act of 1980 allowed universities to take the commercialization route so that the universities began to patent their research findings for generating income from users. Similarly, a wide range of arrangements that include matching grants introduced in the Netherlands and Taiwan included patenting as a critical performance measure in the provision of R&D funding. A similar arrangement that brought industry, universities and governments together under the rubric of the triple helix in Sweden became a model for many countries. The Swedish model has since evolved into a quadruple helix following the inclusion of civil society as a stakeholder (Charminade, 2010; Rasiah, 2019). Government grants in Japan, South Korea and Taiwan actively encourage university researchers to take sabbaticals at firms. Such rewards performance system has set productive universities to patent first as well as to publish in high quality peer-reviewed journals or book.

Given that the filing of resident patents shows a strong relationship with GDP growth (see chapter five), it will be pertinent to examine if efforts to direct knowledge synergies from R&D towards scientific publications does not overlook its critical importance to produce patents. Hence, in this chapter we examine the relationship between scientific publications and patents to see if such a dual role is strong among a pool of economies where data is available, and in Malaysia.

6.2 Critical Issues

In this section, we wish to examine if the dependency on scientific publication will suppress the targeted patenting activity. There are two types of patents i.e. industrial patent and academic patent. Academic patent allows the universities to own and license the IP of the patent, so that it is not owned by an individual, professor, or scientist using public and private endowment. Strong IP laws reform are needed for protection of these IPs to spur innovation as seen implemented in few countries such as US (Bayh-Dole Act), Austria, Denmark, Germany, Japan, Sweden, Canada, China, and other OECD countries. Though there are past literatures indicated that strong IP laws can have negative impact on patenting activity, however a mixed of literatures also found stronger IP protection can steered positive direction for universities to protect its invention from infringement or any informal public disclosure and make full use of its laboratories collaborating research with industry and government (WIPO, 2016).

In fact, the willingness to share secrecy creates positive growth between integration, cooperation, competition and new innovation especially in life sciences, IT and defense.

Universities also have greater freedom to enter into private agreements or with venture capitalist on licensing deals or spinoffs companies. This directive sets the universities (in particular research universities) to strengthen global cooperation between universities and capture innovation beyond the country as internationalization on higher education takes place, however there are evidences that basic research quality has dropped (see Section 2.2) due to the irony of universities focus on the ranking (commonly known as the ivory towers), reputation and commercial rewards to create more patents (especially applied research) which is less vulnerable to failure rate. The spinoff companies require shorter time span from idea creation to patent filing and commercialization, and academicians might prefer to write more publications especially in top tiered journals, rather than focus on the university conventional public mission to create basic research to solve a domestic or international issues and advancement of knowledge which is costly, risky and high resource consumption. The scientific publication can be a quality measure of researchers, scientists and engineers though not necessary a true reflection of patent productivity.

Beside academic patenting, getting the right talent that has good skills on research and publication are equally challenging in developing countries mainly due to incentives and environment. With right talent, it can spur the development of new knowledge and idea dissemination. Scientific publication in high quality peered journal can stimulate positive knowledge spillovers in the specified field. These formal and informal publications will impact creditability of the S&T workers and country reputation to diffuse knowledge and technology transfer. The informal scientific publication can be sort of quick informal education to spark creativity among innovators. There can learning from the existing products in the market, their product designs and specifications, patent documents with inventive contents, verbal or non-formal written communications that increases the learning curve ability of the producers, social networking, hiring their former staff or engineer, own prototype, and do pilot programme or grant project together. This is seen in the financial services, e-commerce, healthcare industries and small enterprises in Malaysia.

Positive impact from the publication will encourage a larger pool of venture capitalist to invest in the start-up companies or raise foreign investment into the country. These scientific literatures can strengthen the country NIS and university performance by uniting teaching and research, drive forward innovation and breakthroughs in S&T research, and lower down the cost to access to local and international contents for public and private institutions such as universities, laboratories, research centers. But past evidences mostly glorified the R&D performance at developed countries i.e. at the American, German, Japanese, European and Scandinavian universities.

Our focus remains back at the challenges on developing countries in the pursuit of R&D output. Although tertiary educated workers increases in these countries, the war on attracting the most productive talents continue to intensify as regional economies are connected and face with shortages of S&T skilled workforce by 2018 to accommodate the rising global demand of academic journal industry approximately US$8.3 billion per year mainly generated through annual subscriptions (Barclay, 2016). These shortages can cut across various specialization on latest technologies such as life science, biotech, supercomputing, big data analytics, Internet of Things, and many more. However, open access publishing has speed up the publications in printed- or electronic-form of materials to disseminate the information from the developed countries to the developing countries especially during the initial stage and convert the S&T achievements into commercial successes between the universities and business communities for the past two decades (a common phenomenon coined as big data to big impact).

In reality, although free access to information is good for the economy and there is a trade-off on the substance of published articles, the competition in academic publishing would be more intense and commercial than ever, similar to higher education becoming more of a commodity and the world is easier to share information almost immediately through Internet. As the overall costs to publish printed academic books and journals are rising, some countries are leading a collective opportunity to produce open access publishing mostly public funded (i.e. European Commission) by OA2020 to increase the transparency of information and impact of their research. This has been supported well by European, Scandinavian and South Korean universities.

Some renown authors such as Kinney et. al. (2004) refuted the claim that patents inhibit publication as they believe that patents are also publications itself to fulfil the criteria set by the technology transfer office rather than editorial board of the journal or book. Likewise, Hal Varian the Chief Economist at Google as cited in Chen et al (2012), highlighted that publication is getting easier as data is getting cheaper and ubiquitous so the complementary part is smart analysis into this data to invent and upgrade new products and processes such as e-commerce, e-banking, e-government, security intelligence, high throughput sensors and instruments, smart living, and others. Binswanger (2014) criticized how impact factors and publication pressure had reduced the quality of scientific publications and is merely qualitative productivity due to mass production of higher education graduates, programs and dissertations, rather than focus on the fundamental of education and research.

In our final analysis, we looked at the extent to which proxies such as patents and scientific publications remain important proxies to measure quality of scientific manpower, technological intelligence, knowledge accumulation happening at the developing country. Moreover, we wish to determine whether there are any differences between impact from patent and from scientific publication. Such publication is a form of scientific knowledge diffusion and also an indicator of a particular area of science concentration, and we shall continue to analyze if the scientific workforce has been contributing the Malaysian economic growth. Our past finding from Section 4 iterated that tertiary educated workforce if not put into S&T-related productive sectors had negatively contributed to the country scientific and economic development. While patent citation is relatively low compared to any existing frontiers US, Japan, South Korea, Taiwan and Singapore as Malaysia had low pool of patents, low domestic innovation that would be least to be cited by any other economies. The fallacy that a small country cannot be play successful catch-up is proven wrong as well as in the case of Israel, Scandinavian, Singapore, Taiwan, South Korea, and many more. We need to know exactly which activity must explode rapidly during the development years.

The search report is based on the patent claims but also takes into account the description and any drawings. We found in past literatures that the application is generally published 18 months after date of filing (publication date). Using this lagged time, we apply the similar time lag adopted from Section 5 or a shorter lags (depending what is the optimal lag) for our final analysis on patent and publication complementing behaviour on the catch up process in developing country.

In the past decades, there are various sources of long term economic growth. For a developing country in their transformation progress towards a knowledge-based economy must focus on the role of innovation in creating that growth. The astounding work of Solow, Nelson, Arrow, Griliches, Schumpeter and Romer (1957-1989) have recognized the role of different types of R&D and knowledge accumulation in specialized human capital can shape the economic activity and generate sufficient growth of which large populous country or investment in higher education are no longer a guarantee to be a competitive nation. Hence, the importance of patent and patent publications that contained considerable amount of technical information which can be useful in quantitative analysis to identify technological trends.

In the case of Malaysia, the developing country has initiated various national development plans and mega S&T Development Plans from 1996 to 2005 (see Figure 6.1). Beside R&D grants, these initiatives were mainly undertaken to restructure existing R&D institutions to be more sustainable and to upgrade the domestic resources capabilities including increasing the supply of S&T manpower is part of the national strategic thrust. It entailed upgrading the S&T curricula in secondary- to tertiary education learning, accelerating the industrial development, laying the foundation for S&T community and graduates to produce more patents and publications to disseminate knowledge, improving the public and private sector R&D, strengthen IP rights, and had structural reforms to expand research facilities and improve quality of S&T manpower. There were also additional scholarships given to public sector researchers in priority areas such as advanced materials and manufacturing, ICT, microelectronics, energy and environment, employing foreign experts in medical, engineering, laser technology and semiconductor. However like we highlighted earlier, the challenges remain the inventor team size was problematic when the targeted R&D sectors are on pure science to applied science such as engineering and computer technology but the ratio of RSE per 10,000 labor force is still lower than OECD average. With weak RSE workforce, it will lower down the scientific discoveries through publications and patents as well.

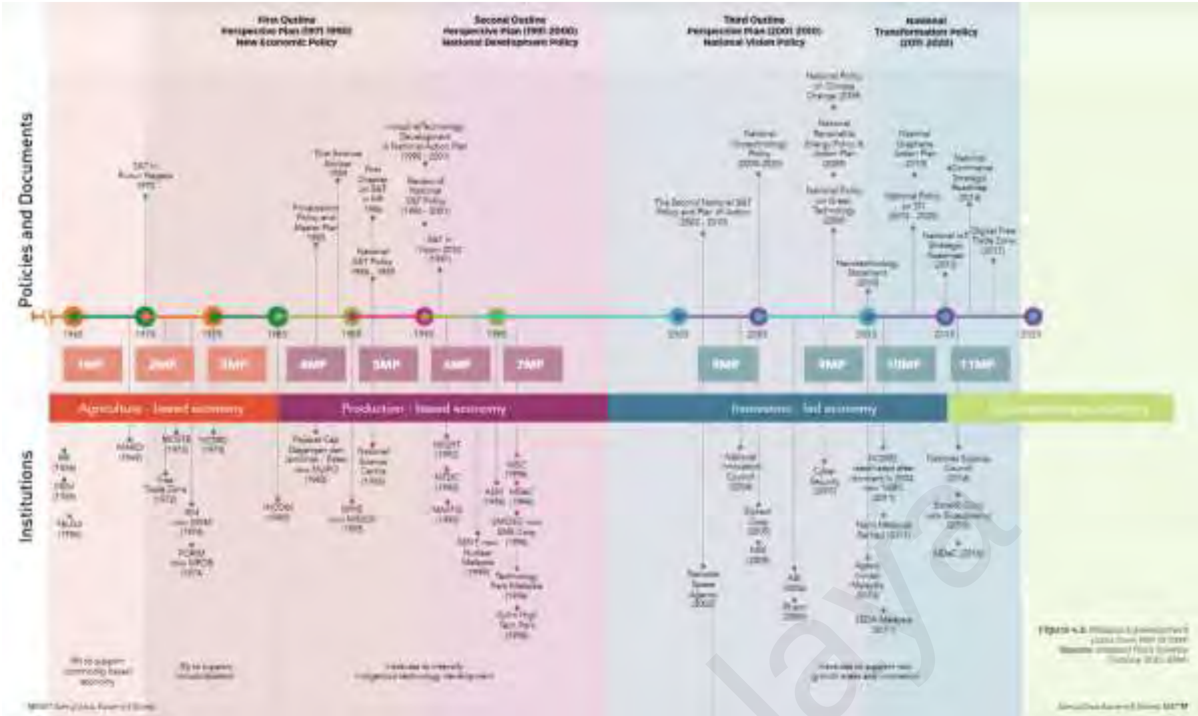


Figure 6.1: Malaysia Development Plans from 1MP to 11MP

Source: Adapted from Malaysia Academy of Sciences (2015)

We noticed the some developing countries have risen in scientific publication including co-authorship with international authors, number of researchers but unable to confirm whether such trends was due to open science or open education as both the agendas are generally the endeavor to improve their country economy to collaborate with the advanced countries. According to UNESCO Science Report (2015), as technological frontiers continue to dominate the publication world of which EU 34% and US 25% represent almost 60% overall publication but there are trends in slowing down, while China is fast catching up with the rapid growth close to 20% in 2015 of world total publications compared to only 5% in 2005. For Malaysia, the patents granted are so small and insignificant (0.1 of world's total patents compared to South Korea has 5%) and since tertiary educated is negatively contributing to the economy, we wish to examine if these publications could have positive impact in the Malaysian case. Even though Malaysian universities are more oriented towards disseminating new knowledge through publications rather than patent, the universities understood they are lacking capability in high R&D output commercialization activities. This is also visible to other competitors when the Malaysian universities are trying to catch-up on the innovations within the Top 75 Asian Universities league mainly outperform by University Malaya and University Putra Malaysia (Ewalt, 2016) which could be a demanding task to advance the nation and compete even within the Asia region. The high dependency on just a few public universities to advance new knowledge can be a key constraint to motivate NIS environment to excel and not all the universities can take advantage of the knowledge spillovers equally. Although the scientific publications numbers still remain low, it achieved far better growth than patents and uses this strategy to disseminate foreign technological advancement in the country which is evident that research collaboration is on the rise when R&D funding continue to rise in absolute value since 1996 to fund the high-tech exports and other innovative sectors like healthcare, education, teaching hospitals, cluster development, etc. Therefore, Malaysian universities are much better in publishing than patenting to accomplish the national R&D objectives.

