

Technology Gaps among South East Asia Countries from the Perspective of Technology Achievement Index

Chyntia Ika Ratnapuri, Tutik Inayati

Abstract: Countries within South East Asia regions have gaps in technology development, where how much the gaps exist is difficult to measure. This study explores the gap among countries utilising Technology Achievement Index as the main indicator and tool and analyse how discrepancies may occur. The results show large amount of data absences that makes acknowledging recent gaps difficult. Despite of data unavailability, gaps among countries are not as dreaded. Among all countries, Singapore still takes the lead of overall Technology Achievement Index compared to other South East Asia countries whilst Timor-Leste becomes the lowest of overall Technology Achievement Index. By knowing the gaps in the Technology Development in South East Asia, this study expected to give a contribution to technology policy makers so that developing countries in the South East Asia can have a room to continue to thrive in economic development because technology advancement is one of the significant factors in the economic growth of a country. Future regional agreements in South East Asia are needed to achieve mutual benefits of technology development especially for science and technology policy makers.

Keywords: Technology measurement (O33), Regional development (R58), Integration (F63), Economic Growth (F62).

I. INTRODUCTION

Developing countries still have rooms to grow in terms of economic circumstances and many of them start to catch up eliminating the deficiencies to become developed countries. Regardless, the world is changing into a more forward condition owing to technology. The technology advancement significantly influences the economic development today more than other aspects of development. Southeast Asia (SEA) is one of regions consist of many countries that should play an important role in technology development. Unlike European Union, SEA consists of developing countries. This means that SEA countries should at least have room to grow in terms of economic and technological development; if they benefit from these opportunities, they could excel in developing themselves and other countries within the same region. However, in order to comprehend how they might be able to assist each other, these countries should recognise their position in technology development within SEA countries. Therefore, this research would like to acknowledge the gaps among countries in SEA and study the discrepancies in order to generate recommendations for policy makers in SEA regional development.

Many policy makers think that the technology achievement or development indicator is based on Research and Development expense; while this is not utterly wrong,

Research and Development budget is considered as input instead of outcome that should be the results of input or effort (Ali et al., 2014). Research and Development (R&D) does not also significantly improve innovation, such example Wang et al. (2010) mentioned that the relationship between R&D and outcome of orientation on innovation is negative curvilinear; therefore, there is no specific relationship between both variables. Cases in Southeast Asia were also pointing at the lack of capable human resources in R&D and created the gap between technology development and national competitiveness (Wang, Chien, and Kao 2007). Hence, there should be another indicator that should emphasize more to the outcome instead of input. In this study, authors think it is appropriate to pursue Technology Achievement Index (TAI) as an indicator for technological development comparison among countries. Southeast Asia is one of the biggest markets in the world; with enormous population in Southeast Asia, the potential to achieve grand technology innovation should be inevitable. However, the reality is there are still discrepancies occurring associated to technology innovation.

II. LITERATURE REVIEW

Technology development comes in different terms and meanings. Ali et al. (2014) defines technology development as technological process, which means improvements that occur continuously in process that apply in scientific fields in form of knowledge, skills, knowledge, and the ability to improve the optimal output that are available to the society. Technology development needs investments both from public and private sector, which makes the spending for R&D considered to be essential for the development in a country. However, there is no clear relationship between R&D and innovation as an output Wang et al. (2010). However, R&D spending is still considered worldwide as one of main factors to enhance technological development (Guloglu and Tekin, 2013). In most of cases, R&D has positive relationships with the number of patents; which will lead to the innovation and product release in the case of Artz et al. (2010). They conducted their research in private firms and concluded that product announcements have positive relationship with performance of the company. This finding was also supported in private industries, such as chemical and computer industries (Ahuja and Katila, 2001; Hagedoorn and Duysters, 2002). Therefore, patents are often utilised as a proxy for technology development (Guan and Gao, 2009).

Technology Achievement index is one of the measurement tools for comparing countries in terms of development; in other words, how countries perform technologically compared to other countries.

