The Utilization of Science Technology and Innovation Performance Index (STIPI): Lessons Learned from Top Performing Countries

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Abstract:- Economic growth is accelerated by the power of science, technology and innovation (STI). For national policy-planners, a deep understanding of the importance of cross-sector linkages among key actors in National Innovation Systems (NIS) can help identify suitable policies. Thus, the appropriate policy-relevant indicators for monitoring and improving country STI performance play a crucial role in policy planning and evaluation process. Recently, STI Performance Index (STIPI) consists of 21 policy-relevant STI indicators, has been developed focusing on cross-sector linkages. The study aims to investigate how to utilize and apply STIPI in NIS framework by studying the lessons of top performing countries and using Thailand as a case study of developing country. Based on the results, we can state that economic growth has been enhanced by adequate STI policy, focusing on the promotion of cross-sector linkages among actors. These findings give the valuable lessons for developing countries, including Thailand.

***Keywords**:- STI performance; National Innovation System (NIS); STI indicator; cross-sector linkages.*

I. INTRODUCTION

Today's global economy, Science Technology and Innovation (STI) is the source of power of economic progress and well-being. Moreover, STI is a key determinant to help response to global challenges, such as climate change, ageing population, and sustainable development [1]. Gurbiel (2002) demonstrated that technology transfer was a crucial factor powerfully impacting on economic growth [2]. Encouraging public-private knowledge and technology transfer are a key activity of National Innovation System (NIS), and are also crucial for improving a country's STI performance [3, 4].

In competitive world, several countries are adopting the NIS concept in an effort to promote STI development as well as a benchmark to evaluate their performance in comparison with more successful countries. National-level policymakers can adopt policy experiences from countries around the world, seek answers to common problems and learn from good practices [5, 6].

During the last few decades a number of STI indicators have been proposed, which are expected to be used to design national STI policies as well as to benchmark national STI performance. Recently, there have been attempts to develop 21 policy-relevant STI composite indicators "STI Performance Index (STIPI)" which represents the new approach focusing on cross-sector linkages among NIS components [7]. When policy planners of developing countries try to implement policies to improve NIS of the country, they may encounter challenges because linkage of activities of each component is less developed in their NIS [8]. They need a help of appropriate performance assessment tools to evaluate and monitor the country's STI performance in the context of NIS.

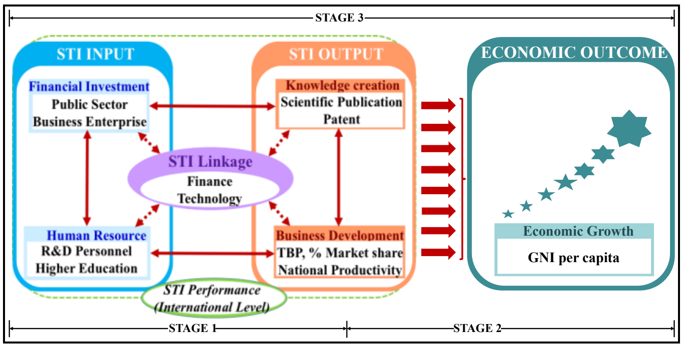
To date, there has been neither review of the correlation analysis between STI linkages and economic performance nor an examination of STI performance in terms of public-private interaction. This paper aims to examine how cross-sector linkages work in economic growth. In addition, this study demonstrates how to utilize and apply STIPI in developing countries' NIS by using Thailand as a case study. Finally, some crucial practices from top performing countries are analyzed and provide recommendations for Thailand to improve STI performance and further expand its economic progress.

This paper is organized as follows: Section II will present the correlation between STIPI and economic performance of selected countries. Section III will provide STI performance and linkage trends in STIPI of selected countries. Finally, in Section IV, some best practices from top performing countries are presented.

II. RELATIONSHIP BETWEEN CROSS-SECTOR LINKAGES AND STI PERFORMANCE TO ECONOMIC GROWTH

In this article, the author presents STI performance evaluation model as an entire cycle of innovation system. The model is shown in Fig. 1. It describes the complex input-output interaction process of NIS, components of which create and disseminate knowledge, skills, new technologies and commercialized products. Aggregated effects of these lead nation's economic development in macroeconomic level.

Based on this STI performance evaluation model, the author developed Science Technology Innovation Performance Index (STIPI), which includes five indicators for financial resource input; five indicators for human resource input; five indicators specifically focused to cross-sector linkages among sectors; three indicators for knowledge creation; and three indicators for business development [7]. The list of 21 policy-relevant STI indicators of STIPI is provided in Table A.1.



TBP: Technology Balance of Payments
GNI: Gross National Income
Fig 1:- Input-Output-Outcome model for NIS.

This section is to investigate a relationship between economic performance and STI performance as measured by STIPI. More specifically the relationship between cross-sector linkages of the country's NIS as measured by STIPI's linkage index and macroeconomic performance of the country as measured by its Gross National Income (GNI) per capita is analyzed. The study was conducted by using correlation analysis. Data is collected for ten OECD member countries (i.e. Belgium (BE), Finland (FI), Germany (DE), Ireland (IR), Italy (IT), Portugal (PT), Spain (ES), United Kingdom (UK), Japan (JP), and South Korea (KR)). In addition, same data for 5 Asian countries (i.e. China (CN), India (IN), Singapore (SG), Malaysia (MY), and Thailand (TH)) is collected. Individual time series data of STIPI's components are collected from various public databases as well as internationally recognized statistics [7].