While Malaysian universities do stand out in certain specialized experience, the international co-author articles are rising, but weak TTO environment pose challenges to grow unlike such trend is less seen in the Asian economies such as Japan, South Korea, China and American regions where this region focus on growing up their TTO maturity to compete in global patenting and high quality publication market. Because the Malaysian NIS specialized experience and skills are still important to enable greater R&D capacity of the universities, international co-authored articles has also increased from 42% to 52% indicated for every one out of two scientific articles are bound to be co-authored as a perception of improved quality of paper, as mentor or colleague of various specialization combined for new discovery, gain popularity, pressure to publish as work performance KPI, seek external funding, cross-sharing mutual expertise to train local researchers, and rationalize scientific manpower. The latter three are critically important to strengthen the basic research development in Malaysia. As a result of Malaysia internationalization, this leads to higher scientific publication output when we see the increasing trends of foreign students' intake, post graduate researchers, scholars mobility network seems to increase link to over 100 countries as a result of improved political ties encouraged these scholars to learn more from the advanced countries and researchers per million inhabitants from 370 in 2006 to 2300 in 2015 (over 500% increase; but stagnating growth at about less than 2% per year since 2010). Nevertheless, we observed a decline in GERD assigned per researchers since 2007 onwards dropped from $274,000 to $123,000 (fall by 55%) for the same period while overall GERD per capita increasing remain puzzled. This shows R&D funds are not channel to the specialist groups i.e. researchers, scientists and engineers (RSE) can reduce the engagement in commercialization activities certainly disadvantage the Malaysian NIS to strengthen its basic research nor even motivate any new discovery per se. Consequently, this cost-cutting measure would surely cause imbalances in domestic innovation or domestic science development in tandem reduces the R&D output performance since the budget allocated to each researchers on average were not only cut by more than half, but more problematic was if the R&D funds were repeatedly over the years not credited to the RSE, where did the funds went and to which profession or possibly non-productive research instead clearly proven slow down research progress on such inefficient allocation of funds for productive use.

Since the R&D output performance is low, UNESCO sees Malaysia as marketing innovator rather than process innovator continue to exhibit the weakness lies on Malaysia NIS while China excel as a product innovator in reputation. Both Malaysia, Singapore and Philippines are strong economies invested heavily to catch-up with the frontiers but clearly the tradeoffs between patents and publications on Malaysia and Philippines are way lacking behind when compared to China and Singapore scientific development are detrimental to the basic research activities for these latecomers developing countries which are unable to catch-up and leapfrog. The product innovators (China, Singapore) stress the implementation of process innovation and see it until completion compared to others (Malaysia, Philippines) have high tendency rate to abandon the ongoing innovation activity due to various reasons can dilute the patenting effect.

The rewarding experiences of Japan, South Korea, Taiwan and China proved a lesson to the Malaysian government to re-focus back to process innovation is the only way to help the country becoming a successful innovator and at the same continuum advancing their S&T curriculum to produce more research output. In addition, although Malaysia has strong MNCs companies which is expected to speed up patenting and publication as knowledge diffusion activity, the country produces less than 3% of world's scientific publication when compared to China 20% within the context of developing country. Worst still, since the country is export-oriented, we also observed from World Bank data's on the high-tech exports as a percent of manufactured exports had not improved much and fall drastically since 2000 from 59% to 42% in 2016 never grew since.

Unsurprisingly, with the above analyses so far we would expect that scientific publications would not have significant contribution to the Malaysia economic growth even after the recent change of new coalition government. Tertiary education continue to be politicized when the country is in substantial needs to enhance the reputation and skills of these vocational or polytechnic graduates confer a special importance and linking them as fast to the local innovation network would accelerate the prototype process and building the domestic skilled manpower to forge ahead. Despite a known fact, it was not done over time so Malaysia has fallen back on the catch-up process in modern science unlike the success of Singapore, Taiwan and Germans where their RSEs are among the main- or co-inventors that contributed to new products and solving common problems for their countries. But we still want to be optimistic and seek an interesting way to test whether our prediction is correct or otherwise to economic impact based on the current scientific progress using the said regression analysis in Section 6.2.

A critical and interesting finding in Section 4 was the implications of PAT, ID and EMPHC. However, academic publishing tends to fend off when unauthorized copyrights are increasing whereby two-thirds (67.4%) of the retractions in these publications reported by Proceedings of the National Academy of Sciences are attributed to scientific misconduct such as composed fraud, duplicated publication and plagiarism (Couzin-Frankel, 2012) and it would not stop to encourage the authors and inventors to produce the numbers rather than quality material. Since many of these are paid research and with entrepreneurship booming among the younger generation Y and millennials, universities are encouraged and committed to get whatever revenue streams of ideas that are commercial potential from their professors and students (including researchers) including building more labs, getting technology transfer office to promote start-up companies, royalty-sharing between inventor and university, and write more peer-reviewed publications.

6.3 Methodology and Data

From earlier Section 5, we have demonstrated that strong resident patent remain the key driver to successful catch up process with the technology leaders. Patents are deem as the most rational intellectual asset, however patent alone is difficult to measure the knowledge spillover so any form scientific publication or patent document would ease the RSE or businesses to retrieve published patents, extract critical information useful for new discovery of knowledge to be diffuse to public or private domain whether directly or indirectly.

The selected countries we examined in Section 4 were also experiencing talents movement or migration but strong resident patenting gave them an edge of sword to leapfrog the frontiers. The classic examples of South Korea and Taiwan showed that there are high indigenous innovation activity in capital accumulation to build a specialize niche to a specific sector. Resident patenting promotes domestic expertise which is hard to be imitated unless strong participation from their own domestic firms would strengthen both supply- and demand side S&T related sectors. The imitation process would only allow them to catch up with the frontiers but to leapfrog the latecomer typically needs very strong and rapid resident patenting from our observation. Thus importing foreign firms and technologies again is a short-term measure but obviously uncompetitive and unsustainable in the long-term.

In this section, we will propose new proxies such as scientific publications and scientific workforce to allow us more detail inferences where the gaps were in the patenting activity. There are many empirical evidence that both the scientific publication and scientific manpower must be monitored to promote academic excellence and S&T advancement as part of the R&D process. These bibliometric indicator is to understand the size of spread of knowledge and appreciation in open science especially in the high-tech sector. Scientific patents and RSE are rich sources of technical information which is valuable in teaching or inventive step while scientific publication is like a pre-grant disclosure to claim the invention. Meo (2013) observed the positive research outcome are likely due to Asian countries have spent more on R&D in recent years with an increase on number of universities were somehow affiliated to produce more research documents and ISI index journal or publications, higher citation per document, and higher H-index.

Nevertheless, higher number of publications do not necessary transpire into good quality research but is more widely accepted compared to citation data. Although some studies on S&T performance uses citation rate on the journals can be useful to narrow down a particular emerging hot topics in science-related, but still many debates were concern on the quality aspect of such citation data due to the possibility of self-citation or required to be carefully interpreted by experts instead as raised by Garfield and Welljams-Dorof (1992). Among a noticeable evidence was by Hasan & Luthra (2014), Current Science 106(12) in the case of China that outperform way better than their peers in the R&D catch up strategy were due to exponential growth publishing in science and engineering research papers, rising universities influences or ranking, and producing higher number of PhD doctorates in science and engineering which could contribute to the researcher or scientific manpower development.

A priori, one might argue that significant increase in GERD has a positive impact on scientific output, research papers and country's growth. However, the key argument we want to know is whether the impact on Malaysia has been positive or inverse along with the knowledge accumulation and scientific manpower (number of researchers, scientists and engineers; RSE) and whether increasing patenting activities will be in favor to generate a higher publication growth rate. We formulated the following hypothesis *H2. Scientific publication has supported Malaysia economic growth* to examine the scenarios we mentioned above. Hence, we shall use the ARDL estimation method and repeat the same procedure were performed added with new variables (described in Section 3 on the selection method and compliance to the ARDL procedures and the right platform for detecting long-run cointegrating relationship and infer the speed of convergence to equilibrium using CECM-ARDL; see Figure 5.2).

Then, we compare our findings with economic theories and past literatures. Similarly to patent, because research process takes time so the lagged effect on scientific publication is estimated between 1 to 2 or lower from the first observed publication date. Hence, in order to give a rough proxy of the effect on capital and labor resources we chose to use RSE per million people to represent part of the brain of high-tech infrastructure rather than any tertiary educated workforce along with the relevant significant knowledge stock predictors from Section 5 to answer the above hypothesis in this section to give a deeper insight.

Again, we obtained and created 22 data points i.e. annual scientific articles statistics, patents, industrial designs, GERD, RSE data sets collected from the Malaysian Intellectual Property Office (MyIPO), Academy of Sciences Malaysia, WIPO, World Bank, UNESCO, ILO, WIPO and USPTO over the period of 1996 to 2017 (22 years) in our analysis based on available information up to-date except that availability of data on industrial design only start from 1999 onwards. The selected variables were used based on the economic theories and past literatures as mentioned in Section 2.

Our sample period is sufficient to be indicative on the progress of Malaysia in scientific publication and patent document of which the two have distinct differences as to whether merely revealing new information or scientific theory or be an inventive solution use for an existing problem, of which the latter has to be higher in order to catch up with the frontiers and which benefit the society the most. In order to investigate these relationships, we proposed basic model to be estimated is as follows. The PUB is regressed over time on the variables of interest which are central to our analysis: PUB = f {past PUB, PAT, ID, GERD, RSE} as explained in Section 3.4.

