IMPACT OF RESEARCH AND DEVELOPMENT CAPITAL ON TFP GROWTH: THE CASE OF ASEAN COUNTRIES

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MASTER OF ECONOMICS IN APPLIED ECONOMICS
MAEJO UNIVERSITY
2022

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ECONOMICS
IN APPLIED ECONOMICS
ACADEMIC ADMINISTRATION AND DEVELOPMENT MAEJO UNIVERSITY
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ชื่อเรื่อง ผลกระทบของการลงทุนด้านการวิจัยและพัฒนาทุนต่อการเจริญเติบโตของผลิตภาพการผลิตรวม กรณีศึกษาประเทศในภูมิภาคอาเซียน

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บทคัดย่อ

งานวิจัยนี้เป็นงานวิจัยเชิงประจักษ์ที่ศึกษาเกี่ยวกับผลกระทบของการลงทุนด้านการวิจัยและพัฒนาทุนต่อการเจริญเติบโตของผลิตภาพการผลิตรวม กรณีศึกษาประเทศในภูมิภาคอาเซียน 6 ประเทศ ตั้งแต่ พ.ศ.2534 ถึงพ.ศ.2561 มีวัตถุประสงค์เพื่อ 1) เพื่อวัดผลิตภาพการผลิตรวมโดยอาศัยวิธี Data Envelopment Analysis (DEA) โดยใช้ Malmquist Productivity Index (MPI) และ 2) เพื่อวิเคราะห์ผลกระทบของการลงทุนด้านการวิจัยและพัฒนาทุนต่อการเจริญเติบโตของผลิตภาพการผลิตรวม โดยใช้แบบจำลอง Panel Estimated Generalized Least Squares (EGLS)

ผลการศึกษาจากการวัดผลิตภาพการผลิตรวมของแต่ละประเทศพบว่าประเทศสิงคโปร์เป็นประเทศที่มีการเติบโตของผลิตภาพการผลิตรวมดีที่สุด เนื่องจากมีความก้าวหน้าทางเทคโนโลยี และผลการศึกษาจากการตรวจสอบปัจจัยที่ส่งผลกระทบต่อผลิตภาพการผลิตรวมของประเทศในภูมิภาคอาเซียนพบว่า การลงทุนด้านการวิจัยและพัฒนาทุนส่งผลกระทบเชิงบวกต่อการเจริญเติบโตของผลิตภาพการผลิตรวม ดังนั้นเพื่อการเจริญเติบโตของผลิตภาพการผลิตรวม องค์กรที่มีส่วนเกี่ยวข้องรวมทั้งผู้ออกนโยบายควรเพิ่มการสนับสนุนการพัฒนาทางด้านเทคโนโลยีและนวัตกรรม เพื่อเป็นการเพิ่มระดับของความก้าวหน้าทางเทคโนโลยีและนวัตกรรมของประเทศกำลังพัฒนาให้สูงขึ้น และเพื่อเป็นการเพิ่มการเติบโตของผลิตภาพการผลิตรวมของประเทศ

คำสำคัญ : ผลิตภาพการผลิตรวม, Data envelopment analysis, Malmquist Productivity Index, การลงทุนด้านการวิจัยและพัฒนา

Title	IMPACT OF RESEARCH AND DEVELOPMENT CAPITAL ON TFP GROWTH: THE CASE OF ASEAN COUNTRIES
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ABSTRACT

This paper provides empirical estimates for the impact of Research and Development (R&D) capital on Total Factor Productivity (TFP) growth of six ASEAN countries over the period from 1991 to 2018. First, from the Production theory we measure TFP growth using Data Envelopment Analysis (DEA) techniques based on Malmquist Productivity Index (MPI). The DEA result found that Singapore is the leader country, which always has TFP growth through Technical Change (TC) progress while other countries always lag behind due to the lack of technical capacities. Second, we estimated how R&D capital, impact TFP growth by the Panel Estimated Generalized Least Squares (EGLS) method. The finding shows R&D capital and human capital are positively impact on TFP, especially R&D capital is the main source of TFP growth through improvement on technology and to catch up with the developed country in terms of TFP growth, ASEAN countries should support more investment in R&D capital specially to technology and innovation capacities.

Keywords : Total Factor Productivity, Data envelopment analysis, Malmquist Productivity Index, Research and Development capital

ACKNOWLEDGEMENTS

This thesis was successfully completed with the help of my thesis advisor, and I would like to express my sincere thanks to my thesis advisor, Asst. Prof. Dr. Jorge Fidel Barahona Caceres, gave very useful advice and recommendation for me to improve this thesis, moreover, the recommendation properly helped to solve various problems. In addition, I am grateful for Asst. Prof. Dr. Wanvilai Chulaphan and Dr. Kantaporn Chuangchid for their guidance and support for this thesis.

Moreover, I most gratefully acknowledge my parents and my friends for all their support throughout the period of this research. Finally, the researcher hopes that this thesis will be useful for relevant agencies and those interested in this field.

Fuangfa Theppitupong

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CHAPTER 1
INTRODUCTION

For about four decades since 1980, the economic growth of the sixth-largest economies in ASEAN member countries was rapid, the most Gross Domestic Product (GDP) growth rate of ASEAN member countries is Vietnam (6.79%) followed by Singapore (5.82%), Malaysia (5.78%), Indonesia (4.94%), Philippines (4.56%), and Thailand (4.38%) (World Bank, 2021). In addition, the most successful economic growth country in this region is Singapore.

Although Singapore has no sufficient natural resources, Singapore's economy has grown continuously influenced by the government investment. Singapore has development of technology, innovation, and human capital since 1965 after Singapore has political Independence from Malaysia (Ambashi, 2018). The government of Singapore uses strategically growth-enhancing policies and the government motivate the investment from many foreign countries (Owoye and Onafowora, 2018).

Therefore, Singapore is the most successful country in this region in dimension of competitiveness according from 2018 Singapore is ranked the 3rd highest per capita income in the world World Bank (2020b), moreover, the Global Competitiveness Index 4.0 report from 2017 to 2019 reveals Singapore is ranked 1st among the 141 countries in 2019 and this country remain in the top ten of the world since 2007 (Schwab, 2020).

Even though ASEAN member countries have economic growth, almost all the ASEAN member countries stuck in the Middle-Income Trap (MIT) since 1987 except for Singapore (Otsuka et al., 2017) as seen in figure 1, Singapore has the highest GDP per capita compared to other countries. Singapore's GDP per capita increased from 16,760 US dollars in years 1984 to 59,073 US dollars in years 2018 affect Singapore shift from Middle-Income Economies (MIEs) status to High-Income Economies (HIEs) status since 1987 (World Bank, 2020a), while the other counties are still in the upper-MIEs status (Malaysia and Thailand), and lower-MIEs status (Indonesia, Philippines, and Vietnam).

The previous study by Rosenblatt and Im (2013) mention that after Low-Income Countries became MICs, it is difficult to transform their production factors to use higher technology and innovation instead of using a lot of labor force and low technology, this also caused MICs to lose their competitiveness in the global market. Also Estrada et al. (2018) reveal the critical factors that affect Taiwan, Korea, and Singapore shift to the HIEs status are the technology development, human capital, and infrastructure. A similar result as Otsuka et al. (2017) mention, if the expenditure on education or human capital and Research and Development (R&D) capital is not sufficient, an economy can be trapped in MIEs because human capital and technology progress are important factors of economic growth in Middle-Income Countries (MICs) and for transition to HIEs status.

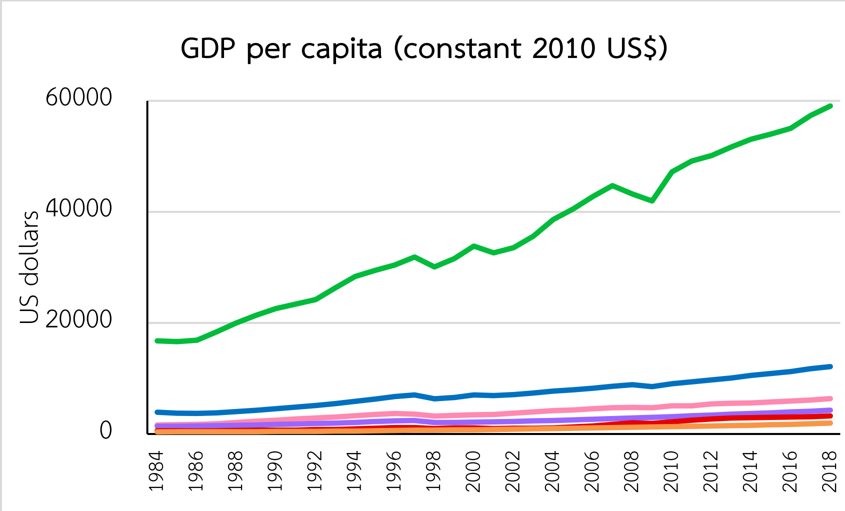

Figure *1 GDP per capita of six ASEAN countries from 1984 to 2018*

Notes: Pink line is Thailand's GDP per capita, green line is Singapore's GDP per capita, blue line is Malaysia's GDP per capita, purple line is Indonesia's GDP per capita, red line is Philippines's GDP per capita, and orange line is Vietnam's GDP per capita.

Source: World Bank (2020b)

Then, the main factors to overcome the MIT and maintain long-run economic growth for MICs are the high accumulation of human capital from supporting expenditure on education and Total Factor Productivity (TFP) growth or technological progress which derived from R&D expenditure (Glawe and Wagner, 2020; Solow, 1957) and the study by Romer (1990) explained the R&D expenditure is the source of technological progress by improving new technology and innovation , moreover, it drives TFP growth and long-run economic growth.

Total Factor Productivity (TFP) is the aggregate productivity in the production which derived from qualitative factors more than from the quantitative factors (capital and labor), such as level of technology and operation manageability which increase efficiency and TFP. TFP also indicates the technological progress of the country level (Jia et al., 2020), and TFP can endogenously explain economic growth (Romer, 1990).

The study from Caselli (2005) explains the reason why there is different income across the country, the finding already explain that economic growth was encouraged by TFP growth. In addition, R&D capital and R&D expenditure are significantly concerned as a determinant of TFP because these are the innovation inputs use to develop new technology and innovation to generate more output in the production (Otsuka et al., 2017).

The empirical study by Bengoa et al. (2017) investigated the impact of R&D capital on TFP, they found that R&D capital is positive and significant effects on TFP. As a result, many developed countries are aware of the benefits of R&D expenditure for many years help to develop new technology of the country and R&D expenditure can improve the competitiveness of the firm or the country (Ho et al., 2009).

For a long time, the R&D expenditure of many ASEAN member countries has been relatively low. As the figure 2 shows the data from UNESCO (2020) over the period from 1996 to 2018, the benchmarking of Gross Domestic Expenditure on R&D

(GERD) as a percentage of GDP for HIEs are 2.12%, upper-MIEs are 1.164 %, and GERD of lower-MIEs are 0.412%. Moreover, Singapore has the highest GERD in ASEAN which is 2.01% followed by Malaysia (0.85%), Vietnam (0.344%), Thailand (0.339%), Indonesia (0.148%), Philippines (0.127%), Cambodia (0.085%), Myanmar (0.071%), Laos PDR (0.04%), and Brunei Darussalam (0.026%). Therefore, in the ASEAN countries, there are a slowdown and low expenditure on R&D in terms of GERD and lower than the world's GERD benchmarking except for Singapore.