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Technology Achievement Index, or TAI, was first developed by Desai, Fukuda-Parr, Johansson, and Sagasti in 2002. Desai generated ranks from 72 countries in the world; hence, they created TAI-02, the first Technology Achievement Index that focused on measuring outcomes on technology sector rather than inputs that are often used as measurement tool for technology development. After Desai, (Nasir *et al.*, 2011) renewed the ranking with new data from 91 countries, reconstructing the ranks of TAI worldwide. Here, they generated TAI-09. Another differentiation of TAI-09 by Nasir *et al.* (2010) is the proposition of standard deviation to understand the variation of the data among countries analysed was introduced for the first time. Another research about Technology Achievement Index is by Ali *et al.* (2014). Different from Desai and Nasir, Ali *et al.* (2014) only focused on Muslim countries, which comprised of 22 countries. This has become the TAI-13 with the limitation of Muslim countries. In conclusion, TAI is one of highly regarded tools to measure technology capability of a country; however, the number of researches that used TAI as the tool is very small.

Eventually, using TAI as a proxy to measure technology development is one possibility that we should consider because it provided rational and had relatively easier approach. Therefore, this study practises method for measuring technology development in smaller scope, Southeast Asia countries, as research objects are seen to lag behind other Asian regions. Technology development in Southeast Asia is also very seldom to discuss in academic researches. Innovation system, however, was mentioned by Asheim and Gertler (2006) who, in their research, stated that location would influence the innovation activities, which means that within geographical parameter, research or innovation activities can spread and result to the decreasing gap of technology or innovation development among countries.

III. METHODOLOGY

To be able to measure TAI, this study collects data from many sources. While collecting data, authors encountered several problems. First, Singapore as a most developing country in ASEAN does not provide complete data related to education. Second, data availability did not exist in all countries; hence, we need to find a system that can accommodate all countries. Hence, we use information on the latest year that has the most complete data.

Table 1. Indicators and sub indicators for TAI

Indicator	Sub indicators	Year	Source
Diffusion of old technology	manufactured exports)	2014	World Bank
	Electric power consumption (kWh per capita)		
Human skills development	Telephone mainlines + cellular subscribers (per 1000 people)	2016	United Nation of Development Programme
	Gross enrollment ratio, primary to tertiary		
Human skills development	Gross enrollment ratio of tertiary degree in science, engineering, manufacturing, and construction major	Most recent year available	UNESCO database

TAI itself consists of four indicators with two sub indicators for every indicator. These four indicators and their sub indicators' data year and source are explained in table 1. As shown, the data year is different between one sub indicator to another because authors proposed to normalise the countries' similar circumstance to objectify the index. To calculate the index, the data is normalised within its sub indicators to achieve objectified results. Therefore, the calculation for each sub indicator are seen in formula below: Where N_j is the data for each country on its sub indicators, J_{min} is the minimum value available for each sub indicator, while J_{max} is the maximum value (adopted from Desai *et al.* (2002) and Nasir *et al.* (2010)). To calculate overall index, TAI averages the number of all indicators. Afterward, we rank country with highest to lowest score of average.

IV. RESULTS

Since data availability becomes one of the problems, it is difficult to make justified analysis based on data available with similar problem also occurred in Nasir *et al.* (2010)'s problem. To tackle this problem, author used same year for each indicator to justify the index with the most complete data of all countries analysed, similar to Nasir *et al.*'s calculation data. Table 2 to 5 are presented below for TAI results.

Indicator	Sub indicators	Year	Source
Creation of technology	Patents granted to residents (per million people)	2014	World Bank
	Recipients of royalties and license fees (US\$/person)	2017	World Bank
Diffusion of recent innovation	Internet users (per 1000 people)	2013	World Bank
	High-technology export (percentage of overall)	2016	World Bank

Creation of technology

Table 2. Creation of technology index

Creation of Technology				
Country	Patent applications, residents	Charges for the use of intellectual property, receipts (BoP, current US\$)	CT Index	Rank
Indonesia	702.0000	49,809,737.2171	0.2724	4
Malaysia	1,353.0000	286,428,399.3120	0.5365	2
Thailand	1,006.0000	101,450,000.0000	0.3922	3
Philippines	334.0000	16,914,324.0400	0.1292	6
Singapore	1,303.0000	8,276,119,267.8820	1.0000	1
Brunei D	26.0000	0.0000	0.0100	7
Lao's PDR	0.0000	0.0000	0.0000	10
Cambodia	2.0000	980,846.5859	0.0008	8
Vietnam	487.0000	0.0000	0.1869	5
Timor-Lest	0.0000	0.0000	0.0000	11
Myanmar	0.0000	2,365,700.2899	0.0001	9