To facilitate the analysis, we estimate the following long run (Eq.10) and short run (Eq.11) ARDL model with five variables:

$$lnDPUB_t = \alpha + \sum_{k=1}^{k_1} \beta_{1k}\, lnDPUB_{t-k} + \sum_{k=1}^{k_2} \beta_{2k}\, lnDPAT_{t-k} + \sum_{k=1}^{k_3} \beta_{3k}\, lnDID_{t-k} + \sum_{k=1}^{k_4} \beta_{4k}\, lnDGERD_{t-k} + \sum_{k=1}^{k_5} \beta_{5k}\, lnDRSE_{t-k} + \varepsilon_t$$

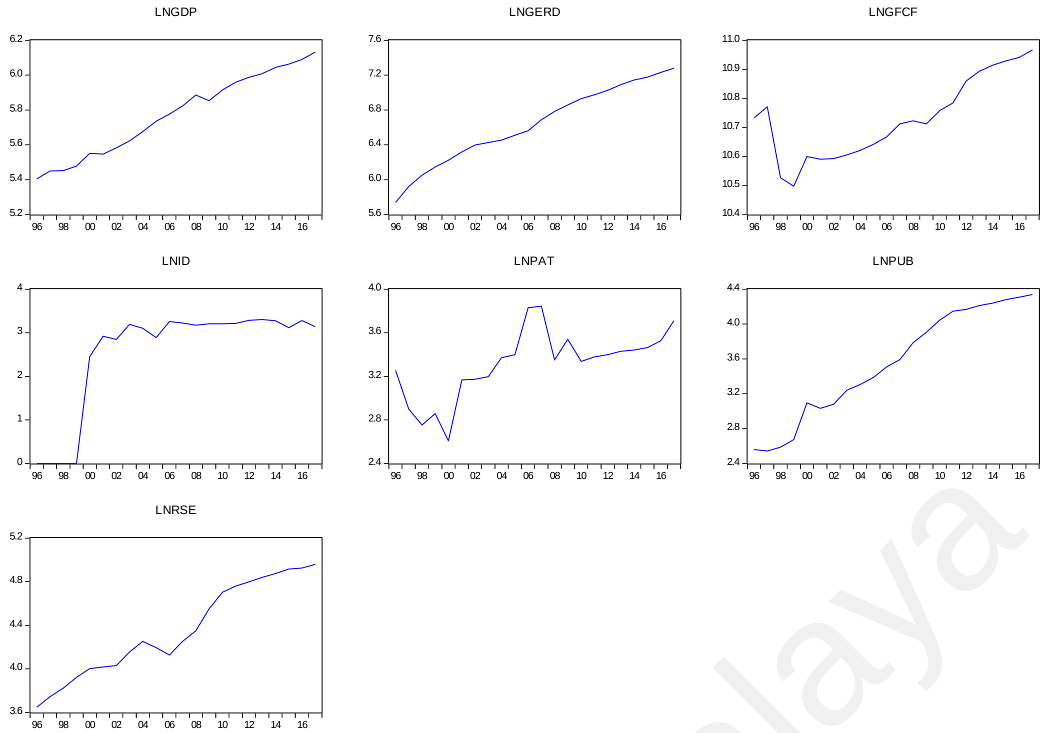
Eq. (10)

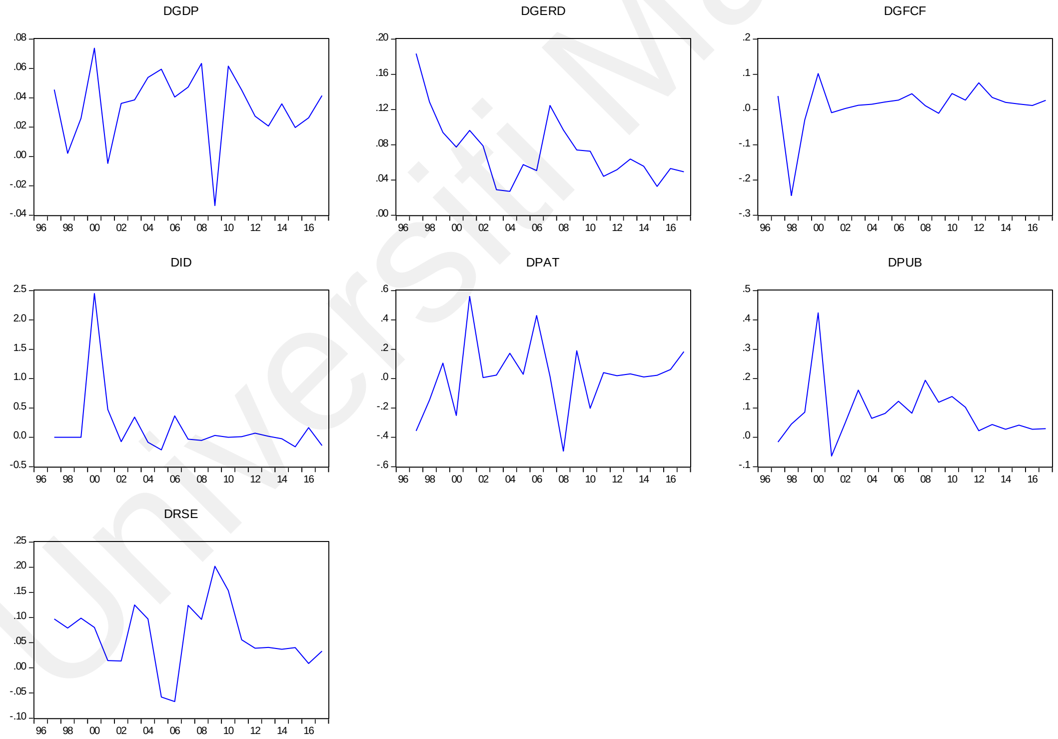
$$\Delta lnDPUB_t = \alpha + \sum_{k=1}^{k_1} \beta_{1k}\, \Delta lnDPUB_{t-k} + \sum_{k=1}^{k_2} \beta_{2k}\, \Delta lnDPAT_{t-k} + \sum_{k=1}^{k_3} \beta_{3k}\, \Delta lnDID_{t-k} + \sum_{k=1}^{k_4} \beta_{4k}\, \Delta lnDGERD_{t-k} + \sum_{k=1}^{k_5} \beta_{5k}\, \Delta lnDRSE_{t-k} + \delta ECT_{t-1} + \varepsilon_t$$

Eq. (11)

where $\Delta lnDPUB_t$ represents the first difference of series on logarithm value of annual number of scientific publications in Malaysia, *t* is time or number of observations for time series model, *t-k* reflect that there is typically a time lag between the input of scientific resources and the research publication and β_0 (α) is a constant term. $|\beta_1 - \beta_5|$ are explanatory variables in first-order or higher order autoregressive parameter or elasticities obtained from the result of ARDL regression estimation and these long run parameters are expected to carry a positive sign. The variables on the right-hand side of the equation are $\beta_1 \Delta lnDPUB_{t-k}$ variable is k lagged years logarithm value of annual scientific publications in Malaysia upon first difference of the series on the right hand side of the equation, $\beta_2 \Delta lnDPAT_{t-k}$ variable is k lagged years logarithm value of total number of patents granted in Malaysia at time *t* upon first difference of the series, $\beta_3 \Delta lnDID_{t-k}$ variable is k lagged years logarithm value of total industrial designs in Malaysia, $\beta_4 \Delta lnDGERD_{t-k}$ variable is k lagged years logarithm of gross expenditure on research and development to GDP in Malaysia, $\beta_5 \Delta lnDRSE_{t-k}$ variable is k lagged years logarithm of number of R&D employees and researchers full-time equivalent as a measure of R&D volume, δECT is the speed of correction derived from lagged error correction term which is expected to be negative and statistically significant, and ε_t is the unexplained residual assumed to be independently distributed over time (white noise error term or any possible factors not captured in the explanatory variables of our model estimation) for Malaysia data over twenty-two years.

We also did some data visualization using SAP Analytics Cloud before proceeding to the econometric analysis. Besides that, we sort the collected data and take a logarithm (including differencing) on these statistics using Excel. Once the dataset is cleanse and prepare according to the format, we will begin to upload the dataset into Eviews 10 to establish the abovementioned Equation (10) five-variable regression model as shown below. We will conduct diagnostic test for goodness-of-fit on the proposed model estimation including checking for serial correlation, normality, and heteroscedasticity tests. We also perform stationarity using ADF or KPSS and stability test using CUSUM on the selected series. Under Test Type, we select either ADF or KPSS to proceed with the unit root test. Without differencing, we observed the data set exhibit a positive trends across all variables. To avoid spurious or biased result, we had normalized the data by taking differencing on the variables. Hence, the trends on had been removed upon differencing took place (see Figure 6.2).





Source: Author's estimates (2018)

Subsequently, upon all conditions are satisfied above, we shall proceed to generate the descriptive statistics and regression estimates by inserting the selected variables into Equation Specification checking on the significant of each variable in predicting the model or removing any insignificant or redundant variable if required. Next, we check on each possible estimation using the smallest AIC and highest log likelihood, of which we will also verify our selection using SIC to ensure consistency in the optimal lag best fit for ARDL model selection process. Finally, we establish the cointegration relationship and use MLE for robustness check to ensure stability of the model using a different technique. A more detailed discussion of the data set is discussed in the next session.

Source: Author's estimates (2018)

6.4 Results and Discussion

The findings are not surprising as the previous two chapters have highlighted the weakness in resident patenting (and also industrial design patent) in Malaysia as a developing country to catch up and leapfrog over the technology frontiers and in the manufacturing industries. The visualization of detailed patent and scientific publication data below (see Figure 6.3) poses new challenges to the country further. First, we observed two strong trends coming from Asian resident patents in force (in parentheses) over the last five years 2012 to 2016 coming from Japan with 8 million patents (84%), South Korea 3 million patents and China 4 million patents (61%) respectively which would further threaten US 6 million patents and Malaysia's small number of patents.

Second, from our visual analysis in this section, the resident patents in force results would indicate that overall developing country including Malaysia 9,996 patents (less than 0.5%; strongly rely on foreign patents in force) are still far away from catch up with the frontiers when these patents in force only approximate to 2% of the total world patents in force.

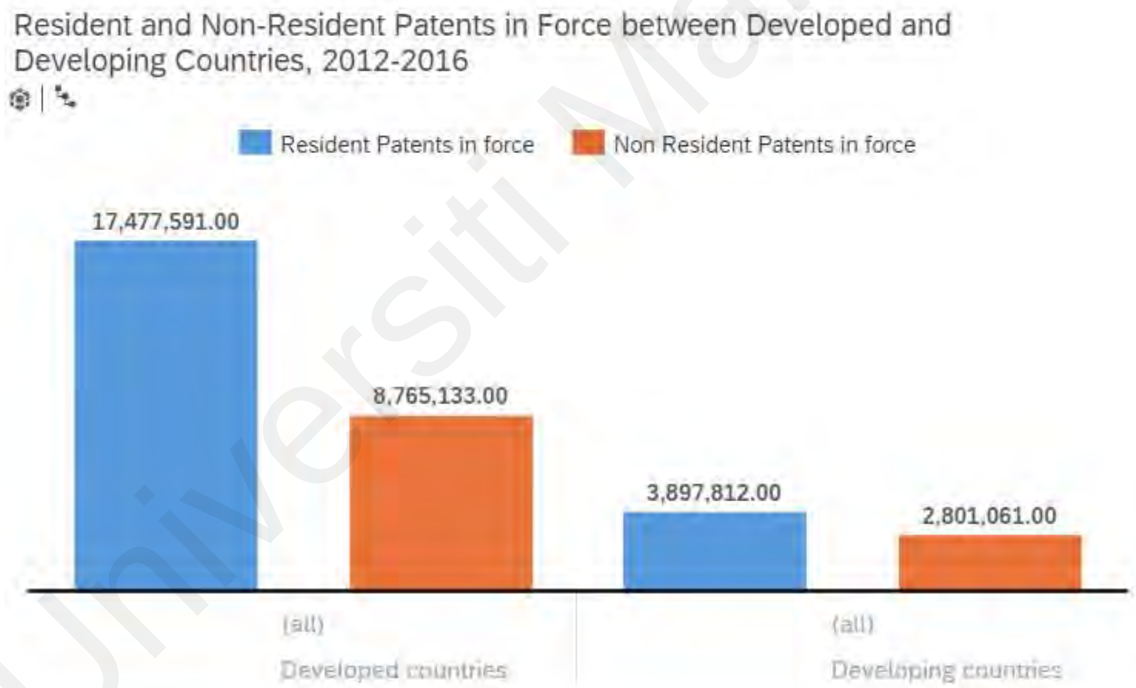


Figure 6.3. Patents in Force between Developed and Developing Countries

Source: Author's estimates (2018)