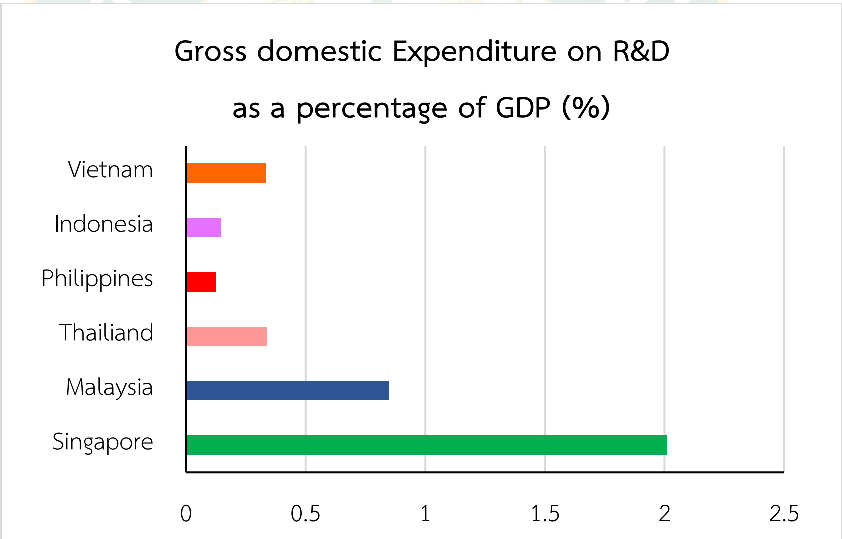

***Figure* 2** *The GERD as a percentage of GDP of from 1996 to 2018 (%)*

Notes: Pink is Thailand's GERD, green is Singapore's GERD, blue is Malaysia's GERD, purple is Indonesia's GERD, red is Philippines's GERD, and orange is Vietnam's GERD.

Source: UNESCO (2020)

In addition, the Global Innovation Index over the period from 2013 to 2020 indicates Singapore has the highest score of R&D expenditure as a percentage of GDP after compared with other ASEAN member countries, Singapore's score is 47.6

followed by Malaysia (26.5), Thailand (11.47), Vietnam (7.95), Philippines (2.53), and Indonesia (1.93) (Cornell University et al., 2021b), correspond to Bobowski and Dobrzanski (2019) illustrated the ASEAN member countries established the National Innovation Systems (NIS) categorized either to frontier phase, and Singapore is a high-level frontier phase of innovation policy followed by catch-up phase (Malaysia), and learning phase (Indonesia, the Philippines, Thailand, and Vietnam).

Therefore, the six ASEAN countries have different technology and innovation development or innovation gap between countries due to differences in the stock of knowledge, human resource, and research infrastructure. In addition, low R&D expenditure can affect low TFP and cannot achieve sustainable economic growth because low R&D expenditure has not been effective enough to boost productivity levels and it is difficult to develop technological progress which is important for obtaining TFP growth (Bengoa et al., 2017). For MICs, R&D capital is also important for technology and innovation to achieve high TFP from attaining the higher value-added goods and services (Akoum, 2016).

Furthermore, the studies of TFP determinant and R&D efficiency are popular topics in the scientific literature and there was the study from Kim and Park (2018) examined the relationship between TFP growth and the factors that affect TFP growth in MICs over the period from 1975 to 2014, the result shows R&D capital and human capital are impact TFP, however, they use regression analysis to measure TFP growth and their result is not specifically explained in region or country.

Then, this study's estimation is focuses on ASEAN countries over the period from 1990 to 2018, and to measure TFP growth, this study applies Malmquist Productivity Index (MPI) using Data Envelopment Analysis (DEA) approach because MPI can decompose TFP growth into its components which are Technical change (TC) and Efficiency Change (EC) (Fragoudaki et al., 2016; Haider et al., 2020; Ma et al., 2009). Then, the awareness of the source of TFP is relevant to the issue to policymakers and researchers in this field because they can solve the problems directly to the point through TFP components.

1.1 IMPORTANCE OF THE STUDY

The finding of this study helps to explain the main sources for the improvement of TFP growth, moreover, the result is directly related to policymakers for supporting the factor that directly contributes to TFP growth, and TFP can drive the economic growth, which is important to improve the citizen's standard of living, infrastructure development, and sustainable economic growth development to overcome the middle-income trap.

1.2 ADVANTAGE OF THE STUDY

The result helps to explain the relationship between R&D capital and TFP growth. In addition, for the benefit of analysts or those who issue policies to support public budget in the form of R&D in the country for economic development.

1.3 OBJECTIVES OF THE STUDY

This study aims to measure TFP growth of selected countries in the ASEAN region using the Data Envelopment Analysis (DEA) based Malmquist Productivity Index (MPI) and estimate the impact of Research and Development (R&D) capital on Total Factor Productivity (TFP) growth of selected countries in the ASEAN region using the Panel Estimated Generalized Least Squares (EGLS) period weight method.

CHAPTER 2
LITERATURE REVIEW

2.1 THE STUDIES INVESTIGATING THE MIDDLE-INCOME TRAP

There were various studies that investigated the “Middle-Income Trap” (MIT), this word was used for the first time by Gill et al. (2007), they also illustrated MIT occurs only in Middle-Income Countries (MICs) or developing countries. The report from Rosenblatt and Im (2013) explains after Low-Income Countries (LICs) became MICs, it is difficult to transform their production factors to using higher technology and innovation instead of a lot of using labor force and low technology, this also caused MICs to lose their competitiveness in the global market, and since 1960 there are 13 countries of 101 MICs became High-Income Countries (HICs) in 2008.

Because of many countries stuck in MIT, it is also a challenging topic use in scientific literature to estimate the approach to escape MIT through technological progress, as the empirical study by Aiyar et al. (2013) found that TFP slowdown in MICs is more frequent than in HICs and LICs because the MIC’s economic deflation is higher than HICs and LICs due to MICs have a lack of economic infrastructure and an inefficient regulation can obstruct technology frontier that important for productivity gains.

Similar result as Yılmaz (2016) reveals the MICs is lag behind the non-MICs because there are sector productivity gains significantly in non-MICs. Also, the study by Eichengreen et al. (2017) suggested for reach High-Income Economy (HIE) status, MICs should encourage TFP growth through the support of innovative capacities because the MIC's economic growth depends on a larger extent on more productive labor forces and machines.

Most Latin American countries, Middle East Asia countries, and Southeast Asia countries are MICs from the 1960s to the present. For the study in Latin American countries, Hernández and Gallego (2019) reported 17 out of 20 countries or 85% of Latin American countries are MICs. In addition, Hernández and Gallego (2019) analyses how Chile managed to achieve HIEs and overcome the MIT, and the study found that Chile has well-developed institutional policies in open mechanisms of both financial and economic structures, moreover, Chile has higher investment in R&D and education.

The study of Kang and Paus (2020) mentioned most Latin American country becoming trapped in MIT and low productivity are the reflections of the low government support on technology and innovation capacities, and Hofman and Valderrama (2021) mentioned Latin America country has not been to use new technology, transport, and electricity in a productive way from the late 19th century and the beginning of the 20th century, moreover, they argue Latin America did not take advantage in an efficient way of the possibilities of copying available technical progress.

For Southeast Asia region, there was the study by Lee (2019) estimated the economic growth experience of MICs in the Southeast Asia region over the period from 1960 to 2016, the result shows the convergence success countries or MICs that graduated to HIEs status tend to maintain strong human capital, effective rule of law, high trade openness, and high investment rate. Lee and Narjoko (2015) examined a dimension of the interrelationship among innovation, productivity, and globalization using manufacturing microdata from five MICs in the Southeast Asia region, they argue an innovation and globalization are still at the early stage, however, trade and FDI as an important development strategy for this region.

Moreover, Estrada et al. (2018) point out that Malaysia and Thailand achieved high productivity close to high-income economies, but these counties have failed to maintain productivity sustainably when faced with higher strong competitors with low-cost production. The study by Otsuka et al. (2017) has investigated the factor that affects economic growth in 12 East Asia countries (the countries in Southeast Asia also included in this study) over the period from 1960 to 2010, the result shows human capital and technology imitation is the essential factors of economic growth in East Asia countries.

2.2 DIFFERENT APPROACHES TO MEASURING TOTAL FACTOR PRODUCTIVITY GROWTH

The TFP growth can measure by various index, from the previous study by Haider et al. (2020) use the Malmquist Productivity Index (MPI) to measure TFP growth, and MPI can be estimated using Data Envelopment Analysis (DEA) approach because MPI is characterized as distance functions that assess TFP changes between two time by decomposing TFP growth into two distinct measures for the changes of Efficiency Change (EC) and Technical Change (TC) or Technological progress. EC represents the change of how far observed production is from maximum potential production between two periods whereas TC represents a shift of technology.

Moreover, many studies use the MPI to measure TFP change or TFP growth (Bassem, 2014; Lee, 2013; Mattsson et al., 2018; Nin et al., 2009; Silva and Thanassoulis, 2006; Suyanto and Salim, 2010). The previous study from Pratt and Yu (2010) mentioned MPI measures the TFP change between two data point by calculating the ratio of the distance of each data point relative to a common technological frontier, they also mention that MPI is extensively used in international comparisons of agricultural productivity because it does not require prices for its estimation. However, Becerra-Peña and Santín (2020) used the Hicks-Moorsteen Total Factor Productivity Index (HMTFP) instead of use MPI because HMTFP is a good alternative for evaluating productivity change of education in the educational sector and this index do not impose Constant Returns to Scale (CRS) technology.

In addition, there are many approaches to estimate TFP growth, the approaches can be classified in four major groups, which are (1) Least-Squares econometric production models, (2) Growth accounting TFP indices, (3) Data Envelopment Analysis (DEA), and (4) Stochastic Frontier Analysis (SFA) (Nin et al., 2009). The study by Konishi and Saito (2020) estimated TFP growth of five manufacturing and 11 services industries in Japan using firm-level data from 1982 to 2016 adopts Cobb–Douglas production function, then apply OLS estimation and fixed-effect estimation to estimate TFP growth.

However, Kong and Tongzon (2006) reported the TFP often estimated in two ways are Parametric estimation and Non-parametric estimation which are SFA and DEA technique, respectively, they reveal these two advanced techniques are uses to estimate production functions, it also improves the results to reliability and robustness. For the use of parametric estimation in the study by See and Coelli (2013) estimated TFP growth of the Malaysian electricity generation industry from 1998 to 2005 use the SFA technique, they argued SFA can decompose TFP growth into EC and TC, however, this technique requires for the high amount of sample and there is the risk for Multicollinearity problem between input factors.

While the use of non-parametric estimation from the various studies, such as Fragoudaki et al. (2016); (Ma et al., 2009; Vassdal et al., 2011) argue the DEA technique often uses to estimate TFP growth through measuring MPI by decomposing TFP growth using output distance functions. As this reason similar as Kong and Tongzon (2006) also estimated TFP growth in the ten major sectors of Singapore using the DEA technique based on MPI, they argue that MPI provides an approach to receive the productivity gain in a specific sample used, moreover, MPI can decompose TFP growth into TC and EC, further, DEA approach can apply to estimate TFP growth the private and public sector, and a good alternative for multi-input and output.