Some researchers have indicated that in the complex and dynamic process of NIS, there may be several years of time delay between STI input and STI output. However, the determination of time lags found in NIS is still lacking sufficiently reliable supporting research [9-11]. In this study, the author assumes one-year and two-year time-lag between the transformation process of STI input to STI output (stage 1) and STI output to economic outcome (stage 2), respectively. Total time-delay between STI input and economic outcome is three years. The author measured STI performance in NIS process by calculating STIPI score from 2004 to 2013 and the level of national economic development from 2007 to 2016.

The findings from Fig. 2 provide the evidence that STI performance has a strong correlation to macroeconomic level outcome, with the correlation coefficient (R) of 0.749. This is also some proof that economic growth has stimulated by the cross-sector linkages in NIS with the correlation coefficient of 0.763. Based on these results, we can state that the countries which have high STI performance, have great competitive advantage in economic growth.

In order to investigate this correlation further at country level, three high performers in STI development, Finland, South Korea, and Singapore are selected and their success process were studied by applying STIPI to these countries. The study then examines the case of Thailand, which is one of the follower countries and the concern of the author.

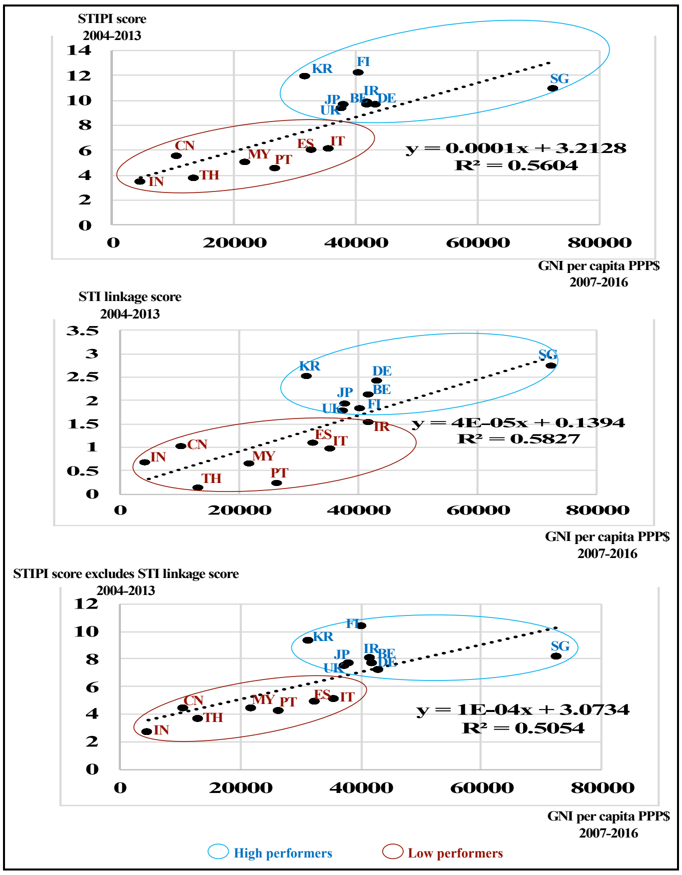


Fig 2:- Correlation analysis between STI performance and economic growth.

III. EMPIRICAL EVIDENCE ON THE STI LINKAGES AND STI PERFORMANCE IN SELECTED COUNTRIES

The study presents the empirical results of STI performance of four countries using STIPI as assessment tools. Finland, South Korea, and Singapore are three top performing countries, and also are seen as a learning model for Thailand. STIPI scores are calculated for STIPI's five dimensions. Data was prepared through three steps; data collection, standardization, and imputation of missing value [12]. Data collection covers 2004 – 2013.

Fig. 3 shows the trends in STIPI scores of four selected countries. Some interesting points will be mentioned in this section. Firstly, in terms of STI performance as measured by STIPI, South Korea was able to catch up Finland and Singapore in 2007. Meanwhile, South Korea shows great improvement in cross-sector linkage scores, resulting in the jump of its score in 2007. Secondly, Finland and South Korea recorded high scores of financial investments, but financial status in Finland are slightly decreased in the late period of study. Thirdly, three high performers are still on the growth trend of Human resource score. Fourthly, Finland and Singapore similarly show high levels of knowledge creation during the period of study. South Korea follows them a little bit behind since the scores of publication/researcher and citation/document have little or no improvement overtime. Lastly, Singapore keeps the position of the top performer in economic development scores, such as achieving a world market share of high-technology, and national competitiveness score.