From Figure 6.4, we filtered further to look at these data related to technology and found that China catching up on resident patents in force had substantially brought positive growth to their resident patent publications in their successful transformation to catch up with the frontiers. In terms of technical information possess from these document, there are huge differences between patent publication (patent document) compared to peer-review scientific publication in general as shown in Figure 6.5. Patent document contained inventive content that is able to increase RSE's knowledge and to be more meaningful. But if we pause for a thought which has practical benefit to a patent practitioner, still the patent or patent document gives the patent owner some special rights and will become an asset in a non-confidential way upon successful patent granted. Recap in our Section 5, we have found that Malaysia was experiencing a very high rejection rate almost up to 83% at one point of time for the last two to three decades have directly raise the issue of poor quality on the invention technical claims itself. Again, we emphasized that strong resident patenting is a must and increase in patent documents will mean the domestic capability and knowledge accumulation have somewhat strengthen the domestic patent information diffuse over the years whether through a formal TTO agent or the inventor self, grasp this technical information, turn it into a creative act or creative imitation and subsequently step forward to produce new innovation on their own (if possible disruptive to the frontiers) and transform themselves into a niche technology exporter in the end.

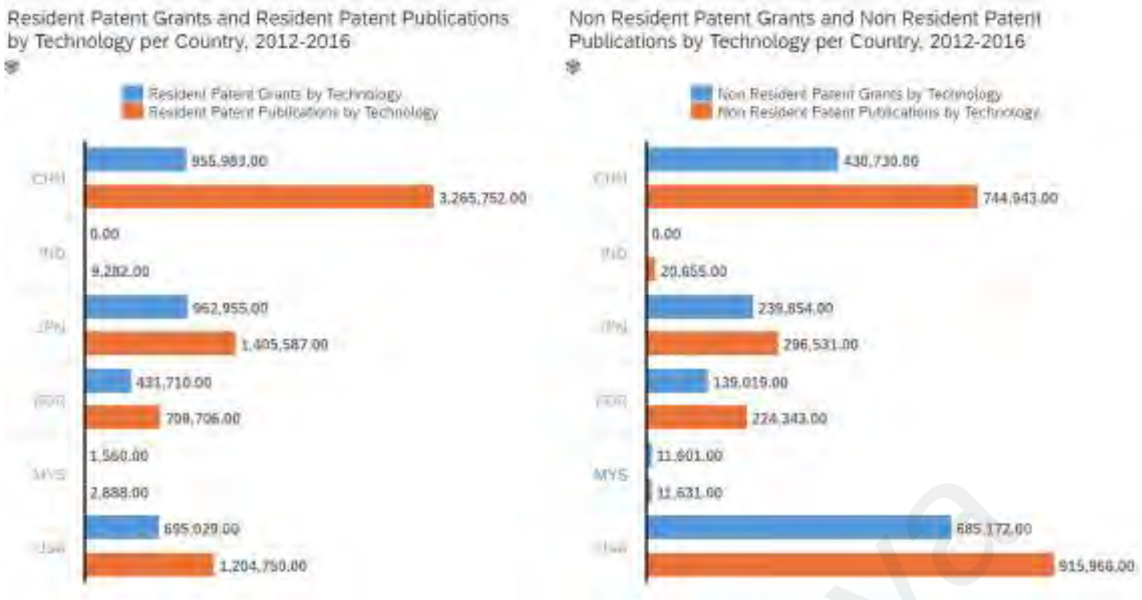


Figure 6.4. Comparison between Selected Countries on Patent Grants and Patent Publications by Technology

Source: Author’s estimates (2018)

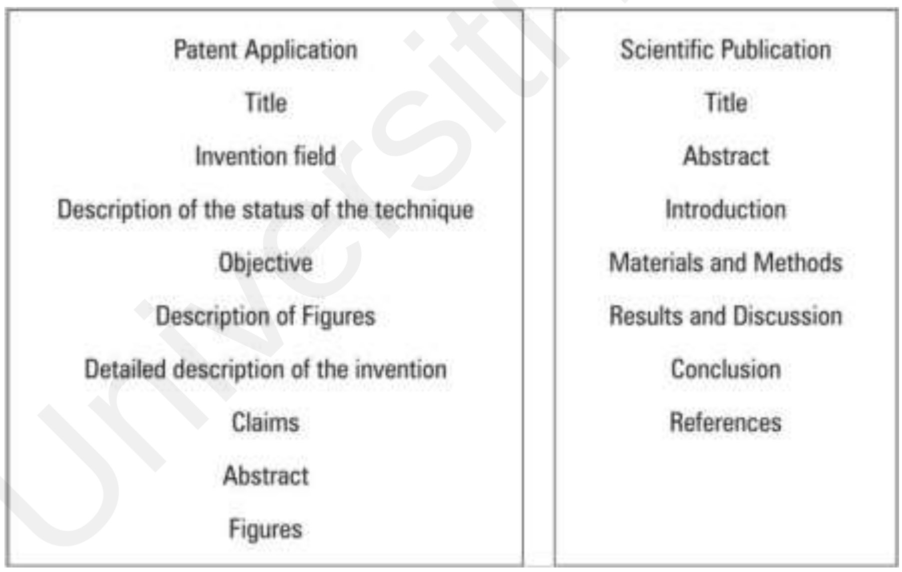


Figure 6.5. Differences between patent document and scientific publication

Source: Dias and de Almeida (2013)

With such trends, the future looks bleak for Malaysia to catch-up with the wide gap whether in patents or patent documents, and it is obvious why the US start to tighten their IP laws and in protectionism mode to slowdown the spillover effect. China technological catch-up are expected to be comparable to the US (or perhaps even better) approaching in 10 to 15 years most likely before 2050. The sense of rapidness is extensive can also be found when we evaluate our database by technology fields on patents granted and patent publications. Out of the 35 fields, we pick up two examples: Both China's and Japan's residents and non-residents technological capability were driven to strengthen each other on similar technology fields, i.e. electrical machinery, apparatus and energy, and in digital communication; similarly, Japan in electrical machinery, apparatus and energy and computer technology. In addition, China's patent publications are concentrated between resident-nonresident in electrical machinery, apparatus and energy and computer technology; Japan also in electrical machinery, apparatus and energy and computer technology. This could indirectly signal that China have learnt to adapt the right strategy in their catch-up process in terms of their process alignment and not just resources allocation alone. While we see a big contrast to Malaysia strategy; the country has devoted their strategy in a different style whereby using non-residents technological capability to produce patents in the industries that the country is weak on, i.e. organic fine chemistry and pharmaceutical. China and Malaysia started almost at the same time of S&T reforms, China has significant progress achieved while Malaysia survived with some unimpressive gaps widen over years. We are not saying it is a wrong catch-up strategy but obviously this also puts deeper into lagging behind and unproductive to catch-up despite decades of R&D efforts and high R&D spending.

In this context, clearly Malaysia and India were lagging behind in technological competitiveness and basically not doing enough to make any major technological disruption which leads to underperformed on securing resident patents in force as well as patent publications. The two countries are still relatively remained weak in resident patenting leads them stuck as basic research follower, a technology importer and perhaps a loss factor[57] due to weaker diffusion of new ideas or knowledge and innovation process altogether. Even when we compared a smaller size country South Korea to Malaysia, it is clear that Malaysia only produce 1.5% of equivalent South Korea's patent publications (see Figure 6.6). The arguments outlined above provide the basis that Malaysia is going to lagged further behind if no good basic research reforms were to be done concretely soonest possible.

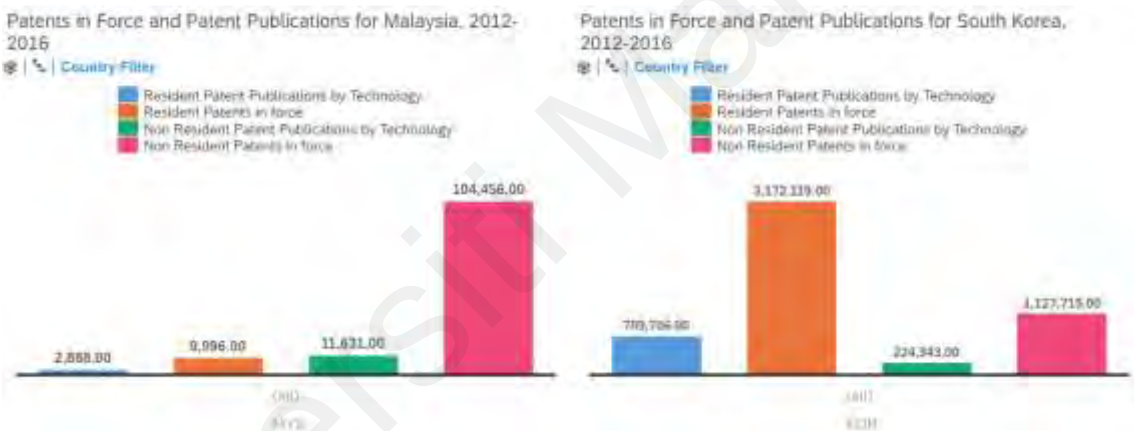


Figure 6.6: Patents in Force and Patent Publications in Selected Countries from 2012 to 2016

Source: Author's estimates (2018)

Majority past literatures use patent data to evaluate R&D performance while we propose to look at the scientific publication data to evaluate the R&D efforts much holistically. We conducted an initial test using LS estimation and found that the overall baseline model is statistically significant at 1% level (p-value 0.0000) and able to predict

[57] In fact, knowledge diffusion is supposed to provide opportunities for domestic firms to catch up technologically with the frontiers by absorbing as much of the technical and management know-how.

74% of the scientific patenting and publication activity impact to the Malaysian economic growth. Since we are using autoregressive AR(1) model, we suspected that we could have possibly undermine or inflate a particular predictor or missing an important predictor to the model such as past publications PUB_{t-1} will impact the current publication growth. We also find that industrial design is important exogenous variable to improvise the prediction with past publication DPUB(-1) and current publication growth, so it is necessary to examine the effect of all variables including the dependent variable with their possible lags.

So, our testing process continue to break up the variables into further investigation in the extended model: DPUB = C(1) + C(2)*DPAT + C(3)*DGERD + C(4)*DRSE + C(5)*DGDP + C(6)*DID + C(7)*DPUB(-1). As per our expectation, we have a stronger prediction using the AR(1) model estimation as the DW improved from 1.29 to 1.54, smaller AIC from -2.92 to -3.02, and larger log-likelihood from 36.7 to 37.2. Upon lagged one period PUB_{t-1} applied to the model, the overall model prediction is still statistically significant at 1% level (p-value 0.0001) and prediction improved to 77% since there is lagged period in publication too (although to be shorter than actual patenting process).