The same methodology with Ramasamy et al. (2017) use DEA to compute MPI as an indicative of TFP growth of the private and public sectors in the Turkish manufacturing industry in the selected provinces for 1990 to 1998, the result reveals that TC or technical progress is the main driver of TFP growth. Färe et al. (2006) calculated productivity growth and its components for a sample of 16 countries (the EU Member States plus Norway) over the period from 1965 to 1998 using DEA to make the best practice EU production frontier and compute a Malmquist index of TFP and its decomposition. Similar to many previous studies that estimate TFP growth as MPI using DEA approach (Färe et al., 2001; Jajri, 2007; Karadağ et al., 2005; Kong and Tongzon, 2006; Le et al., 2019; Ma et al., 2009; Pratt and Yu, 2010).

2.3 THE STUDIES INVESTIGATING TFP DETERMINANTS

The TFP and TFP determinants are the influential variables in the economic sector and the often-used theory to explain is the Solow Growth Model by Solow (1957) explained technology has defined by exogenous technology and this described an economic expansion affected by technological progress, human capital development, and trade openness which affect economic growth. The study about the TFP growth and its measurement has often been debated and interpreted by economists for the proper policy designed to encourage economic growth. The previous study from Carlaw and Lipsey (2003) purposed to determine the relationship between economic growth, technological change and TFP.

In addition, the previous study by Otsuka et al. (2017) used various data from low-income, middle-income, and high-income economies in the East Asia region, this study noted the R&D expenditure can drive technological progress and long-run economic growth through TFP growth. Furthermore, the R&D expenditure is directly expenditure improves the development of the technology and innovation sector such as technology infrastructure, human resources, and R&D expenditure on technology progress able to effective three years ago through the increasing of TFP (Bernini et al., 2017; Haider et al., 2020).

Correspond to the study by Castellani et al. (2019), they estimated TFP of two macro sectors, the result shows TFP increase in high-technology firm more than medium-low technology firm due to the high-technology firm has higher in technical change which from by R&D expenditure supporting because the subsidy on the technological progress and innovation can result in better output such as a product, service, and productivity (Xiong et al., 2020).

Further, the study from Huang et al. (2019) examined the effects of technological factors (R&D expenditure) and technology spillover (FDI and trade) on China's TFP, the sample covered 30 provinces over the period from 2000 to 2014, the result show R&D expenditure is the key factor in promoting TFP. In addition, Park (2012) argue the R&D capital is positively affected to TFP, the result shows the catch-up effect, life expectancy effect, and human capital are the source of TFP in 12 Asian countries especially human capital which contribution to TFP gradually.

Human capital and FDI capital are also the determinants of TFP growth according to endogenous growth theory, human capital and FDI can better result in the economy’s output and the country can maintain the long-run economic growth through the spillover effect and learning by doing from high technology firm by others country, such as knowledge transfer of technological knowledge and personnel practice (Romer, 1990). Then, Human capital is also the source of TFP because the development of the labor force by deriving a high knowledge or access to education result in better productions output or high productivity and TFP growth.

The study by Bandyopadhyay et al. (2019) pointed out that the low rate of human capital investment has an impact on loss of TFP due to financial imperfection or income inequality that affect the ability to allocate input using China's policy. Moreover, FDI is also a determinant of TFP, the previous study from Pietrucha and Żelazny (2020) examined the transmission of TFP spillover effects through trade and FDI of 41 countries (members of the EU and OECD) from 1995 to 2014. The result reveals that FDI and trade are significant sources of TFP.

Also, Tsamadias et al. (2018) pointed out that R&D capital, human capital, and FDI capital are the positive impacts on TFP growth in OECD countries, they divided the sample into two groups: the European and the non-European countries over the period from 1995 to 2005, the result show that R&D capital and human capital have the positive effect on TFP, and the contribution of R&D capital is higher than human capital and FDI in all groups, however, FDI has a positive and significant effect only in non-European countries.

However, the R&D expenditure and human capital are more influence on economic development than international trade (Otsuka et al., 2017), similar as Li and Tanna (2019) examined the relationship between TFP and FDI of 51 developing countries over the period from 1984 to 2010, they found the impact of FDI on TFP is depend on the absorptive capacity of the labor in host country and FDI is not the main driver of TFP similar to Su Dinh and Nguyen (2020) reveal the relationship between FDI and Economic growth in 38 African countries over the period from 2002 to 2017, they argue that high investment in skilled human or high knowledge labor affect to higher ability to utilise new external technology for TFP growth.

In addition the study by Borensztein et al. (1998) found that the effect of FDI on growth for 69 countries is positive but not significant similar result to Abdullah and Chowdhury (2020), they study the relationship between FDI capital and TFP growth in 77 low- and middle-income countries, they found the insignificant impact of FDI on the TFP growth due to the lack of technology absorptive capacity for achieving statistically significant impact on the growth rate of TFP of the developing countries. Therefore, in the developing countries, the ability of labor or human capital is more important for TFP and economic growth rather than FDI capital.

In addition, the main finding of many previous studies which have study on TFP growth, and its determinant can summarize in table 1, which includes the studies related to the relationship between TFP and its determinants, which are R&D capital, human capital, and FDI capital according to the objective of this study which proposes to estimate how R&D capital impact on TFP growth of the selected ASEAN member countries. And in table 1 also provide the methodology and the data used for measuring the TFP growth, which includes the studies related to TFP growth measurement, this study uses MPI as a suitable index to measure the TFP growth of the selected ASEAN member countries by using DEA approach.

Table 1 Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
Bassem (2014)	Total factor productivity change of MENA microfinance institutions: A Malmquist productivity index approach	2006–2011 Annual	Malmquist Productivity Index, DEA approach	There is TFP regress, and TFP growth was mainly dependent on pure technical efficiency rather than an improvement in optimum size.	In panel data, MPI allows the decomposition of TFP growth into TC and EC, but the disadvantage is the necessity to compute distance functions, however, the DEA approach can be used to solve this problem.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
Becerra-Peña and Santín (2020)	Measuring public primary education productivity across Mexican states using a Hicks-Moorsteen index	2006–07 to 2013–14 Annual	Hicks-Moorsteen total factor productivity index, DEA approach	The average positive TFP growth is 1.91%, and TFP growth was driven by technological progress.	Hicks-Moorsteen index has advantages over the well-known Malmquist index for analyzing the educational sector.
Färe et al. (2006)	Productivity growth and convergence in the European Union	1965-1998 Annual	Malmquist Productivity Index, DEA	Luxembourg and Finland are the best average productivity over 2%.	MPI isolate sources of TFP growth shifts in the frontier of technology, -

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
				Moreover, Luxembourg is the only country, which most frequently on the technological frontier.	capital deepening and catching up to the frontier.
Fragoudaki et al. (2016)	Efficiency and productivity changes in Greek airports during the crisis years 2010–2014	2010-2014 Annual	Malmquist Productivity Index, DEA approach	The annual average of TFP growth is 0.9%. this is due to the combination of average TC (0.5%) and average EC (0.4%).	DEA approach has been applied in many studies which aim to analyze the efficiency of airports around the world.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
Haider et al. (2020)	Total factor productivity, its components and drivers. 25 European countries, Japan and the US	1990-2006	Malmquist Productivity Index, DEA approach	The findings show time lags, R&D intensities affect both components of TFP which affects the large differences in TFP across countries, industries, and time.	DEA approach does not require a priori functional specification of the technology and any assumptions.
Jajri (2007)	Determinants of total factor productivity	1971-2004 Annual	Malmquist Productivity	The result shows that Malaysia was able to	DEA approach is use to estimate the changes-

Table 1 (Continued) Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
	growth in Malaysia		Index, DEA approach	shifts in their own frontier due to innovation.	in the production frontier. And the MPI has decomposed TFP into technological change and technical efficiency change.
Karadağ et al. (2005)	Growth of factor productivity in the Turkish manufacturing industry at provincial level	1990-1998 Annual	Malmquist Productivity Index, DEA approach	The result shows TC plays a major role in Private contributing to the overall TFP growth.	MPI does not require specified functional form for technology and maintains hypotheses of technical, allocative efficiency.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
Kong and Tongzon (2006)	Estimating total factor productivity growth in Singapore at sectoral level using data envelopment analysis	1985-2000 Annual	Malmquist Productivity Index, DEA approach	The DEA result shows EC was dominant in the retail sector, while TC was dominant in the manufacturing sector.	Using DEA to obtain MPI at the sectoral level. Moreover, the results can help Singapore identify the best practice sector and laggards in the component of TFP growth.
Konishi and Saito (2020)	Total Factor Productivity Changes in Japanese Small and Medium-Sized	1982–2016 Annual	Ordinary Least Squares (OLS) and	Physical capital and labor in construction, wholesale and retail	Test statistics might be unreliable when the data is not normally distributed.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
	Enterprises in 1982–2016: Suggestive Indications of an IT Revolution?		fixed effects.	trade affect to TFP.	
Lee (2013)	Productivity, technical and efficiency change in Singapore's services sector	2005-2008 Annual	Malmquist Productivity Index	The result shows the productivity of Singapore's services sector was attributed to TC with no improvements in EC.	MPI help to explain to the main source to improve the productivity and MPI has been adopted by many studies that analyses productivity change at the industry level.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
Mattsson et al. (2018)	A bootstrapped Malmquist index applied to Swedish district courts	2012-2015 Annual	Malmquist Productivity Index, DEA approach	The finding shows the average TFP decline at 1.7% was mainly driven by negative technical change.	DEA approach has advantage of relying on few assumptions and able to use the multiple outputs and inputs. DEA is also suitable when analyzing the public sector, which outputs are not sold on the market.
Pratt and Yu (2010)	Getting Implicit Shadow Prices Right for the Estimation of the	1964-2003 Annual	Malmquist Productivity Index, DEA	There was the contribution of EC and TC to total TFP growth.	MPI has become extensively used in international comparisons because MPI-

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
	Malmquist Index: The Case of Agricultural Total Factor Productivity in Developing Countries				does not require prices for its estimation, which are normally not available.
See and Coelli (2013)	Estimating and decomposing productivity growth of the electricity generation industry in Malaysia: A stochastic frontier analysis	1998 to 2005 Annual	Stochastic Frontier Analysis (SFA) approach	The finding shows annual TFP growth of 2.34% which TC mainly contributes to the TFP growth.	The advantage of SFA is allowing for statistical noise, directly. However, the limitation is it requires a specific functional form.

Table* *1 *(Continued), Main finding and methodology of the studies on TFP growth and its determinant*

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
Suyanto and Salim (2010)	Sources of productivity gains from FDI in Indonesia: is it efficiency improvement or technological progress?	1988 and 1995 Annual	Malmquist Productivity Index, DEA approach	The result shows that, in the food-processing industry, TFP was mainly driven by EC, while in the electrical machinery, TFP was mainly driven by TC because it is the capital-intensive industry.	The MPI helps to explain the decomposition of TFP growth.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Data	Methodology	Main findings	Advantages/ limitations
Vassdal et al. (2011)	Technical Progress and Regress in Norwegian Salmon Farming: A Malmquist Index Approach	2001-2005 Annual	Malmquist Productivity Index, DEA approach	The finding shows MPI increased in the period from 2001 to 2005 but regressed after that period because of the regress in the TC.	DEA approach can be defined for input minimization or output maximization problems.