This study assumes that linkages among STI components are crucial for improving NIS and national STI performance [3, 4]. From Fig. 3, it seems apparent that South Korea and Singapore are still gaining high positions, while Finland is lower and slightly decreasing. In order to investigate more specifically scores of cross-sector linkages Figure 4 is prepared. There are two groups of indicators describing the linkage activities of NIS; cross-sector financial flow and cross-sector technological cooperation. The former is composed of two indicators; the cross-sector financial flows include Public Sector Expenditure on R&D (PSERD) financed by industry, and Business Sector Expenditure on R&D (BERD) financed by government. The latter, i.e. cross-sector technological cooperation consists of three indicators; the number of patent with Industry-University-Research Institute cooperation; the USPTO (US Patent and Trademark Office) issued patent citing scientific papers and other references; and patent with foreign co-inventor. All variables are normalized by divided by the number of researchers in the country (Full-time equivalent (FTE)). STIPI is a country-size neutral index.

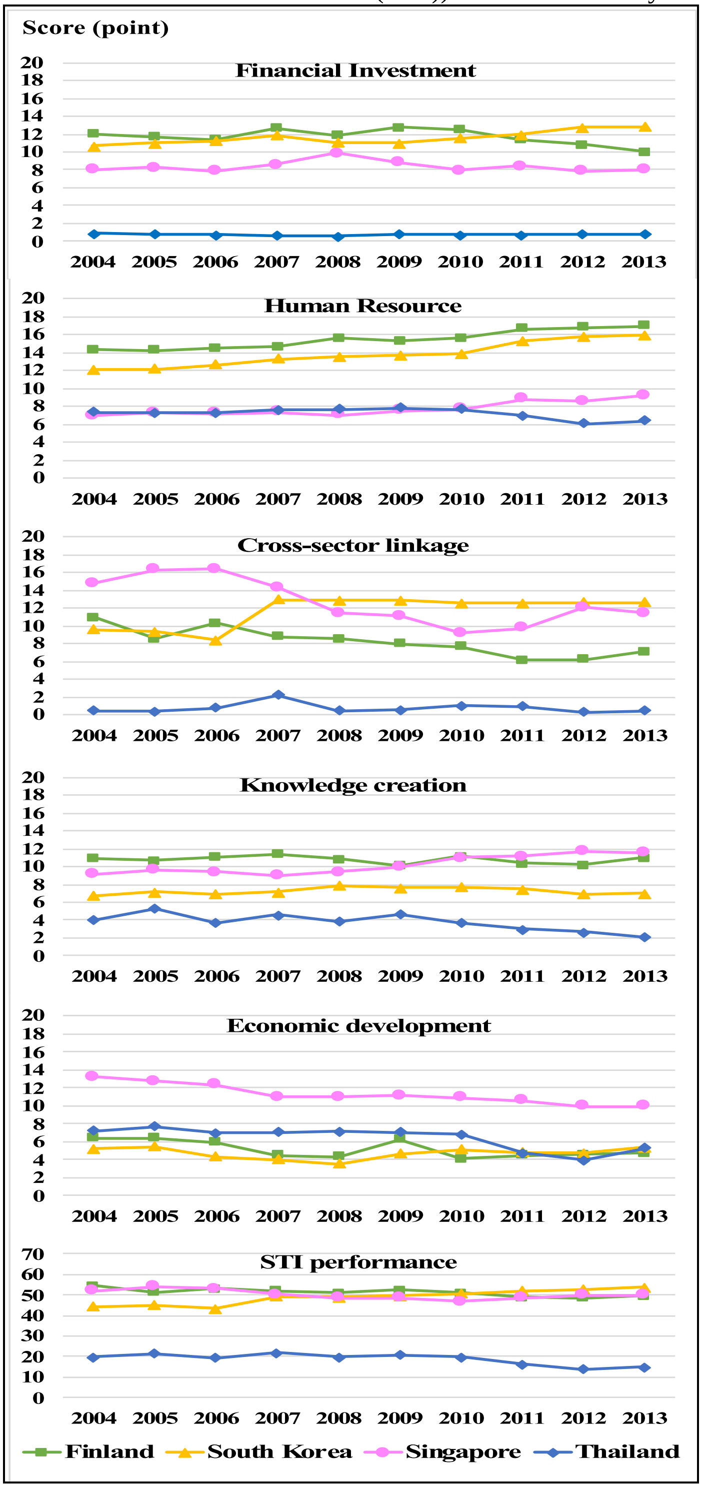
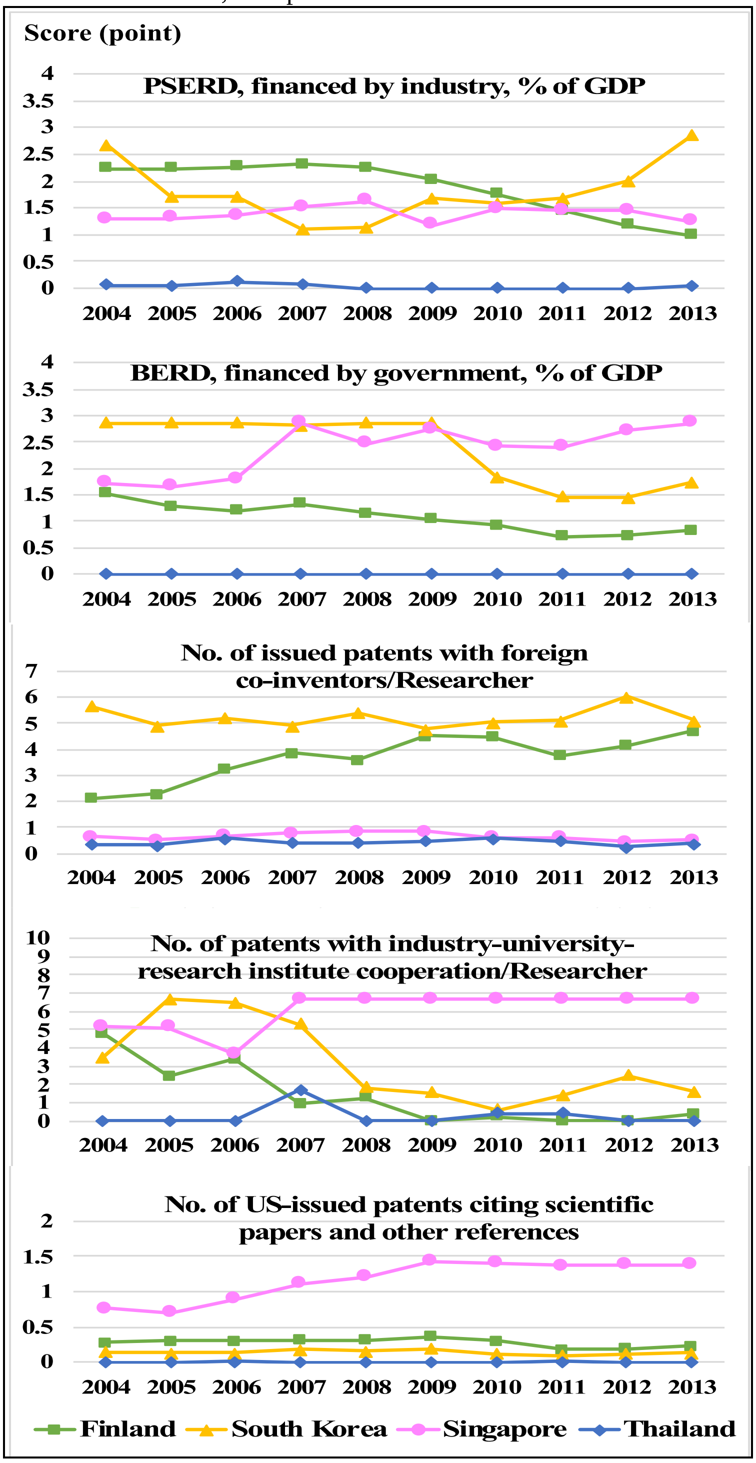