The sign of the coefficients were consistent and did not change when we improvise the model estimation. Patents granted, R&D expenditure, and past scientific publications have inverse relationship to current scientific publications and the said predictors are statistically insignificant at 10% level (with their p-values 0.3777, 0.5899, 0.4103 respectively). Our findings reveal that both have negative effect to publication growth although we do not dismiss the idea of higher patent application will increase scientific literature but not in the case of patent granted. The larger negative effect of R&D spending 0.23 compared to patents 0.08 or past scientific publications 0.12 is expected as R&D spending covers a broader scope than just patentable or published items. A 1% increase in patents will reduce scientific publication by 8% (or 1% increase allocation of R&D expenditure to inventive grants will reduce paper research by 23% or maintaining cost of past patent document will reduce available funds for current paper research by 12%) indicated patent is likely the alternative or better substitute for researchers to promote marginal increase in scientific publications and prevent it from falling too fast jeopardizing paper research creditability in Malaysia when there is limited resources for appropriation purpose or maintaining IP protection especially the cost on patenting activity is typically higher than the cost to write scientific literature.

With patent, the inventor can earn royalties as long as it is still an active patent in use while citation gain to scientific literature would diminish over the years. This also means that the increase in patents will promote more fundamental basic research activity rather than paper research instead. However, Agrawal and Henderson (2002) noted that such substitution effect is usually small and may not be present to all types of researchers as most academic departments emphasize on citation-weighted impact on publication activity unless they are patent-intensive researchers. After all, as the country is transitioning to become high-income country, thus doing some paper research is better than no research being done to a certain extent to learn from the distance frontiers and could enlighten some creative imitation to takes place during catch-up.

We opined that this is also due to the diminishing returns could occur as in publication quality has likely to fall when unable to quickly convert this peer-review scientific publication into actual patent document although such former said publication did increase in absolute number. The large magnitude is possibly unable to capitalize this publication investment to generate any positive returns unlike the case of a quality patent which can be sold for-profit purpose or recurring income. Although the magnitude of R&D spending on publication became lesser and less significant to impact publication growth over time can be due to spending on inputs that do not translate or convert into actual research output such as patent riding on the gain on the industrial design would diminish over time too would not be beneficial to scientific community and raise overall competitiveness of the country.

This shed some light that during the application process could have motivated the inventors to have temporary bargaining claim on the value of their inventions indirectly when research funds are secured as a continuum of their future invention before the final disclosure, thus patents generated in Malaysia was marginally growing in tandem publications when open science in basic research was increasingly made available and patent laws was strengthen has motivated marginally incentivize for more innovation activity to happen to compete with rival products especially in such market like Malaysia whereby many innovation sectors are largely uncaptured to its full socio-economic potential.

Malaysian universities have substantially increased their research activity. Total publications have increased faster than patents do not reinforce that R&D output will intensify. The recent MASTIC STI Indicator 2016 report indicated that Malaysia possess a consistent upward trend in publications in particular Material Science emerged as top field and Universiti Malaya consistently became the top producer of scientific publication since 2001 (MASTIC 2018, Low et al. 2014). Theoretically, anyone would have expected higher R&D funding should lead to higher scientific output or publication. In fact, this is not necessary the case in Malaysia whereby increase in R&D funding will correspond increases in scientific output. Based on our econometric analysis, we find that it is not beneficial to exploit specialized fund such as R&D expenditure for pursuing publishing activity as 1% increase in R&D expenditure will decrease scientific publications by 23%. The R&D funds should be use effectively to produce patentable products or high-value added services or lesser fraction of R&D funds would be left available if allocated to only do paper research rather than large proportion of the funds to spend on commercializing the proprietary knowledge or combined into a single research project constitute of research activity to maintaining patent document with patentable output; or if more funds allocated to patenting activity then less funds are available for scientific publication in journal articles. However, not in the case of Malaysia when the country is willing to sponsor on various R&D grants as the country is in expansion mode. And the funding mechanism does not boost local competition when the public universities and government research institutes remain highly funded by government up to 90% which needs to be change soonest possible to allow the institution itself self-attract private endowments by keeping their best RSE quality and infrastructure.

In contrast, industrial design, RSE and current GDP income have positive relationship to scientific publications and are statistically significant at 10% level (with their p-values 0.0001, 0.0587, 0.1069 respectively). We observed the rise of RSE and positive GDP income to fuel more paper research would certainly be beneficial for the country in the long-term. On a narrow perspective, all this might look good in terms of numbers: a 1% increase in industrial design will increase scientific publication by 12% while a 1% increase in RSE will increase scientific publication by 44%; but ability to catch-up is a different story until we further investigate the short-run to long-run adjustment process.

Much of the initial result above make practical sense in the case of Malaysia. It is indeed of serious concern that the progression of Malaysia as a developing country to grow its scientific agenda remains fragile and unsustainable. The country is allocating more R&D investment to build up their RSE capability but management of this resources is problematic when skewed them well into simpler task i.e. designing and publication process while not embedding them with the true skill of building useful patentable items which solve nation needs poses risk on weak structural reforms in scientific building such as coping towards Fourth Industrial Revolution. Surprisingly despite high investment in R&D, the country does not have a specific basic science policy except for the recent initiated Malaysia Commercialization Year Wave 1 in 2014 and Wave 2 in 2017 by MOSTI and produces extremely high paper research of 91.4% compared to only a small 8% on pre-commercializing prototype or pilot test activity[58]. Hence, the country is likely fall short in their basic research R&D performance when the pool of RSE kept increasing but not integrated with pre-commercialization and the improvement on the design process could be temporary remedy to stay competitive but not on the actual patents count that is increasing instead will still trap as technology importer or in a licensing deficit situation. Majority of the Malaysia publication rising growth rate was due to the rising international co-authorship to push for more but actual research quality is less seen as concur by UNESCO Science Report. Such result also highlighted that the country needs to strongly build up their scientific manpower such as strong STEM and TVET skilled workers remain critical.

After removed insignificant predictors DGERD and DRSE, past publication is still insignificant to the Malaysian publication growth. And we would have expected RSE to improve publication growth but not so in the Malaysia case. As suggested by MIT economist Alberto Abadie makes the case that statistically insignificant results are at least as interesting as significant ones; in a context where many readers would expect a positive result. So, in our view we should not ignore the variable in our estimation process but to transpire what happen on it between short- and long-run for a deeper understanding. We hypothesize that an important reason for the insignificant could be due to growth in labor

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[58] Malaysia is facing with governance issue on STI-related policy if nothing is done soon to overcome the barrier. Read more in Ruban (2018) on the country lagging performance at https://www.malaymail.com/s/1613989/report-malaysia-lagging-behind-in-science-tech-initiatives

productivity has slowed down substantially from on average 3.9% in 1980s to only 1% in 2015 over past three decades which is below its national target 3.7%, and wages in Malaysia are rising faster than productivity (per capita output) of the capital are problematic to long-term convergence and the market loses its appeal to rest of the country. Although the RSE community has a one third fraction and stronger effect than patents, it is less optimistic in Malaysia when the recent trends of these specialized human capital are moving into less productive sectors since year 2000 would further make Malaysia (with per capita output of US$21,000) continuously lagging behind the stronger North Asian countries such as South Korea (US$53,000) and Japan ($64,000)[59].

RSE virtually has 44% predictive effect to scientific publication, however at this point of time seems insignificant in Malaysia are due to limited consumption on high-tech materials also limits the inventive research would not able to create a pool of high-quality and knowledgeable RSEs that can speed up the commercialization process of indigenous products since the domestic market is largely dominated by SMEs and yet to fully capable of exporting home-grown high-tech products. In addition, the slow pace of upskilling the semi- to skilled workforce had stuck the country workers mindset to struggle with producing high-end manufacturing products when in fact the country has hosted many large foreign companies in Electrical and Electronics industry, technology transfer is slow unable to quickly adopt new technology and innovative knowledge which can help to increase productivity in any of the research output be it in patent or publication.

Next to support our correlation empirical analysis, we proceed with the ARDL procedures as it allows us to analyze the past lagged responses on all variables to scientific

[59] It is the leadership, innovation creativity and market integration issues rather than blaming it on political issues when the productivity rates fell. Read more on https://www.thestar.com.my/news/nation/2015/06/16/wages-rising-faster-than-productivity-says-economist/, http://www.theedgemarkets.com/article/msia-labour-productivity-growth-unsatisfactory

publication growth which a traditional AR(1) model has limitation to do so. We also attempt to show the relative magnitudes of these sources R&D growth in Malaysia was faster for paper research compared to practical research. We begin by choosing the optimal lag length using Akaike Info Criterion (AIC) as described in Section 3.4. Then we select the best ARDL model based on the smallest AIC*, highest log-likelihood and unique practical implication. For this particular model, the smallest AIC is -6.14 and highest log-likelihood value is 75.37 up to a maximum of 2 lag order on dependent and explanatory variables were sufficient to confirm that the model is well-fit, reliable with practical implications. We also tested to see whether this is the best model selection using SIC and Adjusted R^2 (see Table 6.7). All the three tests indicated the same results selection of maximum 2 lag order. Although shorter lag is preferred, however not in this case if 1 lag was to be selected the AIC of -3.78 is nowhere near the optimal level, hence for consistency we prefer to select the model with the smallest AIC for our investigation purpose.

Table 6.7: ARDL Model Selection Criteria Table for Top 5 Model

Specification	LogL	AIC*	BIC	HQ	Adj R^2
ARDL(2,2,2,2,1,2)	**75.37**	**-6.14**	**-5.29**	**-6.00**	**0.980**
ARDL(2,2,2,2,2.2)	75.45	-6.04	-5.15	-5.89	0.960
ARDL(2,2,2,2,2,1)	67.99	-5.36	-4.52	-5.22	0.956
ARDL(1,2,2,2,2,2)	67.50	-5.31	-4.47	-5.17	0.954
ARDL(1,2,2,1,2,2)	66.27	-5.29	-4.49	-5.15	0.965

Source: Author’s estimates (2018)

Let us construct the estimated equation: DPUB = C(1)*DPUB(-1) + C(2)*DPUB(-2) + C(3)*DPAT + C(4)*DPAT(-1) + C(5)*DPAT(-2) + C(6)*DID + C(7)*DID(-1) + C(8)*DID(-2) + C(9)*DGERD + C(10)*DGERD(-1) + C(11)*DGERD(-2) + C(12)*DRSE + C(13)*DRSE(-1) + C(14)*DGDP + C(15)*DGDP(-1) + C(16)*DGDP(-2) + C(17). With Eviews evaluated 486 models, we obtained the six variables ARDL model specification as (2,2,2,2,1,2) which satisfies the smallest AIC condition. From Criteria Graph results, we selected 2 as the maximum lag orders with Automatic Selection since we are using annual data and to keep a reasonable degree of freedom. Under this condition, we found that majority of the top 20 suggested models required 2 optimal lag order.

Now given the first four variables i.e. current scientific publications, patents, industrial designs and R&D expenditure are consistent with two lags, but not for RSE and GDP national income which have mixed result ranges between 1 to 2 lags. Thus, through the proposed top 3 models, we will try to infer the underlying preferences and outline this estimation result with shorter lags using AIC selection criteria. We did not select Fixed Selection of 1 lag order for all variables making the model less desirable model with a larger AIC (although it is statistically significant) to explain the phenomenon indicating not an optimal lag model and also is not within the top 10 AIC models presented.