***Table 1** (Continued), Main finding and methodology of the studies on TFP growth and its determinant*

Author (Year)	**Title**	**Country**	**Causality Relationship**
Abdullah and Chowdhury (2020)	Foreign Direct Investment and Total Factor Productivity: Any Nexus?	77 low- and middle-income countries	FDI has positive influence on TFP growth, however, FDI does not have any statistically significant impact on the growth rate of TFP.
Bandyopadhyay et al. (2019)	Human capital misallocation, redistributive policies, and TFP	United States	Human capital cause TFP growth.
Borensztein et al. (1998)	How does foreign direct investment affect economic growth?	69 developing countries	FDI cause economic growth.

***Table* 1** *(Continued), Main finding and methodology of the studies on TFP growth and its determinant*

Author (Year)	**Title**	**Country**	**Causality Relationship**
Castellani et al. (2019)	R&D and productivity in the US and the EU: Sectoral specificities and differences in the crisis	United States firms and European Union firms	R&D expenditure cause productivity growth.
Coe et al. (2009)	International R&D Spillovers and Institutions	18 European countries and Australia, New Zealand, Canada, US, Japan, Korea	R&D capital cause TFP growth.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Country	Causality Relationship
Haider et al. (2020)	Total factor productivity, its components, and drivers.	Austria, Belgium, Denmark, Spain, Finland, France Germany, Italy, Japan, Netherlands United Kingdom, and US	R&D cause TFP growth.
Huang et al. (2019)	Technological factors and total factor productivity in China: Evidence based on a panel threshold model	30 provinces in China	R&D capital cause TFP growth.
Li and Tanna (2019)	The impact of foreign direct investment on productivity: new evidence for developing countries	51 developing countries	Weak direct effect of FDI on TFP growth because low level of absorptive capacities.

Table 1 (Continued), Main finding and methodology of the studies on TFP growth and its determinant

Author (Year)	Title	Country	Causality Relationship
Otsuka et al. (2017)	Middle-income traps in East Asia: An inquiry into causes for slowdown in income growth	High-, Middle- and Low-income economies in East Asia	Human capital and R&D cause economic growth.
Park (2012)	Total factor productivity growth for 12 Asian economies: The past and the future.	12 Asian economies	Human capital cause TFP growth.
Pietrucha and Żelazny (2020)	TFP spillover effects via trade and FDI channels	41 countries (EU and OECD)	FDI cause TFP growth.
Tsamadias et al. (2018)	Does R&D, human capital and FDI matter for TFP in OECD countries?	OECD countries	R&D capital and human capital cause TFP growth, while FDI is positive and significant effect only in the case of non-European countries.

2.4 ASEAN INNOVATION POLICY COMPARISON

According to the the report from Global Innovation Index over the period from 2013 to 2020 indicates Singapore has the highest score of R&D expenditure as a percentage of GDP in Southeast Asia region, Singapore's score is 47.6 followed by Malaysia (26.5), Thailand (11.47), Vietnam (7.95), Philippines (2.53), and Indonesia (1.93) (Cornell University et al., 2021b) correspond to Bobowski and Dobrzanski (2019) illustrated the ASEAN member countries established the National Innovation Systems (NIS) categorized either to frontier phase, and Singapore is a high-level frontier phase of innovation policy followed by catch-up phase (Malaysia), and learning phase (Indonesia, the Philippines, Thailand, and Vietnam). The study from Bobowski and Dobrzanski (2019) also separate the level of innovation policy of ASEAN member country as table 2, which include the comparison of basic infrastructure, high-tech infrastructure, network cohesion and global integration.

***Table 2** ASEAN's innovation policy comparison*

Phase	Basic Infrastructure	High-Tech Infrastructure	Network Cohesion	Global Integration
Learning (Thailand, Indonesia,	Strengthening of basic infrastructure	Learning by doing and imitation from	social institutions expand to formal intermediary	Access to the foreign source of knowledge,

Source: Dobrzanski and Bobowski (2020)

Table 2 (Continued), ASEAN's innovation policy comparison

Phase	Basic Infrastructure	High-Tech Infrastructure	Network Cohesion	Global Integration
Philippines, Vietnam)	with better customs and bureaucratic coordination.	the high technology country.	organizations to promote connections and coordination between economic agents.	imports of material and capital goods, and FDI inflow integrate into the global value chain.
Catch-up (Malaysia)	Smooth links between economic agents, such as consumers, producers, markets, and the economy	Create activity through imports of machinery and equipment, licensing, and creative duplication	cooperation of intermediary and government in coordinating technology inflows, initiation of commercially viable R&D.	Licensing and acquisition of foreign capabilities, technology imports, and the strong technology-based exports

Source: Dobrzanski and Bobowski (2020)

Table 2 (Continued), ASEAN's innovation policy comparison

Phase	Basic Infrastructure	High-Tech Infrastructure	Network Cohesion	Global Integration
Frontier (Singapore)	New infrastructure developed to save resource costs.	R&D support creative knowledge. Technology generates invention and design patents	Cooperation of organizations in two-way flows of knowledge between producers and users.	Connecting to frontier nodes of knowledge, and competitive exports of high-tech products.

Source: Dobrzanski and Bobowski (2020)

2.4.1 Singapore

As the table 2, Singapore remains in the high phase among other ASEAN countries, which is Frontier phase according to the Global innovation index 2019 ranking published by Cornell University et al. (2019) reported Singapore is in the highest rated (8th) position, followed by Malaysia, Vietnam, Thailand, the Philippines, and Indonesia (in 35th, 42nd, 43rd, 54th, and 85^{th} positions, respectively). The economic growth of Singapore was rapid since 1965 after political independence.

Then, Singapore's economic growth was mainly driven by multinational companies from Singapore's business-oriented government policies, such as relatively low taxes and the productive labor force relative to its wages. Moreover, Singapore increases advanced technological operations to Singapore and there was the developing infrastructure and human capital to absorb new technology rapidly since the 1990s (Ambashi, 2018).

According to table 2, Singapore is in the Frontier phase which means the best development of innovation activity and policy includes the basic infrastructure, high-tech infrastructure, network cohesion, and global integration. The examples of Singapore's innovative policies are (1) Public knowledge infrastructure, such as creating new universities and public research institutes, restructuring existing institutions, and Singapore has established the Biomedical Research Council (BMRC) and the Science and Engineering Research Council (SERC), both are under the Agency for Science, Technology and Research (A*STAR). (2) Inducements for private companies to cluster. And (3) Knowledge flows and network links among key actors in the cluster between universities, public research institutes, and private firms (Lim, 2018).

Therefore, the government of Singapore is the main driver and the critical element for the success of innovative knowledge-based development and R&D investment in Singapore is the significant impact on its total factor productivity, such as developing capabilities in selected science and technology clusters.

2.4.2 Malaysia

According to table 2, Malaysia is in the catch-up phase because Malaysia enhances innovation activity by enhancing R&D capacities, building partnerships between public universities and industries, and developing new knowledge-based industries (Dobrzanski and Bobowski, 2020), the study from Narayanan and Lai (2018) report Malaysia's Science Technology and Innovation (STI) policies, which are (1) the stakeholder (ministry, agency, university, and private industry) have to accept and implement with the policy, (2) government provide the support on STI capacity and capability through funding, management, institutions, personnel, and transferring STI knowledge, (3) increasing public and private sector cooperation through increasing the capability of the private sector by the intensive and the measure of innovation activity, (4) improve the public sector for a better quality of STI system, and (5) support advancing of scientific and social, R&D, and commercialization. In addition, Malaysia's innovation policy includes increasing R&D expenditure to at least 2% of GDP, and the ratio of researchers per 10,000 workforces to at least 70 by 2020.

For Malaysia's future innovation policies include consolidating agencies and institutions in the national innovation system, making R&D incentives work whether there is no lack of R&D incentives and grants for R&D, the government should increase the level of awareness among industries regarding these incentives is low, strengthening links between university as the public research agency and industry to increase the opportunity and the platform to disseminate information quickly and efficiently (Narayanan and Lai, 2018).

2.4.3 Thailand

Thailand is the third-largest GDP per capita in ASEAN member countries (World Bank, 2020b), from the 1990s to the present, Thailand had attracted a lot of FDI because of a generally sound macroeconomic environment together with its market size, a well-developed financial market. Nowadays, Thailand has industrialized without developing its own technological capabilities. In the future, Thailand will face many challenges for being the aged society, so the innovation policy is important for Thailand for avoid the middle-income trap (Rattanakhamfu and Tangkitvanich, 2018).

The report from Durongkaveroj (2015) reveals the science, technology and innovation policies in Thailand, which are (1) reform STI administration system to increase the cooperation effectiveness between public and private sector, and also increase the R&D expenditure to 1% of GDP with private/public sector ratio; 70:30, (2) Support for STI manpower development through Science, Technology, Engineering, and Mathematics educations (STEM), work-integrated learning, talent mobility, technological assistance to Small and Medium-sized Enterprises (SMEs), (3) reform incentive systems, regulations and laws to enable commercialization of R&D, (4) use public mega investment projects and government procurement to support innovation in strategic areas, such as rail system and water management, and (5) develop STI infrastructure and services to support R&D and technology commercialization.

However, Thailand's Science, Technology and Innovation (STI) policy is not sufficient to support broad-based growth and enable innovation-led economic development (UNCTAD, 2015). In addition, the report from UNCTAD (2015) reveals the governance issues for Thailand's innovation policies, which are (1) the lack of a strategic driver of policy because the ineffective functioning of the National Research Council, (2) there are several bodies responsible for funding and management leads to potential conflicts of interest, (3) the process of budget allocations are lacked insufficient monitoring and evaluation, (4) lack of prioritisation in many plans and process lists, (5) the ratio of private sector involvement is not much as public sector, and (6) confusing system and misunderstanding among the stakeholders.

Therefore, to solve these innovation and technology development issues, the study from Rattanakhamfu and Tangkitvanich (2018) mention the future directions for innovation policies in Thailand, which are increasing public investment in R&D and increasing the spending the public money to encourage private investment in R&D, setting the clear target in public fund research, and need to support the internationalization education through reform the government scholarship system to improving R&D human resources, such as the university student.

Moreover, Durongkaveroj (2015) suggested Thailand's innovation policy should have (1) the balance of social, environmental and economic objectives through developing a STI strategy to benefit disadvantaged groups, and for the STI in agriculture should more focus on the poor, (2) strengthen STI governance and management by enhance coordination between research, education and industry institutions, and (3) expand international connection by building the business linkages between Transnational Corporations (TNCs) and local firms through the R&D center.

2.4.4 Philippines

For Philippines, there is no emphasis on innovation policy until late the 2000s, then Philippines launches the national STI policy that focuses on STI management and the investment of human capital. However, according to table 2, Philippines is in the learning phase which means there are barriers to implementing and developing the National Innovation System (NIS) which help the country make their own technology to achieve more competitiveness relative to HIC.