Fig 3:- Trends in STIPI of Finland, South Korea, Singapore, and Thailand, 2004-2013.

Fig. 4 presents that South Korea is especially remarkable in two areas, cross-sector financial flows from industries to government and international patent cooperation. Korea also shows some interesting points in interaction of monetary resource for STI. Between 2009-2013, the trend of private sectors financing to public sector slightly went up, the trend of government financing to industries slowly declined. It corresponds to the country's policy development during that time period. Along with Korean businesses find some profits to put their recourses into public research sector, it replaces government spending. Singapore ranked top in the cross-sector technological cooperation, specifically in the number of patent with three actors cooperation and citing scientific references. The cross-sector financial flows of Finland show declining trend, the number of patents in term of national cooperation also dropped throughout the same period. The number of patents with foreign co-inventor, Finland and Korea show the growing trend, while Singapore remains stable.



PSERD: Public Sector Expenditure on R&D
BERD: Business Sector Expenditure on R&D

Fig 4:- Trends in cross-sector linkages of Finland, South Korea, Singapore, and Thailand, 2004-2013.

IV. LESSON LEARNED FROM TOP PERFORMING COUNTRIES TO THAILAND

NIS is the system which incorporates the body of policies, regulations, institutional and infrastructure arrangements and activities of interacting actors; firms, universities, and government agencies concerned with production of STI within national borders. The concept of NIS is emerged in several advanced countries in late 1990s and is diffusing to many developing countries. These countries are adopting the NIS approach in an attempt to repeat these same successful results of forerunners [5, 6, 9].

Recent efforts presented in European Innovation Scoreboard 2017 reported the innovation leaders in Europe. Denmark; Finland; Germany; the Netherlands; Sweden; and the United Kingdom show the highest Summary Innovation Index (SII) scores in the dimension of financial support for linkages [13]. The author attempted to find what happens in these countries' NIS and learn these successful experiences by analyzing their STIPI scores. Three top performers (Finland, South Korea and Singapore) and Thailand are selected for this study.

STI development of top performing countries took their initial stage during the 1960s, then the world economic growth was slowdown because of the economic crises of the 1970s and 1980s. Finland, South Korea, and Singapore successfully revived from the crises and formulated salient STI capabilities such as human resources, infrastructure in the meantime. From 1990s through the present, STI development in these countries has shined to sustaining and innovating new technologies and developing knowledge-based economy as well as inducing creative talents from local and overseas sources [14, 15].