In creation of technology index, patents application and charges for intellectual property are chosen as sub indicators. After calculation, we found that Singapore has the highest index for patents and charges for intellectual property combined. It suggests that Singapore has the highest expertise to create technology compared to other countries South East Asia region. Singapore is well known as the country that is most developed. And as a country well known for most developed, Singapore has the highest patents applied to residents where citizens of Singapore could benefit from newly created technology. Similarly, Singapore is also recognised to have one of the highest patent numbers in Asia, which shows that income received from that patent becomes the highest in Southeast Asia. The gap between Singapore and Malaysia, as the second highest index, is also astonishing: almost half of Singapore's index. This gap shows that there are discrepancies in technology creation between Singapore and other SEA countries. Meanwhile, Lao's PDR and Timor-Leste's data were not to be found; hence, both countries are to be found at the bottom two. Even though Timor-Leste and Lao's PDR are not being determined as zero innovation; nevertheless, considering the history of Timor-Leste, who declared their independence in 2002, the country may not be focusing on current discovery or innovation, yet. Lao's PDR also did not publicise their data comprehensively. However, according to United Nations (2019), innovation will be future agenda for this country; hence, previous years are not reflected as supporting times to produce innovation. This data expectedly will arise in the following years.

Diffusion of recent innovation index

Table 3. Diffusion of recent innovation index

Diffusion of recent innovation

Country	High-technology exports (% of manufactured exports)	Internet users	DRI Index	Rank
Indonesia	7.0527	25.450	0.096	8
Malaysia	43.5738	78.788	0.860	2
Thailand	20.0933	47.505	0.391	6
Philippines	49.2380	55.500	0.747	3
Singapore	46.9944	84.450	0.936	1
Brunei D	15.2422	90.000	0.653	4
Lao's PDR	9.4928	21.870	0.094	9
Cambodia	0.2588	32.398	0.077	10
Vietnam	28.2083	46.500	0.466	5
Timor-Leste	9.7816	25.246	0.122	7
Myanmar	0.2600	25.073	0.024	11

Table 3 consists of data from recent innovation diffusion. Similar to table 2, Singapore has stood out as the highest index holder, while Malaysia is the second. In the meantime, the lowest values, Cambodia and Myanmar were the 10th and 11th rank, respectively. In this index, the data collected were from different years (high-technology export's data was 2016 and internet users' data was 2013). In this case, many countries had improved their performance and some also reduced their performance. Nevertheless, Singapore and Malaysia still excel in this particular index considering difference of data measurement year.

Myanmar is considered as the lowest in recent innovation index due to the type of export that this country performs; according to Workman (2018), Myanmar's top exports are primarily agriculture and mining, which are categorised as low technology exports. Meanwhile, Cambodia even has negative trade balance, meaning that the amount of its import is larger than its export income (World Integrated Trade Solution, 2019). Correspondingly, Cambodia's export items are similar to Myanmar; they are in the low technology exports, whose main export is fabric or textiles.

Diffusion of old technology index

Table 4. Diffusion of old technology index

Country	Diffusion of old technology		DOT Index	Rank
	Electric power consumption (kWh per capita)	Telephone mainlines + Cellular subscribers (per 1000 people)		
Indonesia	811.9002	1,761.2996	0.8627	5
Malaysia	4,596.3319	1,423.7897	0.9360	3
Thailand	2,539.6112	1,739.9670	0.9233	4
Philippines	699.2051	1,136.3557	0.8123	6
Singapore	8,844.6876	1,739.9670	0.9909	1
Brunei D	10,242.7958	1,366.7952	0.9755	2
Lao's PDR	0.0000	545.1943	0.3866	11
Cambodia	271.4332	1,168.5215	0.7637	7
Vietnam	1,410.9149	1,374.1367	0.5448	9
Timor-Leste	1.0000	1,195.6776	0.4625	10
Myanmar	216.7776	906.0447	0.7270	8

Singapore once more excels to be the first in diffusion of old technology index that comprises of electric power consumption and mainlines and cellular subscribers. Remarkably, Brunei Darussalam ranks second after Singapore as a result of large number of electric power consumption on both criteria. Malaysia still follows Singapore as the third highest.