Philippines expand the infrastructure to support the service sector which mostly contributed to the economic growth, whereas Philippines has rapidly economic growth and GII growth rate (Cornell University et al., 2019), there is no connection between the R&D activity and the economic growth, and innovation-related expenditure was ineffectively allocated as the GERD of Philippines is reported under 0.2% of GDP and the average GERD from 1996 to 2018 is 0.127%, which is the lowest rate when compared with other ASEAN countries (Singapore, Malaysia, Vietnam, Thailand, and Indonesia) (UNESCO, 2020).

Moreover, the lack of success stories and proper investment education are affected to commercializing technology from the investment side has been difficult and the report from Hybridigm Consulting and Nesta (2019). Then the analysis of the strengths and weaknesses of an innovation system in Philippines is shown in table 3.

***Table 3** Philippines innovation activity's strengths and weaknesses analysis*

Strengths	**Weaknesses**
Philippines has a lot of young labor forces with good science education.	Philippines does not have enough of engineers and scientists to support its innovation efforts.
There is a growing trend in interest and funding of general innovation	The increasing of fund has not effectively reached to the institution or the sector which related to the innovation activity improvement.
ASEAN integration pushed Philippines to make innovation systematically.	The innovation in Philippines is remain in lag behind others country due to the poor alignment of agency priorities as regards the innovation agenda.

Source: Hybridigm Consulting and Nesta (2019)

Therefore, the innovation policy recommendation for Philippines include National innovation policy should support the various form of cooperation and relate to sector-specific characteristics of firms, the government need to ensure that intellectual property in the Philippines is protected is also essential and the government should foster an innovation ecosystem and support higher encourage of R&D (Francis et al., 2018).

2.4.5 Indonesia

Economic growth of Indonesia was mainly driven by the capital and labor accumulation, such as natural resource and the international trade rather than by innovation and technology or the productivity, and the Total Global Innovation Index Score for Indonesia was decline since 2013 to 2016, and the study from Yose et al. (2018) reported Indonesia face with major factors restricting innovation in Indonesia, such as institutional and regulatory bottlenecks and a lack of knowledge workers.

Moreover, the private participation in R&D activities of government innovation programmes has been limited by the law and the regulations. In addition, the previous study by Putera and Miftahul Jannah (2012) analyses the STI policies in Indonesia, the result show that the national policy of Indonesia from 2000 to 2011 were less supportive to development, research, diffusion, and implementation of technology.

However, in 2011, Indonesia also launches a national innovation strategy called Master Plan for the Acceleration and Expansion of Indonesian Economic Development (2011-2025) include increasing the providing fund and incentives for R&D in universities and firms, tax deductions for R&D, establishment of government R&D institutions, create the business innovation center, science parks, and industrial clusters to contribute the innovation activity, the programme for transfer new technology knowledge for student including the research training and scholarship programs for Indonesian students.

2.4.6 Vietnam

More than 30 years after Vietnam developed the country with the Doi Moi policy in 1986 through the improvement of institutions for the market economy, macroeconomic stabilisation, and integrate into the regional and global economies. Then, Vietnam's economy growth rapidly (Tri et al., 2018). As the figure 3, since 1980 Vietnam is the most Gross Domestic Product (GDP) growth annual rate (6.469%) of ASEAN member countries followed by Singapore (5.959%), Malaysia (5.665%), Thailand (5.052%), Indonesia (4.994%), and Philippines (4.328%) (World Bank, 2022).

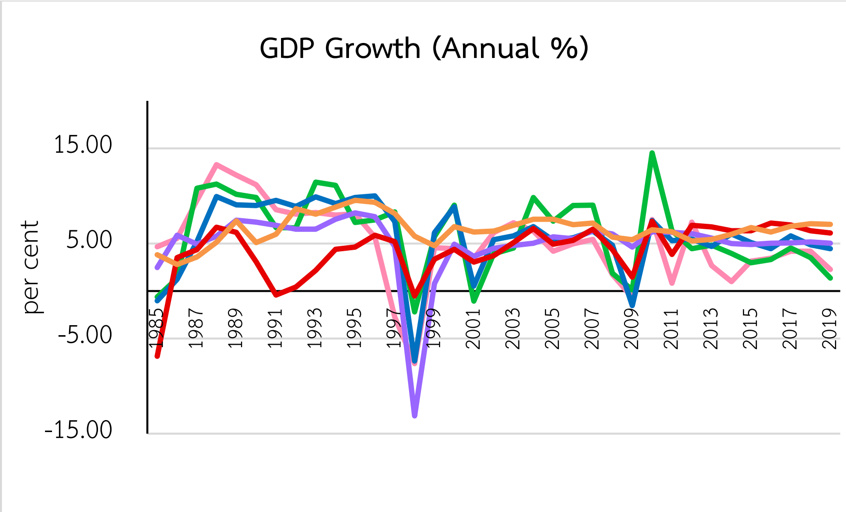

***Figure 3** GDP growth of six ASEAN countries from 1985 to 2019*

Notes: Pink line is Thailand's GDP growth rate, green line is Singapore's growth rate, blue line is Malaysia's growth rate, purple line is Indonesia's growth rate, red line is Philippines's growth rate, and orange line is Vietnam's growth rate.

Source: World Bank (2022)

After Vietnam has the policy revolution, there is more effective S&T innovation-led growth in Viet Nam, the R&D organization has been allowed to make the contract with individuals and non-state institute, and there was implement on regulations of technology transfer, moreover, there were the human resource development and the high technology industries development. Nowadays, Vietnam launch the Scient and Technology (S&T) development as a consist of Socio-economic Development Strategy, 2011–2020 and the Socio-economic Development Plan, 2016–2020, these changes were driven by the need of supporting the national's competitiveness in the global market and the internalization of international rules (Tri et al., 2018).

2.5 CONCEPTUAL FRAMEWORK

This study measure TFP growth of selected ASEAN members countries apply the Production theory to explain the relationship between the input and the output. The output use in this study is real GDP and the inputs use in this study are labor force and gross fixed capital formation which represent labor and physical capital as the input factors in the production. In addition, this study measure TFP growth by DEA model based MPI, the computation of MPI assumes Constant Returns to Scale (CRS) which can be estimated via the DEA technique.

In addition, to estimate how R&D capital affect to TFP growth of selected ASEAN member countries through the applying of Solow growth model to explain the source of TFP growth. Solow (1957) defined the technology level is the TFP growth or Solow residual which is the share of an economy's output growth that cannot be attributed to the accumulation of capital and labor, and from the Solow growth model, the determinants, or the sources of the TFP growth are the consist of Technical Change (TC), Efficiency Change (EC), and Scale Efficiency (SE). Also, Mankiw (2007) explained the Solow growth model shows the saving, population growth, and technological progress affect the level of an economy's output and the long-run economic growth. Then, this study estimates how R&D capital affect to TFP growth by the Panel Estimated Generalized Least Squares (EGLS) period weight method.

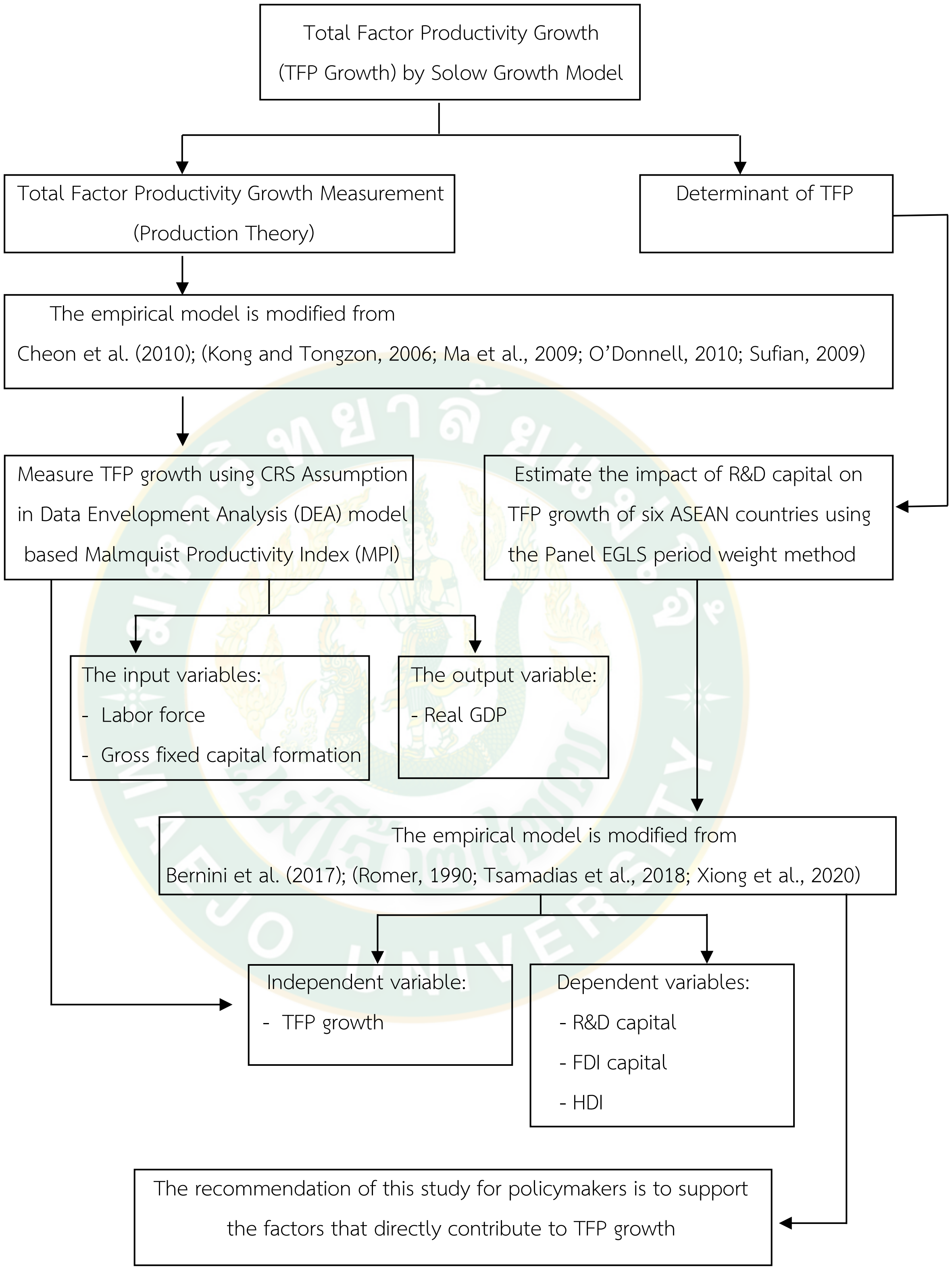

***Figure* 4** *Conceptual Framework*

CHAPTER 3
METHODOLOGY

As the objectives in the previous part, this study aims to measure the TFP growth and estimate the impact of R&D capital on TFP growth. In accordance with these objectives, the structure of the methodology part is as follows: Section 1 introduces the data has collected; Section 2 introduces the theoretical model; finally, Section 3 presents the econometric model.