Because of the limitation of available international statistics, the time scope of this study is rather limited. UNESCO Institute of Statistics (UIS) only provides such data from 1996. Thus, the study conducts investigation of STI investment in selected countries using data from 1996-2015. Fig. 5 provides the triangle charts that present the source composition of STI investment funds. Three corners of the triangle represent government (bottom-left), domestic industry (top) and foreign source (bottom-right). If funding source is solely from government, the circle is located on bottom-left corner. If source composition is balanced the circle is located at the center of the triangle. Also, pie-chart shows the composition of funding source. The size of the circle represents the volume of total investment. By following the trajectory of the country's investment source circle, historical development trend will be visibly understood.

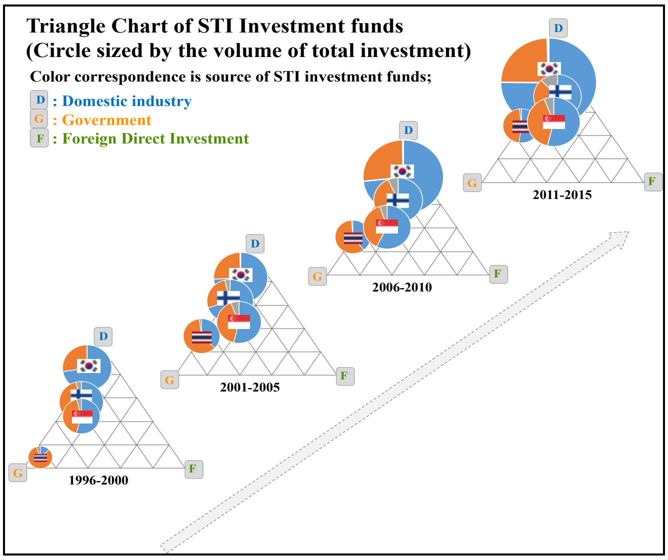


Fig 5:- Triangle Charts of STI investment funds, 1996-2015.

A. Finland

Finland's STI evolution has gone through four stages: (1) initiating the basic structures in the 1960s and 1970s, (2) greater technology push with a focus on intensive development and use of ICT in the 1980s, (3) developing a knowledge-based economy and the NIS in the 1990s (including recession period in 1991-1993), and (4) being early producer of ICT and of setting technology standards, and building innovation ecosystems in the 2000s [15, 16]. Once Finland had been a resource-based economy relying on forest industry until the mid 1980s, but today Finland has been moving into an innovation-driven economy.

Finnish NIS case is worth to learn for every followers. Finland's NIS has been enhanced by institutional structure and the solid government's policy to promote its development. It has not only been strongly government lead as a main coordinator, and a builder of shared and prioritized R&D. But also business sector played a leading role in the formation of NIS. As can be seen from Fig 5, Finnish companies have mainly contributed around 70% of R&D investment in the country during the period 1996-2010, and 60% in 2011-2015, while the share of public finance is around a quarter.

In term of networking, the government has promoted a cluster-based approach to coordinate scattered R&D activities into STI communities through collaborations among universities, research institutes and private companies. For instance, Nokia plays a key role in the ICT cluster and whole Finnish economy. Nokia has gained advantages from Finnish NIS such as the talented labor force under world's best education system, and R&D funding from Finnish Funding Agency for Innovation (Tekes). Meanwhile, Finland has benefited from Nokia. Knowledge and technology has been diffused from universities through Nokia. Ali-Yrkkö (2010) reported that during the 2000s, Nokia received R&D funding an average of 24 projects or average amount of 0.5 million EUR from Tekes [17].

In addition, nationwide networks of technology parks and centers of expertise were set up and became important for technology transfer and commercialization of research results. Moreover, Nokia's international research projects have also significantly activated as a result of the company's global operations [17]. In consequence, Nokia's share of R&D expenditure accounts about a half of private sector, and one third of country total. Between 1998 and 2007, Nokia alone accounted for 3-4 % of Finland's annual GDP. In the 2000s, Finland became a major exporter of electronics and high-tech products and its productivity were very high.

In the last few years, however, Nokia's phone business had been shrunk dramatically due to the increasing significance of the smartphone segment. But government R&D spending has not been dropped and the country's foreign trade surplus is steadily increasing. As shown in Fig 5, foreign investment flows into Finland has been around 5-7% of total investment in 1996-2010 and 12% in 2011-2015. Finnish innovation ecosystem has not been too rigid with a few leading industrial sectors. On the contrary, the Finnish ICT sector has shifted from manufacturing products to producing services and software. Furthermore, Finland is now recognized as at the forefront in industrial sectors: game industry "Angry Birds", clean technology (renewable energy, waste management, and emission reduction) and biotechnology in the fields of biomedical and gene technology [15]. In the late 2010s, the average of Finland's GERD is 3.3% of GDP, being a strong position among OECD countries.

B. South Korea

South Korea case is a typical global model of export-driven economic success. So far as we know, its success begun after the Korean war in the period 1950 to 1953. The Korean NIS has evolved through three phases: (1) a factor-driven stage with imitated technology during the 1960s and the early 1970s, (2) an investment-driven stage from the 1970s through the mid 1990s, (3) an innovation-driven stage and also innovation and industrial cluster in the 1990s through the present [18].

Since the 1970s, the nation has developed a great number of STI mechanisms to overcome the lack of natural resources and to prepare technological base. The higher education system and government-funded research institutes have been created and boosted its national R&D efforts which provided tax incentive for private companies. The Science Park "Daedeok" was also created.

