Lessons from Korean Innovation Model for ASEAN Countries Towards a Knowledge Economy†

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Abstract

The Association of Southeast Asian Nations (ASEAN) achieved relatively rapid economic growth over the past decade. Sustainable growth among member states, however, is put into question due to macroeconomic challenges, political risk, and vulnerability to external shocks. Developed countries, in contrast, have turned into less labor-intensive technologies to further expand their economies. In this paper, we review the science, technology, and innovation (STI) policies and statuses of the scientific and technological capabilities of the ASEAN member countries. Empirical results based on STI indicators (R&D spending, publications, patents, and knowledge economy indices) reveal considerable variation between the science and technology (S&T) competence and effectiveness of STI policies of ASEAN members. We have categorized nations into clusters according their situations in their S&T productivity. Under the Korean Innovation Model, Cambodia, Laos, Myanmar, and Brunei are classified as being in the institutional-building stage, while Malaysia, Thailand, Indonesia, the Philippines, and Vietnam in the catch up stage, and Singapore in the post-catch up stage. Finally, policy prescriptions on how to enhance the S&T capabilities of the developing ASEAN countries, based on the South Korea development experience, are presented.

Keywords
ASEAN, knowledge economy, STI policy, Republic of Korea

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1. INTRODUCTION

1.1. Current Status of the ASEAN

The Association of Southeast Asian Nations (ASEAN) aims to create an integrated market—the ASEAN Economic Community (AEC)—by 2015 (ASEAN Secretariat, 2003). The current upward economic trend of its developing countries in the recent decade bodes well for the integration plan's success. The ASEAN-10, composed of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam, collectively represents one of the most dynamic economies in the world, recording a combined growth rate of 7.1% in 2010 amidst the backdrop of the economic crisis on the other side of the world. The region is home to almost 600 million people and has a total GDP of 2,066 billion USD in 2011, about one-fifth of that of the USA and one-third of China's. Its economic integration comes at a time when the center of economic gravity is shifting from the west towards Asia due to the increasing influence of the People's Republic of China and India. While it is well-known that economic size offers significant advantages in accelerating economic growth and enhancing development in an increasingly borderless world, deepening regional integration in the ASEAN remains a challenge due to the differing economic and social development of its members.

Within 2030, the ASEAN hopes to increase the region's average real per-capita GDP to $10,000, more than three times the current amount (ASEAN Secretariat, 2003). To achieve this, the least developed economies and middle-income countries must work on improving and enforcing their social, economic, and STI policies. Any delay will threaten the "*long-term goal of a Resilient, Inclusive, Competitive, and Harmonious ASEAN or a RICH ASEAN*," as pronounced by the ASEAN Secretariat.

The ASEAN region is ideal for examining differences in STI policies with regard to the countries' economic level. Moreover, comparison of the evolution of their STI policies with those of countries that have successfully cleared the hurdle of the middle-income trap (such as the Republic of Korea) is inevitable. The Korean Innovation Model, which helped morph a foreign aid-dependent nation into a G20 member in a single generation, may provide helpful insight into how policies are carefully developed and successfully applied during the *institutional-building* phase up to the *post-catch up* stage.

1.2. The South Korean Development Experience

The Republic of Korea experienced rapid and sustained economic growth into a developed nation within a single generation. After World War II, its GDP per capita was comparable to the poorest countries of Africa and was lower than the slightly developed countries of the Southeast Asian region. The advent of the Korean War exacerbated the economic situation and made it almost impossible to recover. After more than four decades, however, it rose to be on par with the medium economies of the European Union and became a member of G20 and OECD. Today the tables have turned, as it has become a major contributor in multilateral agencies and an aid donor to many developing economies such as some members of the ASEAN.

The Southeast Asian region is South Korea's second largest trading partner after China. Southeast Asia is also the second largest investment destination for South Korea's FDI outflow, with trade growing at a high rate of 10% annually. Since its rise from one of the poorest countries in the world to a global economic powerhouse, South Korea has assumed a fraternal role to the ASEAN nations. A recent announcement was made concerning the establishment of a new diplomatic mission in Jakarta, home to the ASEAN Secretariat, a move that promises to improve cooperation between ASEAN members and South Korea. Developing ASEAN states in turn can more easily tap into South Korea's own socio-economic development know-how, in particular its STI policies, which were key in transitioning from a technologically backwater agricultural state into an increasingly knowledge-based economy.

Although a number of Korean Innovation Models exist in literature depending on the perspective on stages of technological innovation and units of analysis, a consensus on the basic framework seems to have emerged. First, as noted by Kim (1999), the evolutionary stages of technological innovation activities in Korea shifted from an imitation-focused *institutional-building stage* to an innovation-focused *post-catch up* stage. At the business level, Choi (2010) argued that Korean companies experienced three consecutive phases of development: *path-following*, *path-revealing*, and *path-creating*. The implementation of major S&T policies in the 1960s and 1970s were crucial for supporting industrialization and rapid economic growth. During this *institutional-building* stage, Korea's S&T policies focused on providing scientific and technological support for industrialization, while at the same time never loosing sight on long-term perspective (Hwang, 2011). In the 1980s and 1990s, during the technology *catch up stage*, S&T policies shifted to the *technology drive* strategy in order to solve the unsustainability of the previously export-oriented economy (Hong, 2011). This led to the quick development of high-tech industries (e.g. electronics, computers, and communication), with Korean conglomerates being able to compete with global brands in international markets. The 1997 Asian Financial Crisis, however, delayed the planned transition to a post-catch up strategy. Of late, Korea is now positioning itself in the *post-catch up stage*, where there are no countries or models left to benchmark. Seong and Kim (2010) asserted that the core issue in post-catch up strategy is the development of creative researchers who can define and solve the problems using creative solutions. While catch up strategies were effective in closing in on the level of advanced countries up to a point, the next step can only be an exploration of innovative activities beyond the state-of-the-art technologies. Throughout the economic transformation of South Korea and the changing policy landscape, the government's S&T policy was at the heart of all of these activities.

As part of its trajectory towards a *creative economy*, South Korea recently attempted to position itself as an emerging knowledge economy, establishing the Ministry of Trade, Industry and Energy (or MTIE, formerly Ministry of Knowledge Economy), an agency responsible for fostering traditional industrial structures as well as developing new growth engines at the cutting edge of industrial innovation. The ministry places the highest priority on knowledge-creation activities that can drive the current and future economy. Korea is unique in how in a remarkably short period of time it is making the transition towards an emerging knowledge economy powerhouse. The country's economic growth over the past four decades clearly exhibits the increased contribution of knowledge generation towards productivity. To compare, Mexico's GDP per capita in 1960 was two and a half times larger than that of Korea, but by 2003, Korea's real GDP per capita was already more than twice that of Mexico. This great leap in the economy was propped up by significant contributions from knowledge, without which its GDP per capita would still be lower than Mexico's (Suh & Chen, 2007). Korea's rapid and sustained knowledge-led economic growth makes it particularly interesting as a model for developing ASEAN nations.