3.1 DATA COLLECTION

This study focuses on six ASEAN countries as follows: Thailand, Singapore, Malaysia, Indonesia, Philippines, and Vietnam. The period of investigation is from 1991 to 2018 and this study uses the panel data in terms of annual data. The considered variables to measure the TFP growth which are aggregate output data proxied by real GDP (constant 2010 U.S. dollars) and input data which are total labor force (person), and the capital stock proxied by gross fixed capital formation (constant 2010 U.S. dollars).

The source of real GDP data, labor force data, and gross fixed capital formation data are obtained from the World Bank Database published by the World Bank, International Labour Organization Statistical Database (ILOSTAT), and the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT). In addition, the variables considered to examine the determinant of TFP are FDI capital which measured by this study using Foreign Direct Investment inflow (percentage of GDP) obtained from The United Nations Conference on Trade and Development (UNCTAD), R&D capital which measured by this study using Gross domestic expenditure on R&D (percentage of GDP) for each country obtained from the UNESCO Institute for Statistics (UIS) and Government Technology Agency of each country, and Human capital which proxied by Human Development Index (HDI) obtains from the Human Development Report Office of the United Nations Development Programme.

3.2 THEORETICAL MODEL

3.2.1 Production Function

The theoretical model for TFP growth measurement of selected ASEAN member countries, this study applies the Production theory to explain the relationship between output and input factors in the production because TFP growth is the result of productions output increasing, which is enhanced by technology and innovation used in the production rather than capital accumulation and labor force (Xu et al., 2020) and this study measure TFP growth because TFP basically displays the performance on aggregate production that consist of multi-output and multi-input in terms of country-level (Coelli et al., 1997).

Then, this study measured TFP growth by the concept of aggregate production function with a constant return to scale (CRS), CRS is the same rate of output and input when given input at any ratio to determine the technological possibilities or trend of TFP and shows the relationship of given inputs and output. The production function in the Solow Growth model (Solow, 1957) is as follows:

$$Y_t = Af(K_t, L_t) \tag{1}$$

Where Y represents the aggregate output as GDP, A is technological progress, or TFP refers to level of technology, K represents physical capital, and L represents labor force (Bengoa et al., 2017). From *Equation 1*, the production function will be defined as follows:

$$Y = AK^{\alpha}L^{\beta} \tag{2}$$

As *Equation 2,* Y denotes the output as aggregate GDP, A is TFP, K represents physical capital, L represents labor force, α is an output elasticity of K $(0 < \alpha < 1)$, and β is an output elasticity of L $(\alpha + \beta = 1)$. In the long run, Y/K, and A/K are constant (Solow, 1957) because the economy is on a balanced growth from the stock of capital (K) grows, then the economic growth, in the long run, is the same rate as technological progress (A) as follows:

$$\frac{\Delta Y}{Y} = \frac{\Delta K}{K} = \frac{\Delta A}{A} = g \tag{3}$$

Equation 3 refers to the relationship of output, consumption, investment, and in the long run, will constant increase equal to g which means economic growth rate determined by technical improvements.

3.2.2 Total Factor Productivity and Malmquist Productivity Index

Total Factor Productivity (TFP) indicates the country's technological progress or innovation development that drives economic growth eventually. From *Equation 1*, TFP also refers to the level of technology (A) used in production (Xu et al., 2020). TFP index can decomposed into measures of technical change (TC) and efficiency change (EC) (O'Donnell, 2012). Therefore, this study uses an output-oriented Malmquist Productivity Index (MPI) as a suitable index to measure the TFP growth of the selected ASEAN member countries because MPI is an effective approach to measure TFP growth or TFP change between two time periods.

Furthermore, MPI can evaluates TFP growth by calculating the ratio of the distance function to technology frontier and MPI is also decomposing TFP growth into its components which are TC and EC, then, after we know the main source of TFP growth, it can help the policy makers can directly support to increase TFP through the source of TFP growth (TC and EC) (Cheon et al., 2010; Kong and Tongzon, 2006; Sufian, 2009).

In addition, the formal concept of output-oriented is a measurement that focuses on the maximum amount of output that could be produced when a given amount of input factor in the production and from the study by Cheon et al. (2010); (O'Donnell, 2010) have defined the output-oriented MPI at period t as follows:

$$\frac{TFP_{t+1}}{TFP_t} = {M_0}^t(y_t, y_{t+1}, x_t, x_{t+1}) = \frac{{D_t}^o(x_{t+1}, y_{t+1})}{{D_t}^o(x_t, y_t)} \tag{4}$$

$$M^o{}_{t,t+1}(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{{D_t}^o(x_{t+1}, y_{t+1})}{{D_t}^o(x_t, y_t)} \times \frac{{D_{t+1}}^o(x_{t+1}, y_{t+1})}{{D_{t+1}}^o(x_t, y_t)}\right]^{1/2} \tag{5}$$

From *Equation 4* and *Equation 5*, M represents Malmquist TFP or TFFP index, it compares the next period or next year $(t+1)$ with the current period or current year(t) using distance function that represent the production in year t and year $t+1$. In *Equation 5*, which is the product of a measure of technical change (frontier-shift or best-practice frontier effect) measured by shifts in the frontier between period t (current period) and period $t+1$ (next period) and also measure efficiency change (catch-up effect) over the same period (Lee, 2013).

In addition, From *Equation 4* and *Equation 5* ${D_t}^o(x_t, y_t)$ and ${D_t}^o(x_{t+1}, y_{t+1})$ denote the distance function for unit "o" for the observation at current period (t) and the next period $(t+1)$, respectively and suppose that technological production is CRS between period t and period $t+1$ (Haider et al., 2020). Then, MPI also decompose TFP growth using this linear equation of distance function, and it represent technical change and Efficiency change as *Equation 7*

In addition, MPI became more popular empirical index by Färe et al. (1998), they also revealed the definition of TC is the development of process and product innovation that result captures the shift in technology frontier whereas EC measures the change in efficiency between period t and period $t+1$ are defined as follows:

$$M_0{}^t(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{D_{t+1}{}^o(x_{t+1}, y_{t+1})}{D_t{}^o(x_t, y_t)} \times \left[\frac{D_t{}^o(x_{t+1}, y_{t+1})}{D_{t+1}{}^o(x_{t+1}, y_{t+1})} \times \frac{D_t{}^o(x_t, y_t)}{D_{t+1}{}^o(x_t, y_t)}\right]^{1/2} \quad (6)$$

$$MPI_0{}^t = [Efficiency\ change] \times [Technical\ change] \quad (7)$$

From *Equation 7*, if $MPI_0 > 1$, then, there is growth or progress in TFP. If $MPI_0 = 1$, then there is no change in TFP, and when $MPI_0 < 1$, indicate there is the decline in TFP from the period t to period $t+1$.

3.2.3 The Estimation of TFP determinant

This study applies the Solow Growth Model (Solow, 1957) to analyse how R&D capital affects TFP growth of the selected ASEAN member countries because the Solow Growth Model explained a long-run economic growth is driven by capital accumulation, technological progress, and unrestricted trade as also the driver factors of TFP (Maryam and Jehan, 2018).

Solow (1957) defined the technology level is the TFP growth or Solow residual which is the share of an economy’s output growth that cannot be attributed to the accumulation of capital and labor, and from the Solow growth model, the determinants, or the sources of the TFP growth are the consist of Technical Change

(TC), Efficiency Change (EC), and Scale Efficiency (SE). Also, Mankiw (2007) explained the Solow growth model shows the saving, population growth, and technological progress affect the level of an economy's output and the long-run economic growth.

Moreover, in the TFP growth model, there are the catch-up effect and technological progress or TFP which directly affected by R&D capital (Bernini et al., 2017; Xiong et al., 2020) human capital (Lee and Hong, 2012), and FDI capital (Kim and Park, 2018; Maryam and Jehan, 2018) and remains the important channels to abridge the productivity gap, drive long-run TFP growth and economic growth.

In *Equation 8*, TFP is assumed to be a function of R&D capital, human capital and FDI capital as follows:

$$TFP = f(RD, HDI, FDI) \tag{8}$$

Where TFP is Total Factor Productivity, RD denotes R&D capital, HDI is Human Development Index is a proxy for human capital, and FDI for FDI capital. Thus, an empirical equation to estimate TFP's determinant mention as follows:

$$TFP_{it} = \alpha + \beta_1 RD_{it} + \beta_2 HDI_{it} + \beta_3 FDI_{it} \tag{9}$$

From the Endogenous Growth Theory, R&D capital, human capital, free international trade are sources of technological progress and drive long-run TFP growth and economic growth (Romer, 1990). The high of knowledge accumulation like human capital and R&D capital are important for TFP growth, Hamia (2020) reveals low R&D expenditure affects the long-run economic growth, if there are low R&D expenditure is difficult to develop technological progress due to the innovative input factor is not enough to boost productivity. Moreover, R&D capital has a positive impact on TFP growth because R&D capital increases productivity through technological progress (Bernini et al., 2017; Xiong et al., 2020).

Human capital is one of the important factors that impact TFP growth and economic growth due to human capital reflecting the high of labor's knowledge accumulation which has a significantly positive impact on TFP growth (Lee and Hong, 2012). The study by Park (2012) analyses the determinants of TFP growth, the empirical result shows that R&D capital and human capital are positively affected TFP growth, Kim and Park (2018) also mentions that human capital is a significant source of TFP growth.

FDI capital is another factor that impacts TFP growth. FDI capital increases the rate of technical progress in the host country through better technology and high knowledge transfer from high technology countries to lower technology levels, therefore, FDI capital is contributing to economic growth (Tsamadias et al., 2018). Maryam and Jehan (2018) reveals FDI capital are the technology transmission channel which increases labor skill.

As the theory, the TFP growth is positively affected by R&D, human capital, and FDI capital, therefore, this study expects that R&D, human capital, and FDI inflow are a positive effect on TFP growth.

3.3 ECONOMETRIC MODEL

3.3.1 Measuring Total Factor Productivity growth using DEA technique

The computation of MPI assumes constant returns to scale (CRS) which can be estimated via the DEA technique. In addition, the DEA is a non-parametric methodology technique uses to measure the MPI by decomposing TFP growth using output distance functions (Ma et al., 2009). Even though MPI has the main necessity to compute the distance function, the DEA technique solves this problem (Sufian, 2009).

Moreover, the DEA technique is often used to measure the MPI, Kong and Tongzon (2006) reveal DEA technique does not require any assumptions of the inefficiency terms and can apply with panel data. Similar to many previous studies that estimate TFP growth as MPI using DEA approach (Färe et al., 2001; Jajri, 2007; Karadağ et al., 2005; Kong and Tongzon, 2006; Le et al., 2019; Ma et al., 2009; Pratt and Yu, 2010).