Timor-Leste and Lao's PDR have the lowest rank on diffusion of old technology index. Both Lao's PDR and Timor-Leste are newly formed countries, which means the infrastructure for old technology is not well developed. These countries were also historically under developed in general.

Human skills development index

Table 5. Human skills development index

Human skills development

Country	GER all levels	GER S, E, M, C	DOT Index	Rank
Indonesia	76.0986	21.0506	0.5940	4
Malaysia	77.6700	36.7300	0.7943	2
Thailand	90.8589	22.3800	0.6753	3



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Philippines	84.8517	0.0000	0.3728	8
Singapore	113.7900	29.4300	0.8630	1
Brunei D	79.6465	0.0000	0.3500	9
Lao's PDR	66.1906	18.6900	0.5214	5
Cambodia	60.4570	14.5700	0.4454	7
Vietnam	0.0000	21.4200	0.2642	11
Timor-Leste	76.2500	0.0000	0.3350	10
Myanmar	0.0000	40.5400	0.5000	6

According to human skills development index, Singapore is still the highest rank in education, including all level of education and tertiary degree education in science, engineering, manufacturing, and construction. Human skills development illustrates the human factors that support the technology development in a country. Therefore, education is considered essential to build highly skilled people.

Timor-Leste and Vietnam are two lowest countries seen from this index. However, both countries had unavailable data, which is rationally impossible that both countries do not have enrolment in all level of education or in science and technology fields of study. Nevertheless, the discrepancy between Singapore as the highest rank and Malaysia as the second is quite large (0.2690). Thus, realising that education is significant could lead to technology creation in the future.

Overall Technology Achievement Index

Table 6. Overall Technology Achievement Index (TAI)

Parameter	Overall TAI Index	Rank
Indonesia	0.4537	6
Malaysia	0.7769	2
Thailand	0.5918	3
Philippines	0.5141	4
Singapore	0.9429	1
Brunei D	0.4970	5
Lao's PDR	0.2506	10
Cambodia	0.3218	8
Vietnam	0.3638	7
Timor-Leste	0.2299	11
Myanmar	0.3127	9

Overall TAI (table 6) displays the average of all four indexes. According to this procedure's results, Singapore has become the first rank compared to other countries. Second rank is Malaysia, and then followed by Thailand, The Philippines, Brunei Darussalam, Indonesia, Vietnam, Cambodia, Myanmar, Lao's PDR, and Timor-Leste, respectively. After calculation of all categories in TAI, the next step is to categorise these countries into several categories based on Desai et al.'s (2002). Based on the categorisation, there are five countries that are categorised as leaders, three countries as potential leaders, and the rest are categorised as dynamic adopters. Each category shall be explained further below.

- Leaders (index above 0.5)
Countries that are categorised as leaders are Singapore, Malaysia, Thailand, and The Philippines. Singapore ranks as number one in all indicators, hence brings this country to be the most excellent among Southeast Asia countries.

Malaysia becomes second after Singapore in all indicators except diffusion of old technology, which implies that Malaysia have the potential to be first ranked. Thailand and The Philippines are both in the middle of the ranks for total indicators. Thailand excels more in technology creation, old technology diffusion, and human skills development indicator than The Philippines. The Philippines, on the other hand, are able to exploit its technology well and convey welfare to the country than Thailand. Unfortunately, other three indicators are proofs that The Philippines stay back from other countries that are in "potential leaders" category. Brunei Darussalam stands between potential leader and leader. This country defeats Singapore in old technology diffusion index due to the consumption of electricity. It implies that even though Brunei Darussalam does not perform well as new technology leaders, old technology is highly operated in this country.