1.3. Towards a Knowledge Economy

The idea of knowledge economy covers a broad range of activities and interpretations. All of the major lines of research related to knowledge-driven economy, however, agree that knowledge is the center of this development framework. Knowledge economy is defined as an economy wherein the role of knowledge takes on greater importance over that of natural resources, physical capital, and low-skill labor (OECD, 1996). A knowledge-based economy emphasizes intellectual capabilities over physical input or natural resources, and invests into efforts to integrate improvement in production through the use of research and development. Movement towards the knowledge economy can also be traced based on the increasing share of "intangible" capital in the country's gross domestic product (Abramovitz & David, 1996). Efforts towards a knowledge economy depend on technological capability driven by research and development efforts in science and engineering. Hence, for any country to be successful in shifting to a knowledge-driven economy, public policies must support the establishment of a robust research infrastructure, encourage the creation of a high number of qualified human resources, and continuously provide funding for R&D initiatives.

A challenge in studying any policy is to find the right metrics to gauge the extent of effectiveness. In this particular case, key indicators would be those that can tell whether and how much a country has become more dependent on knowledge production. Although the importance of knowledge and intangible capital in ushering economic growth is unquestionable, making useful metrics from these assets is difficult. Among the metrics that have been devised, popular measures such as the number of R&D personnel, R&D expenditure, and number of research institutions have been widely used as criteria of technological capacity. In addition, scientific research output among peer-reviewed academic journals also represents an important measure of scientific activity and even of the scientific innovation of a country (King, 2004). Patent-based measures have also been used to quantify R&D activity and stocks of knowledge, with patents being a broadly utilized indicator of intellectual capital and economically valuable knowledge (Pakes & Griliches, 1980). Recently, another study suggested that there is a strong correlation between the number of scientific articles and the degree of "knowledgization" of the economy, as measured by the Knowledge Economy Index (KEI) compiled by the World Bank (Nguyen and Pham, 2011).

1.4. Purpose of the Study

To date, there has been neither a review of the current situation of STI policies of the ASEAN countries nor an examination of their effectiveness in terms of commonly used metrics. This study aims to give a qualitative and quantitative measure of the status of S&T productivity in the ASEAN countries. We gathered and analyzed S&T metrics and correlated important policy indicators such as the percentage taken up by R&D expenditures in the GDP, as well as factors of scientific productivity such as papers, patents, and knowledge economy indices. In the succeeding section, we analyzed the STI situation of the ASEAN countries by grouping them into clusters of similar economic and science and technology (S&T) productivity in the context of the Korean Innovation Model framework, from the *institutional-building* stage to *post-catch up* stage. Finally, some crucial lessons from the Korean experience are articulated in the last section.

1.5. Methodology

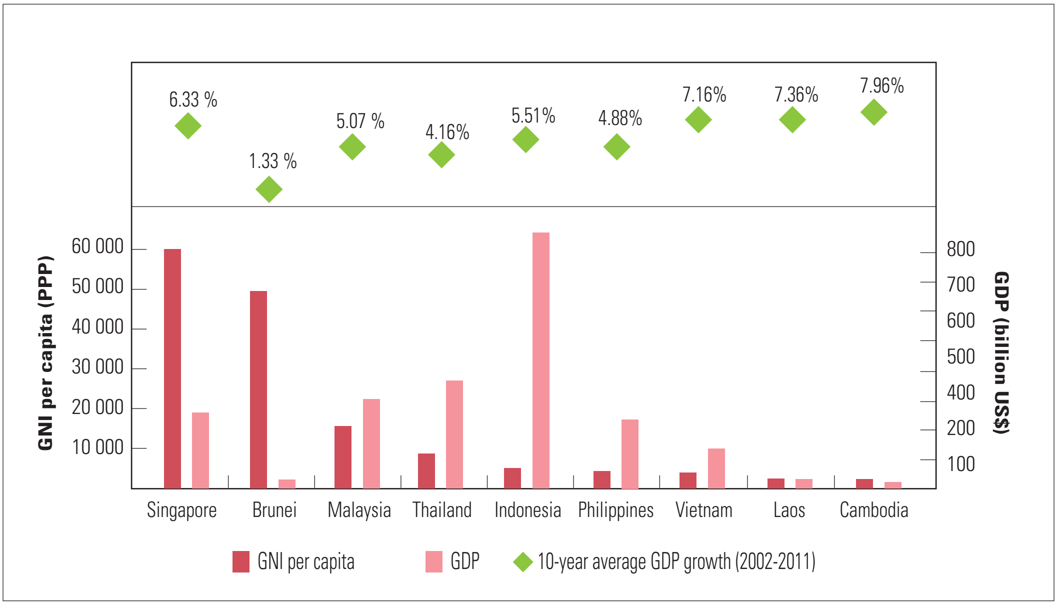
Information on the efforts of each ASEAN member nation towards enhancing competitiveness through STI was collected from local government agencies, recent publications journals, online and print magazines, and reports. Important policy indicators such as R&D expenditure as a fraction of the GDP were taken from the UNESCO Institute of Statistics in the World Bank website. The number of researchers and technicians in R&D per million population and high technology exports were sourced from the World Bank website.

Data used to measure scientific productivity were abstracted and processed from ISI's online citation index *Web of Science,* which contains abstracts and citations for academic journal articles. The database covers titles from more than 8,700 international publishers. Broad searches were used for the searches and country fields for data going back all the way to the database's inception. In addition, knowledge economy indices were extracted from the 2012 World Bank's Knowledge Assessment Methodology (KAM) report. KAM is an online interactive tool that collects data and produces the Knowledge Economy Index (KEI), an aggregate index representing a region's overall preparedness in competing in the knowledge economy. It is a good measure on the effectiveness of a nation's policy towards creating a knowledge-based economy. Data on intellectual property indicators were derived from the Statistics on Patents report of the World Intellectual Property Organization website. The report covers a wide range of indicators such as patents, utility models, trademarks, and industrial design.