From *Equation 6*, this study uses the output-oriented DEA involves the selecting values of the unknown parameters to maximize the value of the output distance function $D^t{}_o(x_t, y_t)$ (O'Donnell, 2010). We calculate four components of distance function involving DEA linear programs (LPs) by assuming CRS is defined by the equations as follows:

$$\begin{gathered}\left[D_o{}^t(x_t, y_t)\right]^{-1} = max_{\phi,\lambda}\ \phi, \\ \text{St} -\phi y_{it} + Y_t\lambda\ \geq 0, \\ x_{it} - X_t\lambda\ \ \geq 0, \\ \lambda \geq 0,\end{gathered} \tag{10}$$

$$\begin{gathered}\left[D_o{}^{t+1}(x_{t+1}, y_{t+1})\right]^{-1} = max_{\phi,\lambda}\ \phi, \\ \text{St} -\phi y_{i,t+1} + Y_{t+1}\lambda\ \geq 0, \\ x_{i,t+1} - X_{t+1}\lambda\ \ \geq 0, \\ \lambda \geq 0,\end{gathered} \tag{11}$$

$$\begin{gathered}\left[D_o{}^t(x_{t+1}, y_{t+1})\right]^{-1} = max_{\phi,\lambda}\ \phi, \\ \text{St} -\phi y_{i,t+1} + Y_t\lambda\ \geq 0, \\ x_{i,t+1} - X_t\lambda\ \ \geq 0, \\ \lambda \geq 0,\end{gathered} \tag{12}$$

$$\begin{gathered}\left[D_o{}^{t+1}(x_{t+1}, y_{t+1})\right]^{-1} = max_{\phi,\lambda}\ \phi, \\ \text{St} -\phi y_{it} + Y_{t+1}\lambda\ \geq 0, \\ x_{it} - X_{t+1}\lambda\ \ \geq 0, \\ \lambda \geq 0,\end{gathered} \tag{13}$$

As *Equation 12* where the production point from period $t+1$ is compared to the technology in period t occur, if the technology progress has occurred, then the value of $\phi < 1$ is possible.

3.3.2 The determinants of TFP

From *Equation 9*, this study estimates the dependence between TFP and the determinants of TFP as follows:

$$TFP_{it} = \alpha + \beta_1 RD_{it} + \beta_2 HDI_{it} + \beta_3 FDI_{it} + \mu_{it} \tag{14}$$

Where subscript i refers to *i-eth* country (1,2, ...,6) and t refers to the time from 1990 to 2018, TFP is TFP change which is measured by this study, RD is the R&D capital measured in *Equation 16*, HDI is Human Development Index is a proxy for human capital, and FDI denotes FDI capital measured in *Equation 18*, and μ is the error term. Following Tsamadias et al. (2018) and achieving the existing information, we extend the model by taking the natural logarithm of RD, HDI, and FDI as follows:

$$TFP_{it} = \alpha + \beta_1 logRD_{it} + \beta_2 logHDI_{it} + \beta_3 logFDI_{it} + \mu_{it} \tag{15}$$

Because the data of R&D capital and FDI capital are not available, then, we calculate both of R&D capital and FDI capital applies methodology from Tsamadias et al. (2018). The R&D capital in the current year (RD_t) is determined by the sum of

R&D capital in the previous year (RD_{t-1}) after deducting the amount of depreciated capital and adding the R&D expenditure in current years as shown in *Equation 16*.

$$RD_t = (1-\delta) \cdot RD_{t-1} + I_t \tag{16}$$

From *Equation 16* RD_t represent the R&D capital in current year, RD_{t-1} represent the R&D capital in previous year, I_t is an expenditure on R&D and δ denotes the depreciation rate.

$$RD_1 = \frac{I_1}{(\delta + g)} \tag{17}$$

As the *Equation 17* defined the calculation of R&D capital in year 1 (RD_1), I_1 denotes an expenditure on R&D in year 1, δ is the annual depreciation rate, and g average of yearly growth rates of R&D expenditure from 1991 to 2018.

In addition, FDI capital has been calculated using the same methodology as follows:

$$FDI_t = (1-\delta) \cdot FDI_{t-1} + I_t \tag{18}$$

In the *Equation 18*, FDI_t denotes FDI capital in the current year, FDI_{t-1} denotes FDI capital in the previous year, I_t denotes an on FDI which proxied by FDI inflow as a percentage of GDP, and δ denotes the depreciation rate. The depreciation rate for R&D capital and FDI capital calculation is set at 10% obtained from the previous study by Tsamadias et al. (2018) as the previous studies from

Griliches (1990); (Kim and Park, 2003; Luintel et al., 2014) used the depreciation rate at 10% because it is the most significant for long-run.

$$FDI_1 = \frac{I_1}{(\delta + g)} \tag{19}$$

In the *Equation 19* defined the calculation of FDI capital in year1 (FDI_1), I_1 denotes an R&D expenditure in year 1, δ is the annual depreciation rate, and g average of yearly growth rates of FDI investment from 1991 to 2018.

Then, we estimate the relationship between TFP and its determinant using the Panel Estimated Generalized Least Squares (EGLS) period weight method. After we use Panel Cross-section Heteroskedasticity LR test to check for Heteroskedasticity problems, H0: Residuals are Homoskedasticity, and H1: Residuals are not Homoskedasticity. The Panel Cross-section test result rejects the Null hypothesis at a 10 percent significant level, then estimation using Panel EGLS (period weight) method is suitable because this method solves inefficient coefficient estimates, biased standard errors, and unreliable hypothesis tests (Pedace, 2013).

In addition, this study expects R&D capital, FDI capital, and HDI are positively impact on TFP. We suppose H0: all explanatory variables affect to TFP and H1: all explanatory variables do not affect to TFP. The positively related between R&D capital and TFP has been investigated by Romer (1990) that R&D capital increase innovative activity and TFP.

In addition, FDI capital is also positively related to TFP growth because technology embodied in FDI cause the transferring technology and knowledge spillover from higher technology country (Tsamadias et al., 2018), there are many studies that mention as FDI is positively affected the growth rate of TFP (Papaioannou and Dimelis, 2018; Pietrucha and Żelazny, 2020; Stojčić and Orlić, 2020). Furthermore, HDI is positively impact TFP because the knowledge and skilled labor contribute to TFP growth (Su and Liu, 2016). Bandyopadhyay et al. (2019) support that the misallocation of human capital affects to TFP was decrease significantly.

CHAPTER 4
RESULT AND DISCUSSION

The result and discussion part have been divided into two sections, first is the result of TFP growth and its component, and the second section is the result of the TFP determinants.

4.1 TOTAL FACTOR PRODUCTIVITY GROWTH AND ITS COMPONENT

This section shows the TFP growth trend from 1991 to 2018 measured by this study. Table 4 shows the Malmquist Productivity Index (MPI) results include TFP and its components are Technical Change and Efficiency Change of each country.

Table 4 *The Malmquist Productivity Index (MPI) results*

Country	Year	TFP	Technical Change: TC	Efficiency Change: EC
Thailand	1991-1995	0.991	1.017	0.975
	1996-2000	1.137	1.053	1.080
	2001-2005	0.968	1.044	0.927
	2006-2010	1.025	0.996	1.029
	2011-2015	0.999	1.019	0.981
	2016-2018	1.012	1.018	0.994

Note: 1991-1995, 1996-2000, 2001-2005, 2006-2010, 2011-2015, and 2016-2018 are five years Geometric Mean.

Table 4 (Continued), The Malmquist Productivity Index (MPI) results

Country	Year	TFP	Technical Change: TC	Efficiency Change: EC
Singapore	1991-1995	1.068	1.068	1.000
	1996-2000	1.033	1.079	0.957
	2001-2005	1.077	1.077	1.000
	2006-2010	1.008	1.008	1.000
	2011-2015	1.127	1.127	1.000
	2016-2018	1.048	1.048	1.000
Malaysia	1991-1995	0.938	1.017	0.923
	1996-2000	1.100	1.056	1.042
	2001-2005	1.027	1.057	0.971
	2006-2010	0.996	1.013	0.984
	2011-2015	0.978	1.010	0.968
	2016-2018	1.016	1.018	0.998
Indonesia	1991-1995	1.000	1.017	0.983
	1996-2000	1.034	1.053	0.982
	2001-2005	0.985	1.044	0.944
	2006-2010	0.992	0.996	0.996

Note: 1991-1995, 1996-2000, 2001-2005, 2006-2010, 2011-2015, and 2016-2018 are five years Geometric Mean.

Table 4 (Continued), The Malmquist Productivity Index (MPI) results

Country	Year	TFP	Technical Change: TC	Efficiency Change: EC
	2011-2015	0.995	1.019	0.976
	2016-2018	0.994	1.018	0.977
Philippines	1991-1995	1.005	1.022	0.983
	1996-2000	1.018	1.019	0.999
	2001-2005	1.028	1.049	0.980
	2006-2010	0.973	0.992	0.980
	2011-2015	0.990	1.020	0.970
	2016-2018	0.948	1.018	0.931
Vietnam	1991-1995	0.951	1.005	0.947
	1996-2000	0.980	1.016	0.964
	2001-2005	0.965	1.023	0.944
	2006-2010	0.955	0.962	0.993
	2011-2015	1.025	0.978	1.049
	2016-2018	0.972	1.003	0.969

Note: 1991-1995, 1996-2000, 2001-2005, 2006-2010, 2011-2015, and 2016-2018 are five years Geometric Mean.

After we show the Malmquist Productivity Index (MPI) results in table 4, then we can combine all six ASEAN countries within one graph to see the trend of TFP growth from 1991 to 2018 of each country as the figure 5 below.

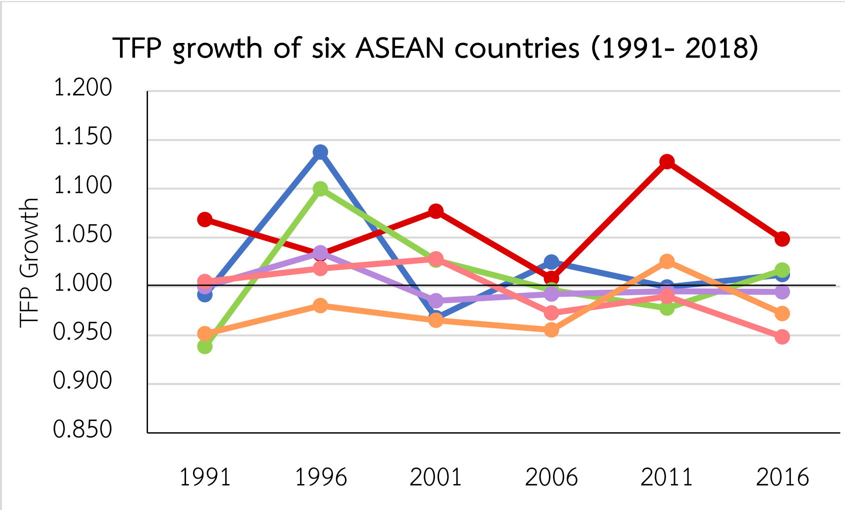

***Figure* 5** *TFP growth trend of the six ASEAN countries from 1991 to 2018*

Notes: Blue line is Thailand's TFP growth, red line is Singapore's TFP growth, green line is Malaysia's TFP growth, purple line is Indonesia's TFP growth, pink line is Philippines's TFP growth, and orange line is Vietnam's TFP growth. Figure is five years Geometric Mean.

From the objective, after we measure TFP growth, we will see the different TFP growth of the six ASEAN countries and for policy recommendation from this study, we can suggest a clearer comparison about the main source of TFP growth of each country as will interpret in the next section. Then, after we consider the TFP growth trend from 1991 to 2018 of each country, the results show that Singapore, Thailand, Malaysia, Indonesia, Philippines, and Vietnam have different TFP growth because it depends on the economic capabilities of each country, then, we can categorize each country's TFP growth into four groups, which are Leader country, Steady Growth country, Lag behind the country, and Catch-up Growth country.