6.4.1 Diagnostic Check

Next, since our interest is on the ARDL (2,2,2,2,1,2) model, we ensure the adopted model pass the diagnostic test assumptions. We are satisfied with the model estimated results do not show any anomalies as reported in Table 3.1. The result of Durbin-Watson statistic 1.4719 on the above specifications which is close to 2 indicated the model does not suffer from any serial correlation; same goes to Breusch-Godfrey LM test results reported the probabilities of 10.9% is more than 5%, so we will accept null hypothesis that no serial correlation at up to 2 lags and Q-statistics are insignificant at all lags (0.315 to 0.859) showed that there is no serial correlation in the residuals (Eviews, 2018). The Jarque-Bera statistic is 0.5254 with probability of 76.9% is more than 5%, so we confirmed the residuals are normally distributed, and the model is homoscedastic with probability 35.3% is more than 5% with the variance of residuals is homogenously spread across zero. Histogram error term shows that it is evenly distributed across 0 between -1 to +1. The results from explanatory centered VIF on this model estimation confirmed that it is not affected by any multicollinearity problem when all the results are above 1 and less than 4 as reported in Table 3.1 VIF for this ARDL specification.

Table 6.8: Robustness Check

	AR(1)		MLE	
Regressor	*Coefficient*	*Std Error*	*Coefficient*	*Std Error*
DPAT	-0.077 (-0.913)	0.084	-0.106** (-2.398)	0.044
DID	0.114*** (5.663)	0.020	0.124*** (5.534)	0.022
DGERD	-0.232 (-0.552)	0.420	-0.991* (-1.863)	0.531
DRSE	0.443** (2.072)	0.214	0.241 (1.449)	0.166
DGDP	1.022* (1.731)	0.590	0.239 (0.552)	0.433
DPUB(-1)	-0.123 (-0.850)	0.144	-0.226* (-1.974)	0.114
Constant (c)	0.039 (0.869)	0.045	0.134** (2.393)	0.056

Notes: 1. ***,**,* are significance at 1%,5%,10% level respectively. 2. Number inside the parenthesis is the t-ratio. 3. Both models estimated are statistically significant (p-value 0.0001) with close range of adjusted R-sq 77~83%, AIC -3.02 ~ -3.25.

Source: Author's estimates (2018)

As noted in Table 6.8 above, we also perform a robustness check using Maximum Likelihood Estimation (MLE) to ensure the estimated regression coefficients above is robust, plausible and reliable causal effects of the associated regressors for valid inference to theory or policy. The signs and magnitudes of the regressors are consistent to the least square estimators indicate no specification problem to the model, while MLE inverted AR roots result of 0.75 is less than 1 indicated a stable (stationary) model.

Next we proceed to check on cointegration behavior of this model. Upon lag selection, we employ the proposed ARDL approach to cointegration on the parameters we observed earlier to establish whether there is any long run relationship between the variables in Equation (10) since they are integrated of different orders. Based on our sample size, the ARDL-Bound test is suitable for a small size study (Pesaran et al., 2001). We proceed to re-parameterized the model by selecting Long Run Form and Bounds Test function in Eviews. The critical value tables are computed under an asymptotic regime (sample size equal to 1000) with referenced from PSS (2001), and for finite sample regimes (sample sizes running from 30 to 80 in increments of 5) is referenced from Narayan (2005). Following our sample size, we can examine the long run relationship using Wald test or F-statistics provided by Eviews. The critical value bounds for n=35 with four regressors were as follows: I(0) 2.331, I(1) 3.417 (at 10% level); I(0) 2.804, I(1) 4.013 (at 5% level); I(0) 3.9, I(1) 5.419 (at 1% level). The computed F-stats 9.3262 is larger than both lower I(0) and higher I(1) critical bounds of finite samples at the 1% significance level, thus we can reject the null hypothesis of no cointegration and conclude there are long run relationships between observed parameters and scientific publications growth (see Table 6.9 below). The single asterisk on lag of dependent variable is expected as a common output generated by Eviews (Eviews, 2018). We do not find any other variables with double asterisk so the model indicated the predictors we selected somewhat is associated with some lags and is not zero lag-free.

Table 6.9: Bounds Test Result

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n=1000		
F-statistic	9.326238	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15
Actual Sample Size	19	Finite Sample: n=35		
		10%	2.331	3.417
		5%	2.804	4.013
		1%	3.9	5.419
		Finite Sample: n=30		
		10%	2.407	3.517
		5%	2.91	4.193
		1%	4.134	5.761

Source: Author's estimates (2018)

Since both series are cointegrated, Granger causality test is used as an approach to discover interesting causal relations between selected variables in different models. As suggested by Toda-Yamamoto, Helmut-Lutkepohl, Dave Giles, we proceed to determine the causality test to cross check if we can regress each variable on their lagged values. Both PAT and PUB are important indicators in this study shows there is causality direction to impact the basic research performance in Malaysia. Overall the granger causality confirmed that there is enough statistical evidence of causal relations between patent, GDP, publication and scientific manpower. The results revealed that patent, industrial design and scientific publication changed before RSE changed. At this point considering up to 5 lags, there is causal relations between patent and GDP and the bi-directional confirmed that patent is able to cause fundamental change in GDP, however longer lags revealed that changes in patent is likely to caused changes in GDP and not the reverse.

On the other hand, the results indicate the existence of causality from RSE to PUB is bi-directional causal when longer lags are applied i.e. 5 to 6 lags indicating fundamental change in place so required longer lags while shorter lags indicate no relationship to produce changed on good quality scientific publications if shorter time frame is set to this scientific manpower. While causality on patent is uni-directional and publication do granger cause patent at lower lag i.e. 1 lag suggested there is a temporary lag rather than fundamental change is present when the scientific manpower in Malaysia are learning-by-doing and studying this technical documents or absorb the technical know-how and turn it into productive use of incremental invention but not a breakthrough invention, and patent will granger cause publication at higher lags (4 to 5 lags), industrial design will granger cause publication between 2 to 4 lags. Since the causality exist, we hypothesized how best to measure this patent and RSE to economic growth particularly for developing countries like Malaysia.

Having established that the variables are cointegrated, we estimate the long-run and short-run elasticities. The long-run coefficients from ARDL Long Run Form and Bounds Test of the model is reported in Table 6.10. The case of Malaysia shows that each of the explanatory variables in the proposed model ARDL(2,2,2,2,1,2) are statistically significant at 5% significance level (p-value 0.0177) and expected to have positive impact. Hence, we conclude that the scientific publication in Malaysia has not contributed positively to the country economic growth, unless the future is shift to increase the production of patent publication (patent document). Since the lagged dependent variable DPUB(-1) is statistically insignificant with a negative coefficient -0.4387, this indicated that a 1% increase in past publications (PUB lagged one or two periods) would not lead to 0.43% to 0.44% fall in current or future scientific publications is due to increasing amount of new projects or co-authorship undertaken to offset the negative contribution.

Compared to physical patent and RSE, both have equally predictive power (0.38 to 0.39 respectively) to positively contribute to Malaysia economic growth, however as time lag RSE substantially is the key driver if Malaysia wants to avoid fallout in the catch-up process compared to patents. RSE can increase 2.1% compared to patents 0.8% to boost scientific publications. Malaysia needs to quickly upgrade its domestic firms capabilities as remain industrial design has less contribution (negative) to economic growth as time lagged. Although, industrial design is commonly use in developing countries as one way to attract capital when their own indigenous development capabilities remain weak, but is definitely more effective than investing into mass higher education that failed the notion of Grossman and Helpman in tertiary education and avoid Malaysia stuck in the *European Paradox*.

For example, it is common these days the Malaysian RSEs have been trying to get their paper research recognized as highly cited papers since 2005 in the areas of agriculture sciences, chemistry, engineering, environment, material science and physics. In the engineering field in Malaysia, over 43,000 Malaysian researchers have engaged actively in collaborative research in this field, so they are not a one-time contributor and have produced over 30 papers each between 2000 to 2010 increasing two folds since 2007 with 94% are published with more than one author. Interestingly, most of the engineering publications in Malaysia had three authors on average and the preference of international collaborative research publication favour these top three countries: US, India and UK acquiring one-third of the engineering publications and seven out of ten international collaborators are linked to developed countries[60].

[60] Over 40% were generated from the seven selected countries. Read more on Salmah Abdullah's bibliometric analysis (2015, Qualitative and Quantitative Methods in Libraries, Special Issue Bibliometrics and Scientometrics: 151-159).

As a developing country, Malaysia has nothing to lose especially for the research universities to acquire the skills that not only to produce papers but to have a good control on the collaboration network and access to advanced infrastructure which are important for their career and country reputation in this discipline even if the country has built some scientific parks but yet to fully develop it into its full potential use would be part of their learning process. One example is on the renewable energy sector of which the Malaysian government has targeted its high growth among the twelve national key economic areas. In this example, the researchers from Universiti Malaysia Sabah (a public university) is task to team up with a German firm Autodisplay Biotech GmBH to build a production facility in Sabah state and become a key bio-ethanol producer using the cheapest method to convert oil palm fruit waste into bio-ethanol as renewable fuel to reduce dependency on fossil fuel. This process allows the Malaysian researchers to build network with German teams, acquired the technology transfer in fermentation and delignification process[61]. another example on producing wind energy with the collaboration between Universiti Malaysia Terengganu with power agencies from China and Thailand. So, this presume the strategy to record and measure the scientific progress in developing country would differ substantially compared to the developed country. The ability to raise productivity and international networking for the Malaysian engineering researchers have significantly impact the ability to secure subsequent funding for their future project or form strategic research council to stimulate local universities (in particular research universities) to advance their scientific activities which is vital in producing good quality basic research output as well for the country in economic progress during the catch-up.

[61] Read more at https://www.thestar.com.my/news/nation/2016/07/02/researchers-to-make-sabah-key-player-in-renewable-fuel/, https://www.nst.com.my/news/government-public-policy/2017/06/252994/kudat-set-become-sabahs-renewable-energy-dynamo

Table 6.10: Long-run Coefficients for ARDL (2,2,2,2,1,2) Model

Regressor	Coefficient	Std Error	t-Statistic	Prob
DPUB(-1)	-0.43	0.20	-2.15	0.163
DPUB(-2)	-0.42	0.21	-1.97	0.186
DPAT	0.38**	0.07	4.89	0.039
DPAT(-1)	0.81**	0.18	4.30	0.049
DPAT(-2)	0.12	0.06	1.89	0.198
DID	0.15***	0.01	13.49	0.005
DID(-1)	-0.12***	0.02	-5.29	0.003
DID(-2)	-0.07	0.03	-2.08	0.172
DGERD	0.11	0.32	0.34	0.764
DGERD(-1)	2.95**	0.61	4.82	0.040
DGERD(-2)	-0.89	0.43	-2.06	0.175
DRSE	0.39*	0.12	3.11	0.089
DRSE(-1)	2.15**	0.44	4.89	0.039
DGDP	-2.47	0.93	-2.65	0.117
DGDP(-1)	2.39**	0.55	4.28	0.050
DGDP(-2)	0.51	0.25	2.03	0.179
Constant (c)	-0.18**	0.03	-5.74	0.029

Notes: 1. Dependent variable is scientific publication (DPUB), 2. ***,**,* are significance at 1%,5%,10% level respectively.

Source: Author’s estimates (2018)

With the proposed model, the patent, R&D expenditure, RSE and its lagged values will improve the positive impact on scientific publication in Malaysia and statistically significant at 5% and 10% level, while the industrial design (as R&D asset focus on outer appearance) and its lagged values are negative and statistically significant at 5% level. A 1% increase in patent, R&D expenditure and RSE manpower results in 0.38%, 0.1% and 0.4% increase in scientific publication growth respectively. Based on the analysis, the results imply that patents (in particular resident patents) and RSE should be given priority for increasing the basic R&D performance in developing country such as Malaysia when a longer time frame is allowed. In fact, the magnitude of patents and RSE indicate it will promote substantial effect to improve the S&T progress given sufficient longer time to extract this benefit. After all from quality aspect both the indicators are important in the learning-by-doing or on-the-job training process, hence the patent is highly dependent on the productivity of these scientific manpower which are significant factors to makes the developing country catch up and becoming advanced in their production process in the long term.