2. GENERAL TRENDS IN THE STI INDICATORS OF THE ASEAN

The vast economic diversity within the ASEAN is compelling, with huge differences in GDP and GNI per capita, as shown in Figure 1. Singapore, the richest state with a GDP per capita income comparable with that of advanced countries in the western hemisphere, has twenty-seven times higher GNI per capita than Cambodia, the least developed among the ten countries. Although one of the smallest economies, Brunei's oil and gas-driven developed economy boasts the second highest per capita income in the region and fifth in the world in GDP per capita income at purchasing parity power (PPP). Meanwhile, five ASEAN members—Indonesia, Malaysia, Thailand, Philippines, and Vietnam—are middle-income level, with Vietnam having joined the group just recently. The biggest challenge for most of these countries is how to escape the middle-income trap experienced previously by most developed countries, a situation arising from increasing wages and declining cost-competitiveness. Meanwhile, the least developed economies—Cambodia, Lao People's Democratic Republic, and Myanmar—are still experiencing underdevelopment and severe poverty despite stellar economic growth. It should be emphasized, therefore, that reducing huge disparities in social and economic levels between ASEAN nations should be a major concern if the AEC is to succeed.

FIGURE 1. 2011 ASEAN Socio-economic Baseline Data

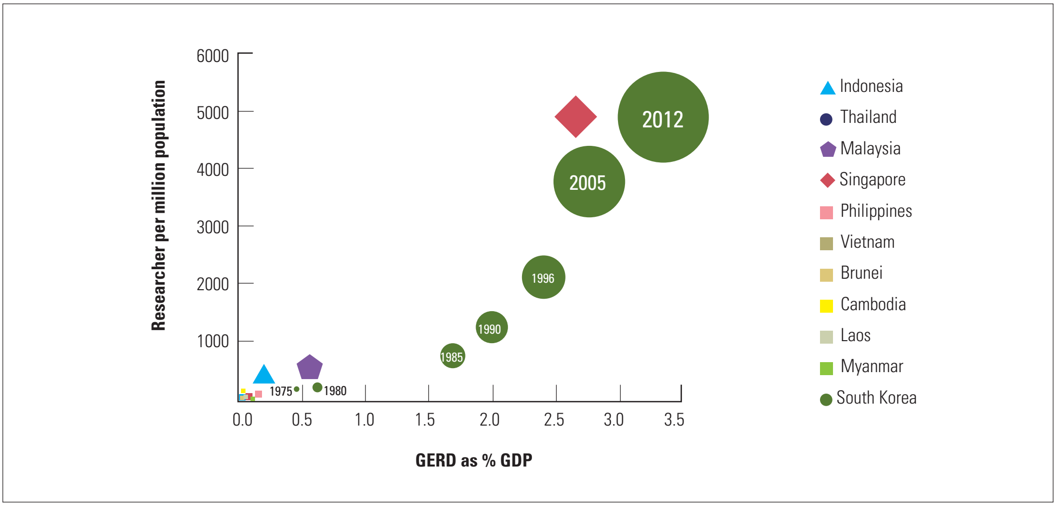


Source: Raw data from World Bank

2.1. R&D Investment

Figure 2 correlates the density of both R&D spending and relative number of researchers for the ASEAN-10 in 2011. For comparison, the illustration also includes the trajectory taken by Korea for the period of 1975-2011. Singapore stands out as a rapidly growing investor in science and technology (S&T), doubling its GERD during the 2000-2007 period. From this figure, we can see that Singapore and Korea have almost the same number of researchers but Korea has a bigger GERD/GDP and absolute GERD size than Singapore. In addition, Korea favored higher R&D funding relative to the size of its research scientists and engineers (RSE), with the S&T workforce catching up only in the last fifteen years.

FIGURE 2. 2011 ASEAN Investment in R&D in Absolute and Relative Terms



Note: The size of the circle reflects the size of GERD for the country.
Source: Based on raw data from the UNESCO Institute for Statistics and World Bank, 2011

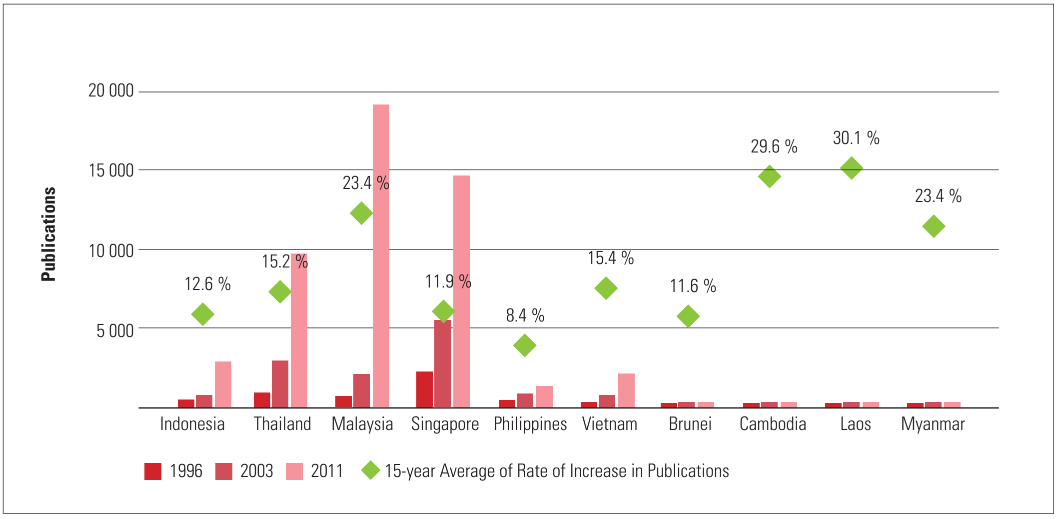
Two countries, Malaysia and Thailand, can be seen emerging from the bottom left-hand side of the graph. Although their GERD/GDP are still below 1% of GDP, they are a cut above the rest of the ASEAN countries due to their relatively higher number of RSE per million of population and R&D funding. Using the UN benchmark of 0.5% of GDP to be allotted for R&D spending, only Singapore and Malaysia fares favorably. Korea, meanwhile, allotted 5% of GDP into research-intensive activities as early as in the late 1970s. In contrast, the R&D intensity and human capital of the rest of the ASEAN-10 remains marginal as seen by the small circles at the bottom left corner of the figure. Specifically, although Indonesia and the Philippines account for slightly more than half the ASEAN's total population, their contribution to the stock of world knowledge remains nominal. Furthermore, R&D investments of the countries in the middle pack (Thailand, Indonesia, and Philippines) have not been able to keep up with growth in GDP.

Another important indicator of the effectiveness of national STI policies is the involvement of the private sector in R&D efforts. Malaysia (84.7%) and the Philippines (62.6%) both scored high in this measure (UNESCO Institute of Statistics, 2013). Nevertheless, the big number of multinational companies operating in these countries skews these numbers. The real challenge for most of the ASEAN countries is to develop their domestic S&T capabilities and use foreign investment to help their economies.