- Potential leaders (index between 0.30 – 0.49) Three countries that are categorised as potential leaders are Indonesia, Vietnam, Cambodia, and Myanmar. Despite of being one of the highest economic development in Southeast Asia, Indonesia is still considered as potential leader according to Desai's index category. The main reason is that Indonesia does not indicate technology development as important factor for a country's development as other countries should. According to Desai's categorisation, Vietnam, Cambodia, and Myanmar were in potential leader category; the probable cause for this is these countries' data were not available, not because of zero as scores. For instance, in human skills development index, Vietnam has zero per cent of Gross Enrolment rate in all level of education, which is impossible to occur in a country. Similar to Myanmar, there is no record on Gross Enrolment rate in in science, engineering, manufacturing, and construction major. In developing countries, it is likely and common to have missing data. Yet, these countries have opportunities to keep growing technology development wise because they have large potential and room to grow.
- Dynamic adopters (index 0.2 – 0.34)
Desai describes dynamic adopters as having high percentage of high-technology exports but low in old technology diffusion. In Desai et al.'s (2002) findings, several countries that are included in this category are Brazil, China, and Indonesia. However today, the technology development has demonstrated in Indonesia that it moved to "potential leader" category. It also indicates that time difference between latest TAI research and current research matters. In this paper, "dynamic adopters" countries are Lao's PDR and Timor-Leste. Aside from lack of data recorded on these countries, both countries are relatively newly formed, as previously explained. Therefore, technology development is not their main concern at the moment. These countries need solid foundation of infrastructure first, then going to technology or industrialisation era.

- Marginalised (index below 0.2)
Auspiciously, even with the unavailability of data for several countries, no country is categorised as marginalised. Hence, it is fair to say that the gap within Southeast Asia countries is not very far from one another. With this analysis, it is easier to seek for alternatives on how to make the gap smaller.

V. CONCLUSIONS AND RECOMMENDATIONS

Technology development measurement should deliver how well a country not only adapts, but also creates new technology. TAI, or Technology Achievement Index, is one way to set a standard that can be utilised for measuring countries' technological progress in comparison to other countries. Hence, this study explores this specific method to comprehend the position of South East Asian countries in terms of technological improvement. This approach is successfully completed, albeit availability of data in developing countries, especially Southeast Asia region, should be comprehensive in order to make this optimal understanding. The result of this study is that the country with highest rank in Technology Achievement Index is Singapore, being number one in all indicators, while the last rank is Timor-Leste. Being the last position, Timor-Leste is defensively one of the youngest members of ASEAN; hence it is reasonable to argue that technology innovation and creating technology as source of economy might not be a priority for Timor-Leste.

The calculation of TAI leads to the categorisation of countries that achieve particular score. As a result of the calculation, countries were categorised into four types. In South East Asian region case, there is no country that is counted in as marginalised; however, there are five countries in the "leaders" category, four countries in the "potential leaders" category, and two countries in "dynamic adopters" category. Hence, there is an indication that the gap of technology advancement is not very large among countries in South East Asia region. From this conclusion, one general recommendation is that ASEAN as an organisation in South East Asia should create a policy of how to reduce the gap.

There are more specific types of policies that could close the gap. First, programs, such as exchange of scientists and engineers from top index countries to lower index countries to apply knowledge transfers. The exchange programs could also be in form of students to open insights from other countries' conditions. The second recommendation is to assist lower index countries to adopt technology from top index countries. By facilitating skilled resources, lower index countries are able to absorb high-technology products and in the future may elevate their volume for high-technology exports. Aside from human development and resource for economic benefits, creation of new technology is also necessary. However, increasing the number of patents and charges for intellectual property are rather difficult since such support in infrastructure and research facilities are essential to be contented by government or private industries. Form of support by other countries can be in knowledge transfer by scientists and engineers from top index countries; another suggestion, although rather extreme, is to help lower index countries to build research facilities, or better, invest. Further development of this study is that

there should be more indicators that might target technology advancement more precisely. Availability of the data is also the cause that should be improved in the near future to achieve further comprehension about South East Asian countries' technological circumstances.

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