Between the 1980s and 1990s the country went through transition to technology-based economy and began its modern development. The large industrial conglomerate "chaebol" such as Samsung, LG and Hyundai grew rapidly and pointed to high-tech innovative industries by active learning, diffusion of R&D, importation of foreign technology, and restricted foreign direct investment [8, 19].

During the last two decades, the nation has moved to a knowledge-based economy. Particularly, after the financial crisis in 1997, the whole economy was restructured, and liberalized. The government is continuously enhancing university research capacity, strengthening of research institutes, and promoting knowledge-intensive industries. Along with the globalization, the country's regional innovation system (RIS) and industrial clusters have been regarded as the key strategies in 2000 onward [20].

Korea has strengthened their economy and became ranked at the top runner of the economic growth race during the last five decades. The GNP per capita of Korea was less than US$100 in 1960, but it increased to US$25,000 in 2015. One characteristics of the achievement is a public-private interaction in boosting the innovative economy, which cannot be accomplished by government effort alone it also requires private sector's active collaboration. Government research institutes (GRIs) have launched National R&D Programs along with priorities aimed at supporting private industries who develop high technologies. Nowadays, major R&D investment is found in the area of green technology, network technology, emerging communication technology and space.

Moreover, Korea is open to learning from outsiders and open up the country to trade and capital movements [20]. As seen from the great number of issued patent with foreign co-inventor. Korea's STI performance is largely attributed to a strong linkage at both international level and inter-regional level. The former is NIS and the latter can be called as Regional Innovation System (RIS). Such a remarkable achievement in the economic growth is closely related to R&D funding by private sector, presented in Fig. 5, more than 70% of Korea's R&D was funded by private sector. It is also confirmed by high score of cross-sector financial flows presented in Fig. 4. Industry financed investment to public sector has significantly increased since the late 2000s.

Increase of Korean investment was the result of strategic approaches to build strong NIS. The economy is keeping strong growth with an average GDP growth of 8% and approximately 3% of the country's GDP is spent on R&D.

C. Singapore

Singapore has accomplished impressive economic growth since its independence in 1965. Singapore's NIS has put its status near the top-ranking of the world's innovative economy. The transformation of Singapore includes four phases: (1) the industrial take-off stage from 1965 through the mid 1970s, (2) the local technological deepening stage from the mid 1970s through the late 1980s, (3) the applied R&D expansion stage from the late 1980s through the late 1990s, and (4) the high-tech entrepreneurship and knowledge-based economy stage from the late 1990s onward [21, 22].

Singapore began the first phase with low-technology and labor-intensive industries relying on technology transfer and investment from foreign multinational corporations (MNCs). Singapore's Economic Development Board has been able to react quickly to pull together attractive, specialized packages for supporting MNCs. Singapore offered tax incentive promotions and grants to MNCs for locating and manufacturing their products in Singapore. This mechanism effectively activated economic growth because a dynamic sectoral allocation of industries and approaching of international human talent to the country. However, many domestic industries faced challenges to overcome disincentive and invested in indigenous innovation. During this period, the government laid the foundation of educational system, emphasized on technical education. The Singaporean education system became one of the best in the world.

In the second stage, MNCs upgraded their operations and local supporting industries had been developed. MNCs provided investments in R&D. The government also fostered activities focusing on S&T infrastructure, Science Park, entrepreneurship program and higher education. In the following the recession in 1985, government implemented venture capital industry assistance program, open-door immigration policy, and trade liberalization.

In the R&D expansion stage, applied R&D activities was increasingly developed by MNCs, The Government has prioritized opening up opportunities for private sector, and building partnerships across the sectors. Public research institutions (PRIs) has developed to support innovative MNCs which coordinates research programs, commercialization, and licensing. Knowledge-intensive services and high-technology manufacturing became key drivers of developed economy.

The fourth stage is the transition to knowledge-based economy by emphasizing domestic STI capability in biomedicine to complement existing competence in electronics, chemicals, and engineering, local high-tech start-ups, and science-based industry. Singapore has capitalized on its R&D strengths leading to a world class biomedical hub. The country has also utilized the co–location of R&D capabilities by the creation of targeted clusters such as the pharmaceutical Biopolis and the formation One-North R&D complex for fostering collaboration between industry, research institute and academia [23].

Until now, Singapore is one of Asia-Pacific region STI hubs: an international business and superior STI hub with the highest GDP per head. One of this result is a large supporting industry for MNCs. It can be seen from Fig.5, there is increase of FDI by MNCs. Important here is the fact that most part of FDI is not in manufacturing facilities but in STI facilities. It often happens that a firm based a hub in Singapore acquires manufacturing facilities in other countries. The amount of FDI into Singapore is continuously growth, it was less than 4.8% of GDP in 1970 [24], but it increased to 23.8% of GDP in 2015. As a percentage of GDP, R&D expenditure rose from 1.8% in 2000 to 2.4% in 2014. In addition, as seen from Fig. 4. The great number of patent and knowledge sharing between business and non-business entities may reflect how STI capacity are strengthened with the assistance of international linkage.