2.2.Scientific Publications

The number of research publications recorded in Elsevier's Scopus database is a commonly used indicator for a country's scientific output. Figure 3 shows Malaysia, Singapore, and Thailand to be the three publication powerhouses in the region. These three alone account for more than 86% of total publications in 2011. It is interesting to note how Malaysia supplanted Singapore as the leading producer of scientific knowledge in the past three years. While the other countries averaged high growth rates in scientific articles, this was primarily due to relatively high annual percentages for low publication output. Indonesia and Vietnam also showed impressive growth in the last five years, mostly due to recent efforts to improve their S&T productivity. During the fifteen-year period from 1996 to 2011, the scientific output in Cambodia grew by a factor of twenty-four while the Philippines tripled their numbers in 1996, still a meager increase compared to the rest of the region and only comparable to Brunei, which grew 3.3 times. The rates of growth of the other countries are as follows: Malaysia (20.1 times), Laos (14.9 times, Myanmar (9.9 times, Thailand (8.1 times), Vietnam (7.4 times), Indonesia (5.3 times), and Singapore (5.2 times).

FIGURE 3. Actual Number and Growth in Scientific Publications Among the ASEAN Countries

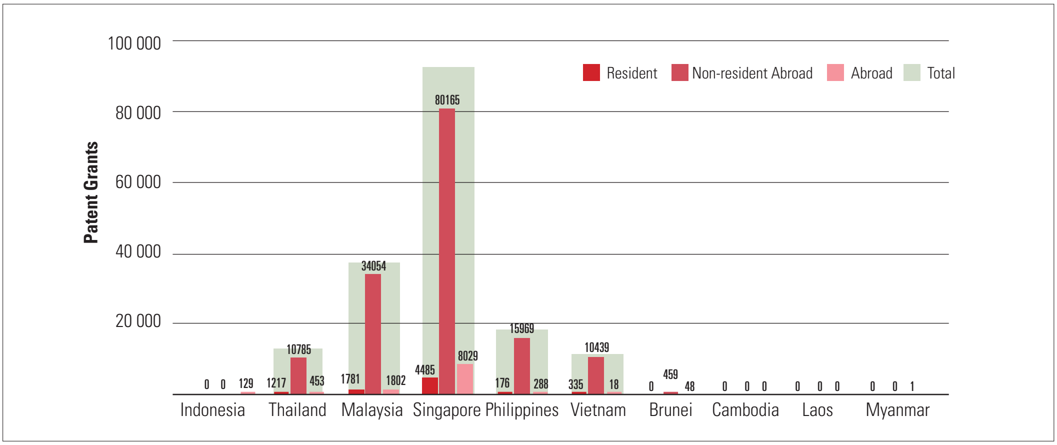


Source: Elsevier's Scopus Database

2.3. Patents

Patents are good measures of quantifying R&D activity and stocks of knowledge. Figure 4 presents the total number of patent applications granted from 1997~2011. Looking at the total patent grant figures alone is not really a good indicator of the effectiveness of the STI policies since the majority of the patents have been granted to foreign companies operating in that country. In terms of patents awarded to residents, Singapore still dominates the share in the total patent grants (56%) while Malaysia (22.3%) and Thailand (15.2%) also generate a considerable number of patents, albeit at relatively lower numbers than Singapore. In the middle are Vietnam (4.2 %) and the Philippines (2.2 %), and no patent was awarded to a resident for the rest of the ASEAN members during this period. Indonesia has surprisingly low patent grant numbers in relation to its economic scale and population size, registering only patents awarded abroad. In contrast, Korea's registered patents to residents during this period were more than eighty-seven times the total of the entire ASEAN region.

FIGURE 4. Patent Grants Among the ASEAN Countries for the Period 1997~2011

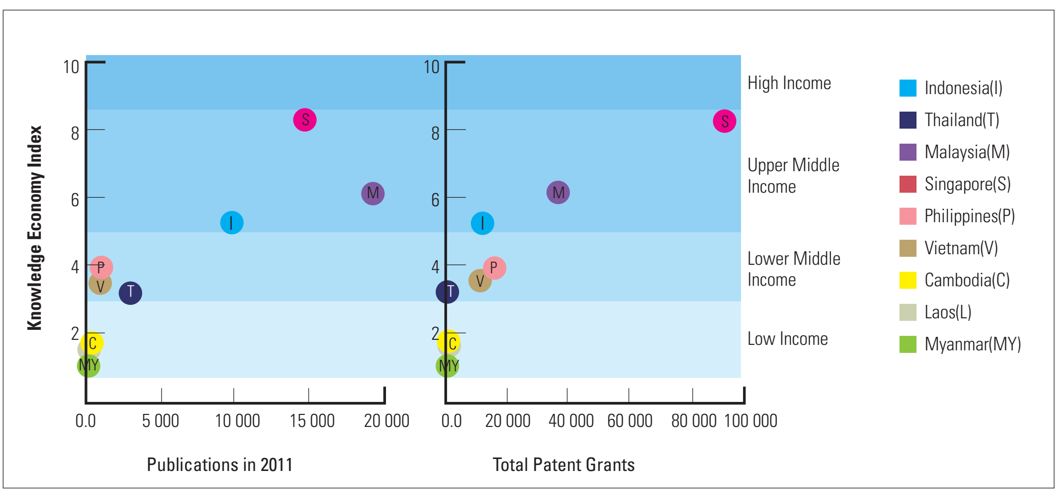


Source: Raw data from the Wold Intellectual Property Office

2.4. Knowledge Economy Index

Introduced by the World Bank, the Knowledge Economy Index (KEI) aims to measure the country's ability to generate, adopt, and diffuse knowledge as well as its capacity to provide the environment that is conducive for the effective use of the knowledge to improve economic conditions. It is an aggregate index that quantifies the overall level of development of any country towards the Knowledge Economy, and is calculated from the average of the normalized performance scores of a country on four groups of variables: economic incentive and institutional regime, education and human resources, the innovation system, and ICT. For our purposes, the KEI serves as one of the best metrics to measure the efficacy of STI policies of the ASEAN nations.