Fairly, the use of industrial design as a strategy to encourage economic and innovation growth is commonly use in developing countries as one way to attract capital[62] when their own indigenous development capabilities remain weak. This is because in invention and innovation activity it comprises two important aspects in order to be successful: technical know-how and design. Thus strengthening experts in industrial design also means can overcome a particular country or industry from stuck in technology stagnation (which gave much help to the automotive industry in India, or Russia with the idea of using graphene which is 200 times stronger than steel to increase its durability) while promoting new products which protect its novelty, have significant societal impact, more efficient, usable to the local needs, aesthetically pleasing and is associated with optimizing a creative act just like the success stories of Germany, France, Japan and South Korea had built a sound base in industrial design to ensure high quality products are offer to the users. Similarly in US, a $1 invested in industrial design can increase sales by $160 which uses it to boost marketability and export performance to weaker developing country to have design dependency to the advanced countries and making their own product became

[62] Universiti Teknologi Petronas partnered with Mitsubishi Corporation of Japan, AIST of Japan, and University of Tokyo to promote research and training in green technology focusing on catalysis and reactor design for converting the biomass to produce fuel and chemical products. This partnership have secured 13 national grants, 10 international grants and published over 40 scientific papers. Read more at https://www.pressreader.com/malaysia/the-star-malaysia-star2/20150416/282381218076055

less competitive or appealing (which is more effective than investing into mass higher education; however cautioned that industrial design is a poor short-term R&D investment especially in high-tech industry unless can increase substantially on market size in the long-term to recover this return on investment)[63].

This result also implied Malaysia is facing a risky situation if the increasing trend in designing activity is faster than patenting activity could land the country stuck remain technologically laggards in the preparation stage, producing only low-valued goods and unable to upgrade its domestic capabilities (technology and firms) including scientific manpower development. So the then developing country like South Korea and Taiwan uses much of this strategy initially too before they catch up and leapfrog to develop their own invention as along its catch up path also enhance the ability of local RSE skills to absorb continuous flow of new technologies from developed country and create localization which is not easily to be imitated by other country.

In our view, the case of Malaysia is no different than any other developing country whom initially also import foreign technologies, talents and design capabilities, and subsequently massive efforts were tried to improve the traditional design approach do benefit the economy at present but relying on MNCs is unsustainable (even if positive spillover exist in the short-term), the weak success to quickly convert domestic design capabilities into new products or applications have hamper the entire R&D efforts in the country (noting that weak vocational education or TVET plays a role in the inability to capture these benefits). The country has slacken to look into the slow progression of TVET workers whereby at present only 28% are semi-skilled still below its national

[63] High quality of industrial design and engineering design can provide continuous growth to raise quality of life and economic stability in the developing countries. Read more in IIT Bombay (2009) report http://www.idc.iitb.ac.in/resources/reports/desing-as-a-strategy-developing-economy.pdf

manpower target of 50%. However, given a longer time period, a 1% increase in industrial design will lead to 0.12% fall in scientific publication growth. The positive effect from patenting activity is larger so is able to then override the fall in scientific publication and turn this into actual patent document or patent in force instead. Thus, it seems to suggest that in the past was dampen by the low fraction of patent publication described in Figure 6.6 as a result of low number of resident patents.

As for the short-run coefficients for Equation (11) reported in Table 6.11, the speed of adjustment CointEq(-1) (lagged one period error correction term; ECT(-1)) will converge towards long-run equilibrium level since it is negative and highly significant (p-value 0.0038) but smaller than -1. According to this estimation result in ARDL Error Correction regression, the magnitude of ECT(-1) between -1 to -2 is within an acceptable range when we analyze macroeconomics data on annual basis (Narayan & Smyth, 2006; Shittu et al., 2012). In the initial ARDL model if we push for shorter lag, the estimated average adjustment speed is about 78% with additional new R&D investment capital flow into Malaysia. Nevertheless in the extended ARDL model we took the optimal longer lag, the average speed of adjustment is -1.86 as noted in Table 6.11. This result shows that the lost year's opportunity can be corrected by 186% by the following years during the catch-up process with the condition of attracting higher R&D capital flow into Malaysia that directly stimulated larger positive effects on RSE and patents and becomes the main funding partner to co-create more resident patent or co-create patent publication whereby first inventor is Malaysian. Furthermore, Malaysia has increased its academic publications growth rate by 594%[64] in one year alone 2012. This implies that instead of monotonically converging to the equilibrium path directly, the error correction process

[64] Public universities researchers are gaining recognition as world's most influential scientific minds by Thomson Reuters https://www.thestar.com.my/opinion/online-exclusive/whats-your-status/2016/09/30/universities-and-honest-expectations-ultimately-a-ranking-number-is-merely-a-guide-not-an-absolute-w/

fluctuates around the long-run value in a dampening manner before convergence and when this process is completed, converging to the equilibrium path is expected to be relatively rapid for the Malaysian case. The above results provided strong evidence that knowledge diffusion can speed up if there is sufficient patent document generated in the economy.

Table 6.11: Short-run Coefficients for ARDL (2,2,2,2,1,2) Model

Regressor	Coefficient	Std Error	t-Statistic	Prob
ΔDPUB(-1)	0.42**	0.07	5.72	0.029
ΔDPAT	0.38***	0.02	13.29	0.005
ΔDPAT(-1)	-0.12**	0.02	-6.06	0.026
ΔDID	0.15***	0.004	39.03	0.001
ΔDID(-1)	0.07**	0.01	6.69	0.021
ΔDGERD	0.11	0.10	1.07	0.393
ΔDGERD(-1)	0.89**	0.11	7.85	0.015
ΔDRSE	0.39***	0.02	13.43	0.005
ΔDGDP	-2.47***	0.24	-10.30	0.009
ΔDGDP(-1)	-0.51**	0.09	-5.70	0.029
ECT(-1)	-1.86***	0.11	-16.15	0.003
Constant (c)	-0.09**	0.01	-6.02	0.026
	R2=0.999	Adj-R2=0.998		DW stat=1.472
	AIC=-6.776	Log-likelihood=75.373		

Note: ***,**,* are significance at 1%,5%,10% level respectively.

Source: Author’s estimates (2018)

6.5 Summary

The triple-digit percentage expansion in scientific publications from Malaysia, both those coauthored with international scholars, and those from national authors has manifested little in domestic capability building as resident patents only grew by 5 percent in the same period. The growing gap between scientific publications and filing of resident patents is part of the reason why firms in Malaysia have not been able to catchup and leapfrog like the way their counterparts have successfully managed in Taiwan and South Korea. A major reason for the low turnover in resident patenting could be because of weak linkages between universities and industry, which is reflected in the studies by Rasiah and Chandran (2009) and Hema and Rasiah (2016).

This chapter also examined the relationship between scientific publications and patents to answer the question of whether the R&D expenditure invested in particularly universities have been playing the dual role of generating scientific publications and patents. The results show that the expansion in scientific publications have not been matched by equally rapid growth in residents. Consequently, the overwhelming focus on scientific publications in the provision of incentives and grants has raised the ranking of Malaysian universities globally, but have not produced the requisite patents and industrial designs to support rapid economic growth.

CHAPTER SEVEN

CONCLUSIONS

Doctoral theses, being the outcome of serious scientific research, inevitably possess the potential for advancing the body of knowledge in related areas. Having spent a good part of my time problematizing the topic of science and technology, and economic growth, collecting and analyzing data, and using the estimates to establish the direction of causation, this final chapter shall focus on drawing implications for the developing countries in general and Malaysia in particular. In addition to the usual synthesis of findings, the conclusions of the thesis will draw implications for theory and policy.

7.1 Synthesis of Findings

We produced simple statistics and growth rates to show in chapter four that the successful developers to high income status, such as the United States, Japan, Germany, South Korea and Taiwan have filed massive numbers of patents and scientific publications among their innovation outputs. Malaysia has also expanded sharply its scientific publications. However, unlike the high-income economies of the United States, Japan, Germany, South Korea and Taiwan, Malaysia has enjoyed only a slow increase in patent filing. The deficiency in generating patents as an innovation output is drawback that will have to be rectified if it is do enjoy sustained economic growth to become a high-income economy. The overwhelming focus among universities to produce scientific publications will have to change to equal promotion of resident patents to close the knowledge gap with the high-income economies.

In addition, whereas resident patents have dominated patent filing in the United States, Germany, Japan, South Korea and Taiwan, most patents filed in Malaysia are from foreign individuals and firms, which offers the country little knowledge spillover potential nationally. The widening gap in patenting by ownership will only reduce the potential for stronger knowledge spillover from the R&D expenditure in Malaysia as much of the foreign patents files will be internalized in the multinational set up. While it is important to solve bureaucratic problems in the filing of patents, the focus of incentives to universities towards scientific publications should balanced with equal emphasis on the take of patents. Weak university-industry linkages (Rasiah & Chandran, 2009; Hema & Rasiah, 2016) has not helped address the lack of patent take up from R&D grants allocated to universities.

The findings in chapter five merely confirm the observations in chapter four that resident patents and industrial designs have a strong impact on GDP growth in both the pooled sample and in Malaysia. Germany, Japan, South Korea and Taiwan have appropriated significant growth synergies from the filing of residents, while the slow growth of lack has stalled Malaysia's economic growth effect, which has been aggravated by its failure to grow basic science with the selected eight IPCs in the patent- and industrial-design intensive industries in which the country has potential competitive advantage.

The empirical findings show that R&D remains a high-cost investment, but nevertheless is associated with generating long term lagged returns among the developing countries. Consequently, some economies underspend GERD, while others overspend in relation to their GDP. While most countries have focused on attracting FDI to support development, the evidence shows that STI policies and governance is important to stimulate innovation spillover. The relationship between R&D expenditure and economic growth is strong and statistically significant. Similarly, the Countries lacking strong STI policies tend to be trapped into being technology importers. The thesis also offers evidence to suggest that the lack of financial capacity among developing economies forces them to direct R&D funds to targeted industries rather than to a liberal setting with equal access for all industries.

7.2 Implications for Theory

The results of this thesis suggest that theoretically R&D activity enjoys a bi-directional growth relationship with GDP. In words, R&D spurs innovation, while subsequent innovations regenerates new R&D investment. The methodology used in the thesis offers a better explanation of the link between technology and GDP growth than the neoclassical TFP growth theory (see also Rasiah, 2015), which explains why Young (1994, 1995) came up with conclusions that South Korea, Taiwan and Singapore's could not be sustained owing to their reliance of factor inputs. Being output of the most sophisticated innovation activity, i.e., R&D, patents and industrial designs, which are intellectual properties that is widely targeted to generate new products and process, offers direct link between innovative activity and commercialization. Also, both the original Solow (1956, 1957) measure that captured productivity and technical change in the residue, and the computerised general equilibrium approach of Romer (1986), (which endogenized technological change) remain impressionistic at most since they are still limited by the production function assumptions of perfect substitution between capital and labour and input-output coordinates (see also Rasiah, 2015. Consequently, there is a need for new growth theory to progress to include resident patent granted as innovation indicators in the long-run to measure accurately the performance of country-level innovation.

In addition, simply using R&D expenditure will also likely offer little innovation effect as a significant amount of such outlays are often dissipated with little take up of patents and industrial designs, as well as real innovation in the country. Where foreign firms and national firms are involved, there is a need to differentiate the awards between them so that the former can be conditioned to support the NIS ecosystem to benefit nationals and national firms a la Brazil (in the developed states) and Singapore (Rasiah, 2013; 2020). It is in this context that a focus on resident patents rather than all ownership of patents is important as resident patent serves as an enabler of economic catch-up and sustained growth to the technological frontier. Governments should introduce appraisal mechanisms to ensure that the relationship between R&D investment and economic growth is positive and strong through effective coordination. It is also good to take up patents in important markets abroad to exports in knowledge-intensive goods *a la* South Korea and Taiwan. Governments should also tighten the procedures with patenting to reduce the rate of filing rejections. Malaysia is one example of a developing countries where the empirical evidence suggests that IP filing and protection procedures require reforms.