D. Thailand

Thailand's NIS has been described as being in the process of transitioning from lower to upper-middle-income status and agriculture-based to innovation-driven economy [25]. There are four stages for the STI development. Thailand started the first phase by formulating STI government agencies and universities and implementing national research policy and strategies for S&T, the environment, and energy in order to bring about the socio-economic growth and national capability building from the late 1950s through 1980s.

In the 1980s, the nation developed technology plans and established public research institute in order to promote S&T for agriculture, manufacturing, and energy. In addition, the twenty-year S&T master plan (1990-2011) started to conduct, support, coordinate, and promote efforts in scientific and technological development in the public and the private sectors. The national R&D centers were formulated to build R&D capabilities in the field of natural resources, genetic engineering, biotechnology, electronics and computer. These centers have served as a linkage point between research communities and industrial clusters.

Since the 1990s, Thailand' NIS has been in the state of transition towards economic growth and more interaction among its actors. Thailand's National Science and Technology Development Agency (NSTDA) was established for conducting R&D in the four main technology areas: ICT, biotechnology, materials technology and nanotechnology. NSTDA also supports R&D in universities and other institutions, promotes a knowledge-based society through R&D, technology transfer, STI human resources development leading to encourage innovation.

After Asian economic crisis in the late 1990s, Thailand paid attention to integrate knowledge learning and linkage creation for supporting industries and enhancing their regional competitiveness [26]. In 2002, the first Thailand Science Park (TSP) was formulated with the objective to make it a national technological innovation hub [27]. The country developed ten-year S&T plan (2004-2013) to implement the NIS concept along with cluster approach for building industries growth towards a knowledge-based economy [28]. Meanwhile, the innovation system in Thailand is for the first time systematically introduced by strategic policies and frameworks of National STI Policy and Plan 2012-2021. This plan has identified challenging issues impacting the development of STI that better serve the needs of economy and society throughout the next decade [25].

In recent decades, private industries have increasingly contributed to STI investment. As the Fig. 5 presented, the share of business sector clearly shows the increasing trend. In 2011-2015, it grew 52 %, and the business share reached 70% in 2015. This indicates that private sectors have appeared as a greater attendance of R&D investment to sustain competitiveness. However, R&D expenditure in Thailand still accounted less than 1% of GDP (0.6% in 2015). Thailand still needs to learn from other countries to continue strengthening of STI capabilities and achieve its goals.

V. DISCUSSION AND CONCLUSIONS

The study investigated how to utilize and apply STIPI in NIS framework by analyzing best practices of top performing countries and that of Thailand as a case of developing country. The findings demonstrated that the economic performance and STI linkage score has a strong correlation at macroeconomic level. Based on these results, it can be said that the countries with high performance on public-private interaction have great competitive advantage in economic growth. In case of Thailand, cross-sector financial and knowledge flows is still low level and the total R&D expenditure/GDP is also still less than 1%. Therefore, Thailand needs to learn from successful countries in line with this context. In particular the interaction between business and non-business sectors should be strengthened in STI investment and technological cooperation.

Three top performing countries are selected through evaluating STIPI. These are Finland, South Korea, and Singapore. These countries are also identified as STI top performers in other existing STI indices and study reports. The study presented the interesting lessons learned from three country cases, which the latecomer countries can adopt, especially for the improvement of cross-sector linkages. But it should be noted that each country has its own socio-economic conditions. Simple introduction of good practices of other countries cannot produce the same results. Policy planners should carefully learn what kind of adjustments should be made.

Three countries have transformed their NIS into the knowledge-based and innovative stage for the further expansion of their economies. The following part will provide the key practices that we would like to recommend to the poorer performers. Although it will be helpful for the countries in order to enhance their collaboration among public and private sector, it can be applied if the policy implementers apply those lessons by preparing appropriate environment and condition.

Firstly, the government is the main actor in integrating all the actors, their functions and facilities for R&D, innovation, technology transfer, and utilization in order to improving their NIS. With appropriate cross-sector linkage policy, the businesses find some profits to induce their involvement in academic and public research institutions, and thus the government spending can be reduced. It can be seen from South Korea case in 2009-2013, the trend of private sector's finance to public sector slightly went up, the trend of government finance to industries slowly declined.

Secondly, STI policy should integrate all relevant policies undertaken by national government, including R&D spending policy, human resource development policy, trade policy and even market creation policy. It provides the entire nation with clear direction of the STI policy. Therefore, roles and responsibilities of each actor are clearly understood by every sectors and create cooperative attitudes among them.

Thirdly, there is a strong agreement that the successful economic development would not be possible without strong educational system. It is well-known that the education systems of those three countries are always highly rated in the world. The provision of good education is the fundamental precondition of the knowledge-based society. Policy efforts to enhance cross-sector linkages will bring fruitful results only when highly-skilled human resource is available throughout the economy. Then knowledge and technology may diffuse to other sectors and improve the performance of the country's NIS. Policy planners of the follower countries should put emphasis in building-up their skillful human resources along with S&T capabilities.

In addition, there are individual success cases that formulated and implemented under country-specific conditions. Those who would like to learn from three countries should take note of that point.