FIGURE 5. Relationship Between Scientific Publications and Total Patent Grants to the Knowledge Economy Index (KEI)



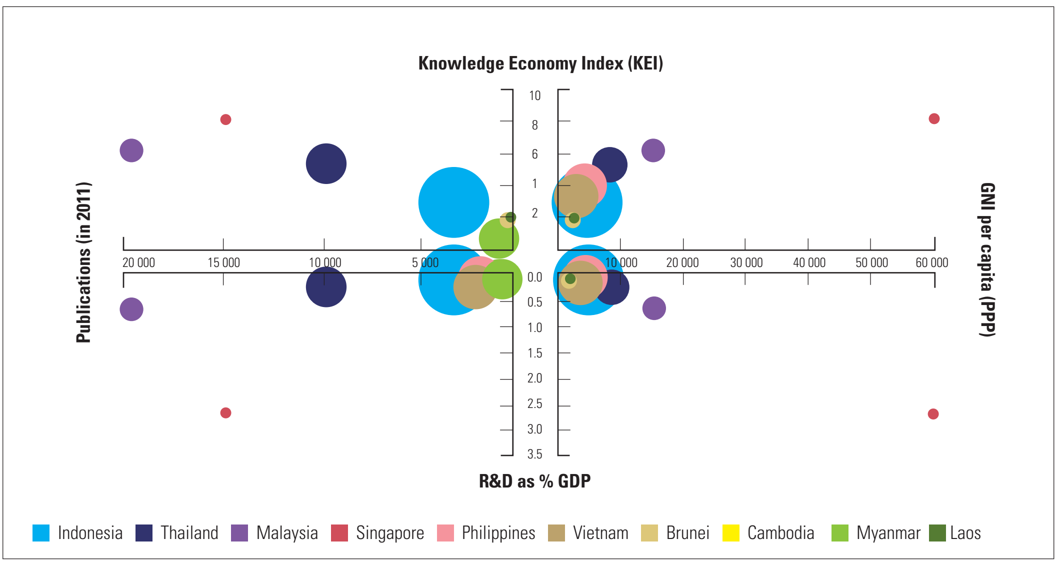
Source: Raw data from World Bank and Elsevier's Scopus Database

As seen in the figure, there is strong correlation between scientific and technological output and KEI scores, in good agreement with previous studies (Nguyen & Pham, 2011). Figure 5 also indicates the KEI averages for different income levels, and the locations of the data points are consistent with the GDP per capita income data. Singapore stands out among the ASEAN, yet it has had a hard time moving up in the recent decade. Only Indonesia received a strong bump in the rankings, moving up nine places from 117th to 108th in the span of seventeen years.

2.5. Emergence of S&T Productivity Clusters

The members of the ASEAN-10 are diverse in terms of stage of development, quality of life, and S&T capability. Nevertheless, it is not difficult categorize them into clusters. Singapore outshines its ASEAN neighbors, recording the highest GNI per capita in the region. Malaysia and Thailand make up the second group of upper middle-income countries, still relatively far behind Singapore in terms of national income per capita. The third group, Indonesia, the Philippines, and Vietnam, hold lower middle-income status. The last group includes low income and underdeveloped Cambodia, Laos, and Myanmar. Brunei also belongs to the last group. Although Brunei has a higher fiscal position than most of the ASEAN countries, it has little motivation for growth due to its reliance on abundant oil reserves. In addition, we found a strong correlation between STI indicators and ASEAN countries' economic levels. Trends in STI indicators, such as publications and KEI, matched well with those of socio-economic indicators. Figure 6 exhibits the clustering of the ASEAN-10 in this system and matching illustrations among four key indicators.

FIGURE 6. System Matching Between Key STI Indicators



Note: The size of the circle reflects the population size for the country.

3. POLICY GAPS AND LESSONS FROM THE KOREAN INNOVATION MODEL

Most observers agree that the impressive economic transformation of Korea would not have been possible without a corresponding emphasis on the build-up of human capital along with domestic S&T capabilities. As such, ASEAN governments struggling to build their S&T capabilities must play a central role in upgrading their capabilities though a mix of various industrial and STI policy measures (Jones, 2005). In the arena of foreign exchanges, for example, Korea allocated in favor of the importation of goods and technology over consumer items. The majority of the ASEAN members rely on exports to support their economies. Technology imports and foreign investment were also regulated in order to ensure the transfer and subsequent development of local technologies. This close relationship between STI policies and economic and industrial policies has characterized much of Korea's economic history. These are just some of the lessons that developing ASEAN countries can learn from Korea. In view of the Korean Innovation Model, the ASEAN-10 members can be further grouped into three distinct phases of economic development: *the institutional-building stage*, the *catch up stage*, and the *post-catch up stage*.

3.1. Institutional-Building Stage (Brunei, Cambodia, Laos, and Myanmar)

Countries in the *institutional-building stage* belong to the low-income and underdeveloped countries as discussed in the previous section. These countries are currently import-dependent and mainly reliant on primary resource-driven industries, which limit incentives and opportunities for economic and technological upgrading.These countries, however, have already realized the need to develop their STI capacity to take advantage of changing technologies and the emergence of the knowledge economy.

STI systems in these countries are still in nascent stages. They mostly focus on utilization and the primary processing of resources. Brunei, in spite of its enviable fiscal position compared to its neighbors, acknowledges it is lagging behind in STI. Myanmar still has no institution responsible for collecting STI indicators. Public resources needed to develop STI are lacking in financing, manpower and management competencies. There is heavy dependence on imported technologies while awareness and appreciation of S&T across society is low. In Cambodia, the bulk of R&D investment comes from non-government organizations and from abroad. Governance problems and politics often complicate R&D efforts. Although there may be a government organization responsible for STI involvement, for example the Ministry of Science and Technology in Laos, there is still a need for coordination and a comprehensive strategy among the STI actors.

Korea currently has relatively advanced S&T capabilities, although this was not the case five decades ago when it was a devastated country after the Korean War. However, it demonstrated how a very poor country could lift itself into a dynamic developing nation to become one of the world's leaders. A historic feature of the Korean innovation model is how Korea laid a strong economic foundation supported by the growth of the STI sector. Korean advancement started with an export-oriented mindset and an emphasis on educating human resources, paving the way for industrialization.

Countries currently in the *institutional-building stage* are highly dependent on imported technologies. During the first phase of the Korean model, promoting the inward transfer of foreign technologies played a vital role. STI policies were formulated to prevent imitation issues, and policies were fashioned to fit foreign-acquired technologies to the local setting through small modifications, which pushed enhanced technological capabilities. These policies were initially geared towards promoting industries, and later on, Korea recognized the need for technological self-reliance, which led to prioritizing STI system development in national planning strategies. The government's role at this stage was to assume the bulk of R&D activities and disseminate the importance of STI. They started by building the necessary institutions that define the direction of STI and implement appropriate STI policies in connection with economic development plans. Following this path would be difficult for the ASEAN countries in the *institutional-building stage*, for the bulk of R&D investment comes from non-government organizations and from abroad. On the other hand, it is important to note that an important key to Korea's advancement is that it has always had a long-term outlook about its STI sector. From the start, the government wanted research expansion to be placed under the private sector. Government only initiated research activities as an initial push for Korea's fast S&T progress.

Alongside strengthening of the technological base is building a competent domestic human capital. The low GERD as percentage of GDP of these countries needs to be improved immediately. The ASEAN countries in this stage need to invest in basic and higher education. In the 1960s, Korea focused on improving the number of their technicians but after a decade it needed more qualified engineers. Building the appropriate institutions like the Korean Institute of Science and Technology expanded Korea's R&D capacities. It was under President Jung-hee Park's initiative, however, that the Korea Institute of Science and Technology (KIST) was able to autonomously perform intensified research activities, which developed excellent scientists and engineers.