As argued in chapter four, while some developing governments, including Malaysia, have been targeting applied R&D more than basic R&D, it is pertinent that it is not the specific shares that matter. What is important is that there should be no disconnect between the two so that the flow of basic knowledge from basic research to applied research does not create a wasteful flow of knowledge that may either be leaked abroad or simply dissipated without any appropriation.

Another important finding of this thesis is the importance of a country's NIS being supported by sufficient number of research universities. Malaysia had five research universities out of around 50 universities in 2020, but none of them support frontier research in activities that show university-industry linkages. For example, in the semiconductor industry, the lack of such intensity of R&D has meant that wafer fabrication in the country has been confined to second and third generation technologies (see Rasiah & Yap, 2019). Importantly, the SMEs in developing countries, not just Malaysia, will require R&D support from research universities, which is how the early university-industry linkages evolved in Taiwan and Chile (Rasiah & Vinanchiarachi, 2013).

Chapter four also showed that it is plausible to imagine that the technology gap on utility patents in Malaysia has widened when we continuously examine the possible conditions leading to the underperformance of R&D investments in the country. In normal circumstances, past theoretical arguments mainly pointed that patents in general shall bring positive economic impact, like the case of tertiary education without considering the details of catch-up and leapfrogging strategy (Patel & Pavitt, 1998). The evidence amassed in this thesis calls for governments to screen the specific types of patents to determine the ones that actually lead to commercialization.

Chapter five also showed the importance of patents in supporting commercialization and economic growth, which is a major reason why Malaysia have yet to become a knowledge-driven economy. A significant volume of incentives and grants allocated to firms and universities in the country have not succeeded in yielding the requisite patents and industrial designs required to support rapid economic growth in the country. While the Malaysian universities have successfully raised the volume of scientific publications from Malaysia, the lack of similar success with patents and industrial designs will continue to hold back the country's efforts to become a high income economy. Also, among the patent filers in Malaysia, foreign individuals and firms still dominate, suggesting that their spillover effects to national individuals and firms will be limited. On this count, successful patent filings in Japan, South Korea, Taiwan and China are largely citizens of their respective countries. Consequently, theory should focus more on he specific innovation outputs that are likely to produce the highest productivity effects from R&D investment, as well as, the need to emphasize the R&D spillover effects of national owned firms over foreign owned firms. Countries where the converse has occurred as in

Brazil and Singapore, governments have played a critical leveraging role to enforce foreign firms' use of national universities and buyer supplier linkages with national firms (Rasiah, 2020; Rasiah, 2020).

While a rapid expansion of scientific publications is not a problem theoretically, it should be seen as a joint output of knowledge creation so that it is equally realized in the filing of patents and industrial designs. Indeed, the rapid expansion in scientific publications demonstrates that localized knowledge production has become important in Malaysia. However, the Malaysian experience has hit a conundrum because such knowledge synergies have largely leaked out, or have not been realized domestically owing to a disconnect between the knowledge producers and users (individuals and firms), or that they have been allocated in areas that offer little patent-based spillover. Although countries demonstrate different strategies at different locations in the trajectory of development, (which is defined by developmental stages), the lack of synergy between patent take up and economic growth in Malaysia demonstrates weak policy connect between R&D incentives and grants, and economic growth. The evidence confirms that patents and industrial designs are among the most feasible means to measure the impact of R&D since they offer significant effect on economic growth in the long run, while capital formation have significant impact in the short run to pilot the Malaysia innovation system.[65] While not all patents and industrial designs eventually hit the market, they extend paths for scientific and technical progress that will be necessary to direct innovations through new paths.

[65] Rodrik (2016) focuses on capital formation as the prime stimulant of latecomer growth.

Chapter six provided empirical evidence to confirm that the rapid expansion in scientific publications in Malaysia, i.e., those coauthored with international scholars, and from national authors translated little into domestic capability building as resident patents only grew by 5 percent over the last few decades. In sync with the findings from chapters four and five, the growing gap between scientific publications and filing of resident patents is part of the reason why firms in Malaysia have not been able to catchup and leapfrog frontier firms to follow the path taken by Taiwan and South Korea. This disconnect could be a consequence of weak linkages between universities and industries which is reflected in the findings of Rasiah and Chandran (2009) and Hema and Rasiah (2016). Consequently, the overwhelming focus on scientific publications in the provision of incentives and grants has raised the ranking of Malaysian universities globally, but have not produced the requisite patents to support rapid economic growth. While theory recognizes the need for strong university-industry linkages to stimulate patenting and commercialization, chapter six reinforces our argument that countries can reduce dissipation of R&D rents by imposing patenting as a critical condition when offering R&D incentives and grants to individuals and firms.

7.3 Implications for Policy

The findings on Malaysia in particular has extended the existing empirical literature on the importance of patents and industrial designs in driving economic growth, which offer important implications for policy, especially for the developing countries. Firstly, the findings show that Malaysia is unable to stimulate economic specialization from low to high value added activities owing to a disconnect between R&D incentives and grants and patenting activity. With low rates of patenting, the Malaysian economy has lacked the innovation spur to raise the competitiveness of national firms. While government policy has functioned well with scientific publications and citations, there must be a rethink with the filing of resident patents and industrial designs. R&D incentives and grants must provide strong emphasis on the filing of patents and industrial designs *a la* the experience of Japan, South Korea and Taiwan. Such an emphasis must also extend to universities. The Bayh Dole Act of 1980 in the United States could be a good example to adapt from.

Secondly, the government must address the widening the capabilities catch-up gap as the filing of both utility and design patents have grown slowly even after R&D grants were raised from 2002. Government programmes to boost R&D output have lacked the human capital (talent) to drive innovations despite several efforts to attract the Malaysian diaspora from abroad. Not only that the share of scientists and engineers in the population remains significantly lower than in China, Singapore, South Korea and Taiwan, the major source of such human capital in Malaysia come from fresh graduates while the former set of countries have continued to attract significant numbers of such human capital endowed with tacit knowledge from experience gained working in leading multinationals abroad (Rasiah & Lin, 2005; Saxenian, 2006; Rasiah, Lin & Anandakrishnan, 2015).

One policy instrument the government could use has been in place in the developed states of Brazil, such as Sao Paolo where foreign firms seeking to operate in the developed states have to show strong share of national scientists and engineers, and use of domestic universities to support R&D (Rasiah, 2004). Firms have greater capacity than government bodies to locate human capital that are capable of no only patenting but also filing commercializable patents. What the government can do is to improve the bureaucratic processes to ensure that they a complimentary to firms' activities. Such an initiative should include making amendments to the technology transfer agreement (TTA) in the country, which was originally enacted in 1975. Additionally, the TTA should also emphasize the appropriation of economic synergies domestically from patents filed in the country.

Thirdly, given the limited resources the country possesses, it will be critical for developing countries in general and the Malaysian government in particular to prioritize the industries that should be targeted to support R&D activity. Malaysia has had a history of leading R&D in rubber cultivation and processing since colonial rule, though much of its lead have faded since the 1980s as other countries, such as Thailand overtook Malaysia in the industry. In addition to a focus on palm oil and other industrial crops, such as cocoa and rubber and food crops, such paddy, chilies, legumes, vegetables, and tomatoes, the government can target the electronics, automotive, aerospace, machinery and equipment, and the scientific instruments industries for stimulate R&D activity. This is the path South Korea and Taiwan did as their governments identified strategic industries for technological upgrading and industrial catch up (see Amsden, 1989; Wade, 1990). Indeed, both South Korea and Taiwan stepped up rapidly patenting in the US rapidly since the 1990s in the critical industries of electronics and automotive products (Rasiah and Wong, 2021).

Fourthly, the high rejection rates of resident patent applications in Malaysia is likely to be a consequence of weak institutional links between knowledge producers and the organizations supporting them, which call for an upgrading of institutional mechanisms governing patenting in the country. In doing so, efforts must be taken to promote patenting by universities and firms, including jointly between them. This can stimulate more firms and university academics to patent their findings. On this there needs to be a streamlining of government policy on patenting. Strategies varied with a big contrast across the thirty-five technology classes that examined in the thesis in Malaysia.

Fifthly, it is critical for the government in Malaysia to identify the causes of why patents and industrial designs show a negative relationship with GDP. The findings show that utility patents rather than design patents generate more value to support GDP growth.

In addition, the findings also show that industrial designs supports domestic innovation capability to stimulate GDP growth. In this regard, the government should improve the administrative process to quicken firms' approval procedures to raise the pace of commercialization once the patents are filed. Efforts must also be taken to solve coordination failures associated with R&D activity. Nevertheless, Malaysia has performed better than what Sahin and Inekwe (2014, 2015) had predicted for the small upper middle-income countries.

Sixthly, tertiary educated employed human capital show limited patenting and innovation capabilities in Malaysia. While significant works exists criticizing both the supply and capability of tertiary educated human capital, little work has examined the importance of non-professional human capital beyond engineers and scientists, such as technicians and foremen. While extensive works exist on the shortcomings of technical labour, especially from technical and vocational education training (TVET) schools, few of them link their critical role as team players to complement the patenting capacity of engineers and scientists (Cheong & Lee, 2021). Indeed, TVET-based human capital has been a weak component of Malaysia's NIS. The TVET-skilled workers are strategic enablers that compliments the work of engineers and scientists to strengthen domestic capability building to stimulate technological progress.

Seventhly, GERD spending overall in Malaysia has risen, GERD spending per researcher has declined. Further research is needed to explore the reasons behind the fall in GERD intensity in the country. It could be a consequence of increased focus by Malaysian universities to raise scientific publications, which show increased collaboration among researchers. In other words, the increase in GERD has been shared increasingly by more collaborators than in the past. While collaboration can be productive, the governance mechanisms of grants should eliminate those who are simply piggy-bagging from others work.

Interestingly, the scientific publications show a positive relationship with patent applications, but not with patents granted, which may indicate that Malaysian firms have not successfully exploited the learning curve to produce patents. As competition becomes stiffer, latecomer countries, such as Malaysia should take the opportunity to leapfrog other countries by skipping the costly transition stages by striking into developing new technologies that are more efficient. In this regard, the results In show that promoting RSE is also essential to raise patents, but it can only strengthen the patenting impact by one-third with two-thirds of the impact still reliant on physical high-value patent itself. Consequently, the government should strengthen the scientific linkages between producers and users of knowledge *a la* Japan, Taiwan, South Korea, US, Japan and China.

In short, it is a necessary condition to produce a critical mass of own resident patents which must go hand in hand with linkages between individuals and firms, and science and technology parks (Rasiah & Gopi Krishnan, 2020). While it may be more difficult for developing countries with limited R&D resources and know-how to support R&D activity, such a reality to should push governments of developing countries to install effective appraisal mechanisms to ensure that R&D fund are appropriately allocated and regulated to ensure that much of it is directed at filing resident patents.

7.4 Directions for Future Research

Future research should examine inter-countries' per capita income comparability among developing countries. Different per capita income in the developing countries can illustrate further details the different stages in economic and innovation development. Since our study we only consider a few fast-developing innovation economies at the developing countries and developed countries to contrast with the Malaysian innovation performance, it will be interesting to contrast the performance of resident patent to innovation growth in different blocks of per capita income groups to measure the speed of catch up and leapfrogging, and spurts of sustained economic growth.

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