In Finnish NIS, Nokia has been playing a dominant role in STI development. Nokia had been the "enabling factor" in the past decades. However, Finnish innovation ecosystem could still be a model even in countries where such enabling factor does not exist. Finland itself proved it. Finnish innovative ecosystem is surviving even after the increased importance of competition in the smartphone industry. Government spending has not been dropped, and Finland's foreign trade surplus is rapidly increasing. Finnish ICT sector has recently shifted from manufacturing products to producing services and software. Remarkably, Finland is keeping high-level private sector R&D expenditures despite the fact that Finnish government has neither substantial direct nor indirect R&D subsidies. The high-level private sector R&D spending can be explained by its tax policy and business attitude orienting human-capital-intensive production. Finland has the lowest statutory tax rates on business income (29%) among OECD. Based on these, it can be said that tax incentives and a sort of business sector culture to focus on human-capital-intensive production is compensating the lack of "enabling conditions" [29].

In the case of South Korea, innovative restructuring of Korean conglomerates (chaebols) has been a crucial factor in the transformation process of the country's NIS. Korea's technology development performance as observed in the number of issued patent with foreign co-inventor is largely attributed to a strong international collaboration effort of the Korean conglomerates, which keenly pursuing international linkage. And this effort has been adequately supported by government policy instruments such as mentoring for start-ups, technology development subsidies, and other kind of financial support. These policies helped not only chaebols but also many local communities to attract creative talents and investment, both local and foreign.

The success story of Singapore gives another case which are promoted by government facilitation of technological adoption from MNCs. Singapore government has eagerly promoted the establishment of corporate R&D hubs in Singapore, especially targeted to big MNCs. In order to make Singapore as the best place for locating such hubs, the government has invested a big amount of money to its universities and public research institutes during last few decades. Reputed overseas talents has been recruited to universities and good laboratory infrastructure had been provided by back-up of the government. Such public-private sector alliances have greatly influenced strong international linkage in high technology sectors.

Through this study, STIPI is applied to selected OECD and Asian country's STI performance analysis. In Section II, the correlation between economic performance and STIPI's linkage index is presented at macroscopic level. In Section III, three top performers, Finland, Korea and Singapore are selected, and individual linkage index of those countries are examined in detail. Analysis of Thailand is added to make comparison of top performers and the late comer country. The result showed that top performers present a high-level score of STIPI's linkage index in the last ten years. In Section IV, a bit descriptive review of the top performers and Thailand case is given. Such microscopic level analysis also seems to endorse the correlation between economic performance and STI linkage of the country. Finally, in the last Section, policy level analysis is made for three top performers and lessons for STI policy planners are extracted. We should note that while country-specific enabling factors do exist, the lessons learnt in the fifth chapters can be applied to other countries when appropriate consideration is given. As a conclusion, STIPI can be a useful monitoring tool for STI policy planners and implementors to monitor and evaluate STI performance of the country concerned, including Thailand.

VI. APPENDIX

Dimension	Indicator		Data source
Financial investment	GERD as % of GDP		OECD stats/UNESCO Statistics/ World bank/GEM Report/EURO Stats
	Government-financed GERD as % of GDP		
	Industry-financed GERD as % of GDP		
	BERD as % of GDP		
	Venture capital investment as % of GDP		
Human Resource	R&D personnel (FTE)/ 1,000 employment		OECD stats/UNESCO Statistics
	Researcher (FTE)/ 1,000 employment		
	No. of students enrolled in tertiary education (ISCED 5-8)/ 10,000 population		UNESCO Statistics/World bank
	No. of students graduated from tertiary education (ISCED 5-8)/ 10,000 population		
	Pupil-teacher ratio in tertiary education*		
Cross-sector linkage	Financial flows	Government-financed BERD as % of GDP*	COSTII/OECD stats/USPTO
		Industry-financed PSERD as % of GDP**	
	Technological cooperation	No. of patent with Industry-University-Research Institute cooperation/Researcher (FTE)	
		No. of USPTO issued patent citing scientific papers and other references/Researcher (FTE)**	
		No. of patent with foreign co-inventor/Researcher (FTE)	
Knowledge creation	No. of Scientific publication/Researcher		Scimago/OECD stats/ UNESCO Statistics
	No. of USPTO issued patent/GERD		USPTO Patent Full-Text and Image Database (PatFT)/OECD stats
	No. of Citation/paper		Scimago/OECD stats/ UNESCO Statistics
Business development	TBP as a % of GERD		OECD stats/World bank/IMD
	% Market share of high-technology*		
	National competitiveness score (IMD)**		

Table 1. The composite indicator of STIPI

*Modified indicators, **Newly proposed indicators

GERD: Gross Domestic Expenditure on Research and Development
GDP: Gross Domestic Product
BERD: Business Enterprise Expenditure on Research and Development
FTE: Full-Time Equivalent
ISCED: The International Standard Classification of Education
PSERD: Public Sector Expenditure on Research and Development
USPTO: United States Patent and Trademark Office
TBP: Technology Balance of Payments
IMD: International Institute for Management Development
GEM: Global Entrepreneurship Monitor
GII: Global Innovation Index
SII: The Summary Innovation Index
COSTII: The Composite S&T Innovation Index
STIPI: STI Performance Index

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