At this development stage, the government steers the wheel of the country. Suitable STI policies are important in driving the countries for fast economic and S&T advancement. Moreover, a well-defined long-term plan is necessary to find a direction towards national development.

3.2. Catch up Stage (Indonesia, Malaysia, Philippines, Thailand, and Vietnam)

In the 1980s, the Korean government realized that heavy dependence on imported raw materials for its exports was unsustainable. Moreover, the rising labor movement was undermining the price competitiveness of Korea's low-wage labor. This led to the "technology drive" strategy to replace the "export drive" that led to growth during the 1960s and 1970s. Korea was able to establish its key high-tech industries (electronics, computers, computers, and communications) following this transition. It was also in this stage when emerging conglomerates such as Samsung and Hyundai were starting to become household names. Korea's catch-up efforts were centered primarily on previously established government-funded research institutions (GFRIs) and the creation of a National Innovation System (NIS), which includes the higher educations institutions and the private sector (Moon, 2011). Revisiting key policies of Korea during the catch-up stage will be helpful for the ASEAN countries in similar situations in order to avoid the middle-income trap, commonly experienced by semi-developed countries.

Among the five countries we believe to be in the catch up stage, Malaysia and Thailand fare positively compared to the other three in terms of STI development. For example, Malaysia spends 6.26 percent of GDP in education as of 2009, and is highest in the region and even higher than Korea. This figure is roughly a fifth of the government's national budget. Thailand's education expenditures in 2010 accounted for 3.75 percent of GDP and 22.31 percent of its national budget. These two countries' governments are leading renewed efforts towards a virtuous cycle of development of key domestic technologies in the level of advanced countries.

Malaysia's Ministry of Science, Technology and Innovation (MOSTI), the lead government agency in STI policy formulation, acts as secretariat to the National Council of Scientific Research and Development (NSCRD), which is composed of key government line agencies and representatives from universities, research institutions, and the private sector. Givindaraju *et al*. (2005) stated that the importance of STI has long been acknowledged with the National S&T Policy incorporated in the Fifth Malaysia Plan (1986-1990) and the launching of the National Action Plan for Industrial Technology Development in 1991. Subsequent plans and programs "became more market-oriented by exploiting the commercialization of research and technology." In 2003, the Second National S&T Policy was unveiled "to address the gaps in the national innovation system and focus on strengthening research and technological capacity and capability with emphasis on commercialization of research outputs, strengthening institutional framework and management of S&T" (Krishna, 2006).

The country's National STI Policy 2013~2020, similar to the developments in Korea in 1980s and 1990s, has the following strategic thrusts (Ahmad, 2012):

- Generating, deploying and diffusing STI knowledge: involves formulating and implementing innovation roadmaps, designating the National Science and Research Council to lead coordination efforts in public R&D efforts, and ensuring sufficient funding through an R&D intensity of at least 2.0% of GDP by 2020.
- Developing, harnessing and intensifying talent: focuses on improved science, technology, engineering, and mathematics (STEM) education; talent development, management, and retention; and domestic and international networking.
- Energizing industries: includes enhancing funding mechanisms for industry R&D, incentivizing knowledge transfer, and improving existing public programs to promote indigenous innovations and solutions.
- Transforming STI governance framework: aims to improve oversight, strengthen governance structures and management of IP, and enhance public sector innovation.
- Enculturation of STI in society: entails awareness and appreciation programs, popularization and promotion of S&T to the general public and as a career option.

In contrast, STI development in Thailand was not conducted under a broader framework of industrial policy and overall economic strategies. STI development since the 1990s centered on four functions: R&D, human resource development, technology transfer, and S&T infrastructure. The ten-year Science and Technology Action Plan (2004-2013) employs the concept of an NIS and the clustering approach for industries. The focus is on strengthening the NIS and human resources, creating an environment that encourages development and capacity-building in new growth industries such as ICT, biotechnology, materials technology, and nanotechnology (Mukdapitak, 2012).

Thailand's NIS has been described as being in a state of transition towards growth and more synergy among its actors. At present, the NIS is said to be fragmented, as collaboration between industry and the academy has been weak. With respect to human resources, Thailand faces a general shortage of STI workers at the tertiary and postgraduate levels. The government also needs to foster the right incentives to encourage R&D activities in the private sector. The country's move towards R&D clustering in industries cover food, automotives, textiles, software, electronics, tourism, life sciences, and rural or community-based products. These are areas where Thailand already exercises a degree of comparative advantage, suggesting that the country intends to move into and push the technological frontier in these industries. For most of these industries however, Thailand's competitors already enjoy a considerable head start. Success in this case will also be determined by the degree to which Thailand can differentiate and set itself apart in these areas (Durongkaveroj, 2012).

Meanwhile, the state of the STI system in Indonesia, the Philippines, and Vietnam leaves much to be desired. Measures of public spending on education as compared to national output and the national budget are way below international benchmarks, although this might change soon for Vietnam with the current president promising increased funding in the coming years. These countries suffer from a scarcity of S&T personnel and researchers, with Indonesia showing no signs of improvement over the years. Given this picture, strengthening human resources and national S&T activities should be pursued more aggressively.

In Indonesia, food and agriculture is at the top of the list due to how its large population is pressed for food security and the fact that agriculture still accounts for a significant share of employment and economic activity (Lakitan, 2011). It also focuses on energy and tries to diversify from oil and gas towards other indigenous energy sources such as renewable energy. Its defense focus emphasizes self-reliance on local defense technology. Transportation is a perennial concern given the country's archipelagic nature and antiquated infrastructure. ICT is a fast-growing area although the country needs to further develop its ICT infrastructure and applications for productivity improvement. Lastly, health and pharmaceuticals bank on Indonesia's rich natural resources with its reefs and rainforests being potential sources of herbal and pharmaceutical products. Like much of the Indonesian bureaucracy, Indonesia's STI organization, overseen by the National Innovation Committee, is large and complex. At this stage of its development, private R&D activities are low and Indonesia has to rely on the public sector to carry most of the burden. Moreover, the country has limited industrial and technological capabilities even as linkages between STI actors and industry are weak.

Under the Suharto regime, Indonesia engaged in a development and industrial policy strategy that included the promotion of S&T. Like in the case of the Philippines however, the Indonesian experience with industrial policy was largely a failure. Selective industrial policy effectively creates “rents” in the participating industries, making these industries attractive to capital and investment. Unlike East Asian countries that employed such policies, however, Indonesia and the Philippines are characterized by weak states. State capture by rent-seekers practically siphoned off government support and resources towards favored groups and private interests.

It thus becomes understandable how the state has largely retreated from industrial involvement and market interventions, although these are still considerable across a range of sectors. Nevertheless, the government still holds to the import of national S&T development in national planning. State funding, for example, accounts for almost 70 percent of all R&D funding sources. Most of these go to universities and research institutions. The state considers productivity improvement through capacity development as a means for creating competitive advantage rather than taking this as a given, a throwback to the old days of traditional industrial policy even as the country has embraced more market-oriented mechanisms.

Aside from the need for increased R&D funding, some of the issues raised in the Indonesian STI system include weak technology transfer, knowledge dissemination, and application, as well as weak collaboration between industry and domestic R&D actors. On top of this, there is a need for improved policies and coordination in order to further the growth of the national innovation system. The government has moved to address some of these issues through plans to provide fiscal incentives for R&D, innovation, technology transfer, and utilization. Moreover, funding regulation will also be improved to ensure that R&D activities align with industry needs and the national goal of improved productivity. A clustering strategy in the proposed economic corridors will also be employed in order to benefit from knowledge spillovers, scale economies, and improved coordination. These policy reforms become all the more urgent as Indonesia tries to finally wean itself away from resource-driven growth towards a more technology-driven strategy. While agriculture and resource exploitation is and will continue to be significant components of the economy, future growth will increasingly come from the upgrading of local capabilities in order to take advantage of constantly evolving technological and economic landscapes (OECD, 2012).

The Philippine STI system by any measure is underdeveloped and lagging with regard to its Asian peers. This is already glaringly evident in the scarcity and low quality of local statistics and indicators needed to measure its performance. Apart from the STI supply system, national technology transfer also remains weak and the national production system have limited productive and technological capabilities. Nowhere is this most obvious, for instance, than in the agricultural sector, particularly with traditional crops such as rice and corn. The latest technologies and best practices in rice cultivation have long been available to the Philippines through institutions such as the International Rice Research Institute and its local counterpart, the Philippine Rice Research Institute, among others. Yet these technologies have not become widely adopted, and agricultural productivity, mainly comprised of rice growing areas, has stagnated (although there is more to the issue than simply improved technology transfer and production practices). This is because the subcomponents of the national STI system are fragmented, with very little linkages between the supply and demand sides.

In the Philippines, the development of the S&T supply system is spearheaded by the Department of Science and Technology (DOST), with programs that support S&T education, training, and research activities. To a very limited extent, the DOST also engages in efforts to promote technology transfer and commercialization. Meanwhile, the National Economic and Development Authority (NEDA) is responsible for the country's economic and development policies. Since the late 1980s, the government has shied away from state intervention towards more market-determined outcomes under the ambit of economic efficiency.

It can be argued that one reason why STI policy in the Philippines has been largely ineffective is that it has been unfocused, not being guided by a deliberate industrial policy under an overall development strategy that asserts national interest over market considerations. Leaving investment, innovation, and R&D decisions to the market has not produced clear "winners" in Philippine industry. In the case of the electronics industry, most firms are engaged in assembly-type operations with little value added or improvement in technological capability. In contrast, most finished high-tech products are imported from abroad.

While not all countries have been successful at state-led industrialization, nevertheless, there are lessons in that direction that may be worth considering for the Philippines. For one, economic literature recognizes that there is a tendency by firms to underinvest in R&D activities when such decisions are left purely to the private sector. This happens because firms do not take into consideration the social benefits of R&D, leading to socially sub-optimal levels of R&D. Thus, there is a role for the state in encouraging and supporting R&D. This should go beyond the current track of general R&D activities, however, where the direction is still left to the market to determine. Given scarce public resources, the government cannot equally invest in all sectors and industries. As argued by Chang (2010), even "general" policy choices have discriminatory effects that effectively amount to selectivity and targeting. It would thus make sense for the government to focus its resources on strategic industries that will have the most impact on the economy.

As is the case with most of its ASEAN neighbors, the Vietnamese economy can be characterized by its low levels of R&D investment and activity in the public and private spheres, weak coordination and collaboration among STI actors, and human resource challenges particularly in the higher education sector and the lack of S&T personnel. There are also perceived weaknesses in STI infrastructure and technology management. While policymakers have recognized these issues and have incorporated solutions in their S&T and economic plans, there seems to be dissatisfaction in terms of the government's ability to implement plans and policies.

Owing to its history of centralized economic planning, the government plays the lead role in the STI system. The main STI policy-making bodies are the Department of Science, Technology and Environment, and the Committee on Science, Technology and Environment of the legislature, but we note that execution and implementation have checkered records. There are different bureaucracies devoted to STI programs, funding, promotion, commercialization, advisory services, and information and statistics, on top of various public sector research institutes.

Interestingly, Vietnam does not provide STI initiatives that directly assist private firms despite the pervasiveness of the public sector in varied aspects of the STI system. Moreover, R&D efforts were not integrated with the production system until 1981. This is a departure from the East Asian route of economic development employed by Japan and the NICs. While the state apparatus in Vietnam has the ability to assert its will with regard to STI and economic strategies, the direction of Vietnam's STI and economic development has been towards liberalization with emphasis on demand-driven technological development (Kang, 2001).

One likely reason behind this reluctance to employ more direct, targeted STI initiatives aimed at upgrading the industrial-technological capability and productivity of firms could be the implicit recognition of inefficiency and lack of competency of the bureaucracy. As mentioned earlier, the government is perceived to have problems in execution and implementation, and the experience with R&D assistance to SOEs have not been encouraging. As Chang (2010) argues, however, the difficulty of policy implementation need not be reason for inaction, and the willingness to pursue difficult processes is part of learning-by-doing in the build-up of bureaucratic capabilities—that is, should Vietnam decide to go the industrial policy route.

This is not to say that Vietnam does not engage in industrial policy in a broader sense. Financial incentives, for instance, have been crafted to encourage investment in STI activities to promote targeted high-technology industries such as ICT, biotechnology, and materials science. These along with automation, new energies, space technology, mechanical and engineering, and agro-processing were the priority sectors announced in 2010. While there is reason to consider closer state involvement in STI development under industrial policy, perhaps there are more urgent reasons for the government to scale back in certain aspects of STI. This is seen in the large number of public research organizations (PROs), most of which are small, underfunded, and lacking in technical resources. Rationalizing these PROs and diverting public resources towards priority R&D and development areas such as agriculture and biotechnology may be a more effective way maximizing public R&D investment (Ca, 2012).

Clearly, political leadership is crucial in prioritizing progress over vested interests among these countries. South Korea had strong and capable government leaders who not only had vision but the ability to implement them as well. In the past decades, the political economy of the Philippines and Indonesia may at least partly explain the failure of earlier efforts at industrial policy. Chang (2010) notes that the states' systemic and long-term perspective that allows it to improve on market outcomes must be accompanied by the ability to impose discipline on recipients of its support.

Moreover, South Korea's experience with industrial policy during the *catch up stage* demonstrates how countries can enjoy the benefits of investment coordination towards complementation, exploitation of economies of scale, technology transfer policies, export promotion, and the role of the state in supporting emerging high-tech industries (Chang, 2010). It needs to be emphasized, however, that these policies were formulated and implemented under different socio-economic contexts in these various countries. Global economic context has changed remarkably from the time South Korea pursued technological and industrial upgrading. Weiss (2005) explains that membership in the World Trade Organization (WTO) already limits many selective industrial policy interventions such as import controls, firm subsidies, and the copying of foreign technology, among others, though there exists some scope for intervention especially for least-developed countries.

Although the current context of the ASEAN countries' development and South Korea's path towards prosperity might be different, many lessons are still applicable. The private sector, for instance, should take the lead in the implementation of technology development activities with the government and the GFRIs helping them. As seen earlier, the share of the private sector in R&D spending and outputs is relatively small, except in Singapore. In addition, setting STI policy must begin at the highest level of the decision-making body of the government. In terms of research capacities, the ASEAN countries can follow other advanced countries' example of overcoming the limitations of the traditional roles of universities and develop them into research universities, which will help drive the countries towards knowledge-based economies.

3.3. Post-Catch up Stage (Singapore)

The economic development timeline of Singapore can be viewed as a progression from labor-intensive industries in the 1960s, manpower skill in the 1970s, infrastructures in the 1980s, technologies in the 1990s, and finally the knowledge economy at present. The economic building stage of Singapore started about the same time as Korea in the 1960s. Fortunately for Singapore, the country had stayed stable in terms of internal politics before shifting into the economic-changing era, unlike in Korea where after suffering from the Korean War was still under military government. It was noticeable, however, that the process of economic development of the both countries began from an import-focused to an export-driven economy.

Significant changes in Singapore began in 1968 when the government emphasized improving and restructuring the country's economy through the support of R&D capability in the beginning of the economic era. In the same year, Singapore established the Ministry of Science and Technology and promoted the role of science and technology in the education system and the economy. Later on, it focused on developing R&D capability in specific fields such as information technology, biotechnology, robotics and artificial intelligence, microelectronics, laser technology and optics, and communications technology. One of the main functions of the Singapore R&D organization is the creation and improvement of manpower knowledge and professional skills.

Similar to Korea, Singapore initiated the same strategy of institutional-building in its early years of statehood. During that time, STI actors were assigned. Singapore created science institutes and universities, which play key roles in the development of quality human resources, high and advanced technologies, and knowledge-intensive products and services. Currently, the main STI actors are the National University of Singapore (NUS), the Nanyang Technological University (NTU), the Agency for Science, Technology and Research (A*STAR) under the MTI, and the NRF. The latter two are funding agencies, though the A*STAR also operates a research center while the NRF is purely devoted to funding non-A*STAR institutes (Benzarti, 2010).

Up to now, S&T development of Korea and Singapore has come to a comparable situation. It is a challenge for Korea to create a new development path based on creative innovation and to secure system capability for the production of creative knowledge and talent towards inducing a competitive society (Lee, 2011). The key challenges require new approaches, perspectives, and knowledge to develop capabilities to forecast future technologies. An element of this stage is drawn to inducing creative talent to move away from caught-up technologies towards innovating new ones. Korea is currently focusing on five major efforts to achieve the goal including: 1) strengthening admission to accept a portion of creative students, 2) setting up "creativity-nurturing programs" at the early education level, 3) strengthening the creativity of university students, 4) assessing the performances of universities and professors for creative educational capability, and 5) enhancing the ability of universities to serve the demand of companies and of society (Seong, 2010).

Similarly, Singapore, after a long-term focus on R&D development, is building up to becoming a leading global city of talent, enterprise, and innovation by trying to attract, develop, and nurture research talent. The strategy is put into five key thrusts; 1) sustaining PhD talent, 2) attracting international talent, 3) creating a world-class environment for scientific careers, 4) bridging academia with industry and 5) promoting science to young people and building up a pipeline of R&D talent. The Science and Engineering Research Council (SERC) focuses on fields essential to the Singaporean manufacturing industry. Under the SERC, seven research institutions involved in leading ICT, multimedia, and physical and engineering technologies were put together to form the *Fusionopolis* research center. Its counterpart for the biomedical sciences is *Biopolis*, a public-private biomedical research center composed of five institutions under the Biomedical and Research Council. This R&D clustering and co-location strategy has served Singapore well (Benzarti, 2010).

It is notable that the development of S&T in Korea and Singapore has come to comparable stages in sustaining and innovating new technologies and utilizing the talent of human resources. Korea has emphasized the concrete strategy of building up professional skills and knowledge from imported technologies to serve practical needs, which effectively resulted in a significant improvement of the country's overall economy and elevated the citizen's quality of life. Likewise, Singapore has achieved a reputable world-class education system that brings out talented researchers and intellects. This could be a moment for the two countries with so much in common to take stock and learn from each other's mistakes and accomplishments.

4. CONCLUSIONS

Overall, we found a strong correlation between STI indicators and the ASEAN countries' economic level. Results of the examination of STI indicators (such as publications and the knowledge economy index) for ASEAN countries matched well with that of socio-economic indicators. Although the ASEAN is diverse group in terms of stages of development and quality of life, it is still possible to categorize them into groups according to their socio-economic status and development stage in the context of the Korean Innovation Model. For instance, Singapore shines over its ASEAN neighbors, recording the highest GNI per capita in the region, and is seen as a country in the post-*catch up stage*. Malaysia, Thailand, Indonesia, Philippines and Vietnam, are countries with middle-income status and are still in the *catch up stage*. Finally, the last group includes low-income and underdeveloped Cambodia, Laos, and Myanmar, nations in the *institutional-building stage*. Although Brunei has a better fiscal position than most of the ASEAN countries due to its rich oil reserves, it is also part of this group because of its underdeveloped S&T ecosystem.

This observed clustering still exists in examinations of the S&T outputs of the ASEAN. Expectedly, Singapore leads in the number of publications and knowledge economy index, followed by the other countries in accordance with their socio-economic groupings. Although the ASEAN countries have recognized the importance of STI in national development, most of the countries are far from achieving a knowledge economy because of limited resources and capabilities. Those that have already included STI as part of their national development planning are constrained by the lack of R&D funding, ill-defined industrial policies, and laidback implementation. An innovation-driven economy is still a long way off unless the link between STI players and the industry are strengthened. ASEAN countries can follow in the footsteps of South Korea's STI trajectory by accurately implementing clear policies geared towards a holistic and long-term framework.

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