Firstly, the leader country is Singapore because from 1991 to 2018 Singapore can maintain TFP growth every year, as the figure 5, Singapore has continuously TFP growth (TFP > 1) every year although there was an Asian Financial Crisis (AFC) in the late 1990s and from figure 6 Singapore's TFP growth is mainly due to an increase in Technical Change (TC) means that there is technological progress.

Secondly, the steady growth countries are Thailand and Malaysia because there was TFP growth but both countries cannot maintain their TFP growth every year, as shown in figure 5, Thailand and Malaysia have remained the steady TFP growth (TFP > 1) from 1991 to 2019 but the TFP grew is slightly not sharply increase like leader country (Singapore) because as figure 7 and figure 8 show TFP growth of both countries is mainly due to an increase in Efficiency Change (EC) rather than TC.

Thirdly, the lag behind countries are Philippines and Indonesia because as shown in figure 5, both countries have TFP growth at the beginning but recently both countries cannot maintain their TFP growth, because of the low EC, then the TFP had significant fall eventually. Finally, the catch-up growth country is Vietnam because this country has slightly TFP growth at the beginning, however, the TFP of Vietnam has increased recently because of the economic development with the Doi Moi policy in 1986 through the improvement of institutions for the market economy, macroeconomic stabilisation, and integrate into the regional and global economies. Then, Vietnam's economy growth rapidly (Tri et al., 2018).

4.1.1 Leader country's TFP growth and its component

The leader country is Singapore, in the period from 1996 to 2001, the TFP of Singapore is declining from 1.068 to 1.033 according to figure 6 due to the AFC in the late 1990s, however, there was TFP growth in the period from 2001 to 2005 because of the country's economic recovery. After that, during the period from 2006 to 2010, TFP of Singapore fall again because of the Global Financial Crisis in 2007-2008.

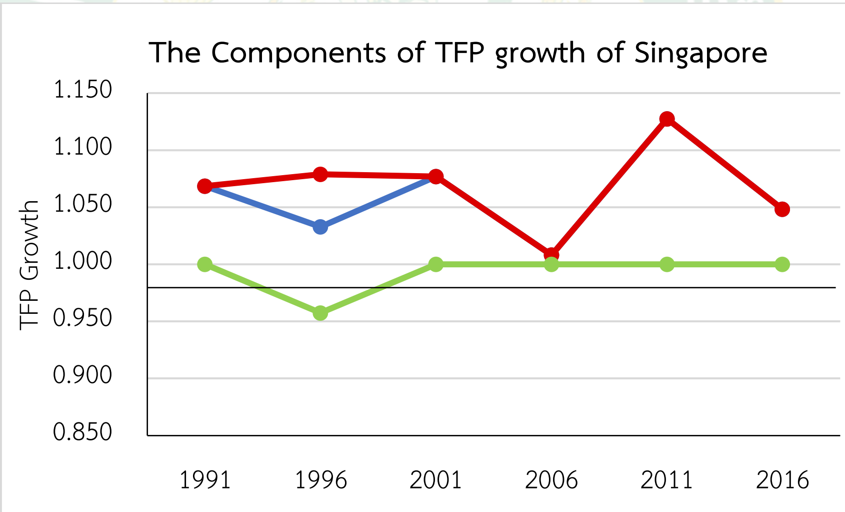

***Figure* 6** *The Components of TFP growth of Singapore*

Notes: Blue line is TFP represent TFP growth; red line is TC represent technical change; green line is EC represent efficiency change. Figure is five years Geometric Mean.

Then, as the figure 6, we interpret that Singapore's TFP growth was mainly due to Technical Change due to Singapore has technological development since

1965 and the government had attract a lot of inward FDI affect Singapore is an intensive innovation country and knowledge-based economy (Bobowski and Dobrzanski, 2019; Shahabadi et al., 2018) and Ho et al. (2009) reveal the higher in R&D expenditure of Singapore affect to TC that contribute to TFP growth.

4.1.2 The steady growth country's TFP growth and its component

The steady growth countries are Thailand and Malaysia because both countries have slightly TFP growth and cannot maintain all the time as the leader country. First, as shown in figure 7, Thailand has exhibited TFP progress, which is 1.025 during the period from 2006 to 2010 before declining to 0.999 in the period 2011 to 2015 because in 2011, there was the great flood in Thailand and (Nguyen Nhu and Noy, 2017).

Moreover, the great flood had an enormous negative impact on life, property, economic system, society, and the environment, especially in industrial sectors such as the automotive industry. Electronics and electrical appliances industry, Food and beverage industry Rubber and plastic products industry, as a result, the overall economic growth rate of Thailand decreased by 2.3% in 2011 (Office of the National Economic and Social Development Council, 2011).

However, Thailand's TFP grew steadily from 0.999 to 1.012 due to the economic recovery. Therefore, the TFP growth of Thailand was mainly due to EC more than TC because there was a lack of TC or technological progress and high-tech infrastructure (Bobowski and Dobrzanski, 2019). In addition, Thailand has industrialized without developing its own technological capabilities. the report from UNCTAD (2015) reported the governance issues for Thailand's innovation policies, such as many innovative organizations of the Thai state but has many of ineffective functioning and the cooperation between the public sector and private sector and the private sector involvement is not much as public sector ratio, and the lack of prioritization of many plans and process lists.

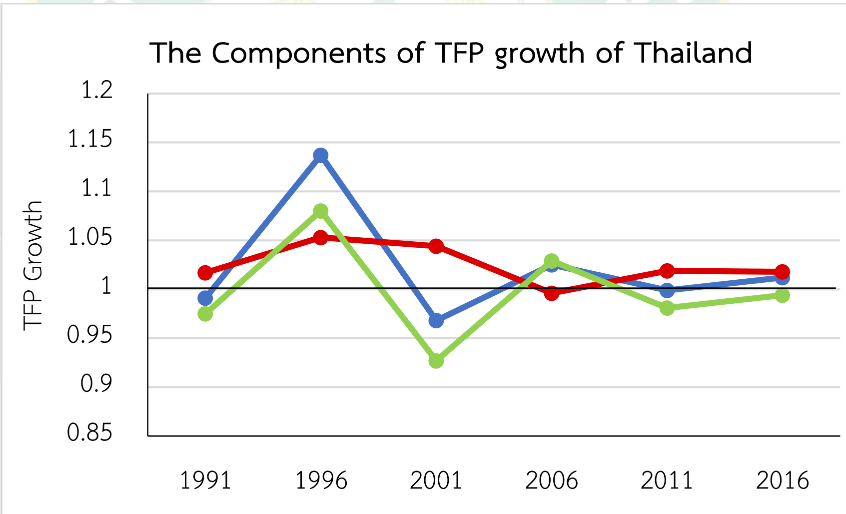

***Figure* 7** *The Components of TFP growth of Thailand*

Notes: Blue line is TFP represent TFP growth; red line is TC represent technical change; green line is EC represent efficiency change. Figure is five years Geometric Mean.

Second, Malaysia is also in the steady growth country as shown in figure 8, Malaysia has reached the peak of TFP growth during the period 1996 to 2000 before fall in the period from 2001 to 2005 because export is stuck due to the AFC, the study by Nambiar (2009) Malaysia has a strong export-dependent manufacturing sector. However, TFP increases significantly since 2011, and the TFP growth of Malaysia was mainly driven by EC. In addition, the study by Bobowski and Dobrzanski (2019) reveals Malaysia and Thailand are in the catching-up phase, thus still need to improve and advance both of Thailand and Malaysia's innovation policies.

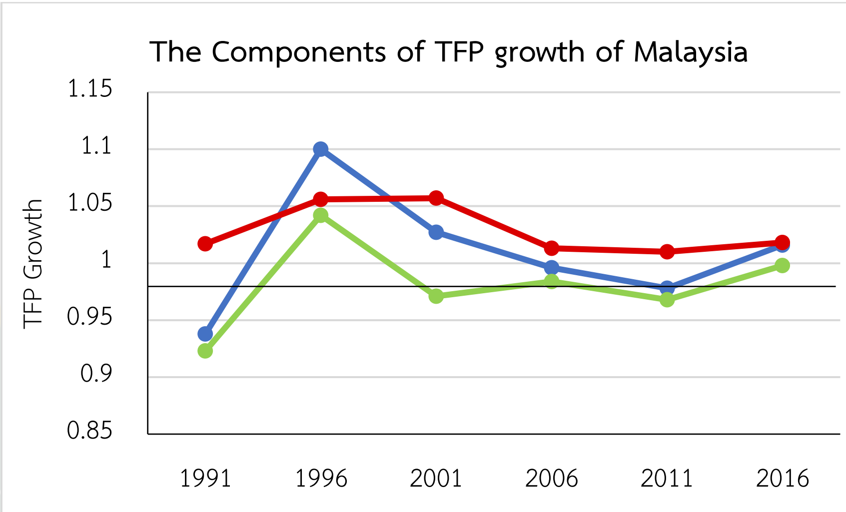

***Figure* 8** *The Components of TFP growth of Malaysia*

Notes: Blue line is TFP represent TFP growth; red line is TC represent technical change; green line is EC represent efficiency change. Figure is five years Geometric Mean.

In addition, figure 8 shows Malaysia had peak TFP growth during the period 1996 to 2000 before fall in the period from 2001 to 2005 because export is stuck due to the AFC because the economy depend on export-dependent manufacturing sector (Nambiar, 2009). However, TFP increases significantly since 2011, and the TFP growth of Malaysia was mainly driven by EC. Bobowski and Dobrzanski (2019) reveals Malaysia and Thailand are in the catching-up phase, thus still needs to improve and advance its innovation policy.

4.1.3 Lag behind country's TFP growth and its component

The lag behind countries are Philippines and Indonesia because there is TFP growth at the beginning period but in the recent period both countries cannot maintain their TFP growth due to the low EC, then the TFP had significant fall. First, as shown in figure 9, the period from 1991 to 1995, Philippines had TFP growth (1.005) and its higher than Thailand (0.991), Malaysia (0.938), Indonesia (1.000), and Vietnam (0.951) because Philippines had expand the infrastructure to support the service sector which mostly contributed to the economic growth, whereas Philippines has rapidly economic growth (Cornell University et al., 2019).

In addition, during the period from 1996 to 2000, Philippines had the least affected by the AFC because Philippines' economy is mainly depending on foreign remittances and since 2000, the government of Philippines launched the innovation and technology policy or the national STI policy, which is useful for Philippines's economic development, especially on the accumulate of human capital because Philippines has a lot of young labor force (Hybridigm Consulting and Nesta, 2019).

However, in the period from 2006 to 2010, TFP fell to 0.973 because the export was decreased and there were political and security issues in Philippines. Further, the Global Innovation Index, Philippines was arranged in weak innovation country (Cornell University et al., 2021a). In addition, to improve the TFP growth and also innovation capacities, the study by Bobowski and Dobrzanski (2019) suggests that Philippines need to enhance more cooperation among industry, government, and academia.

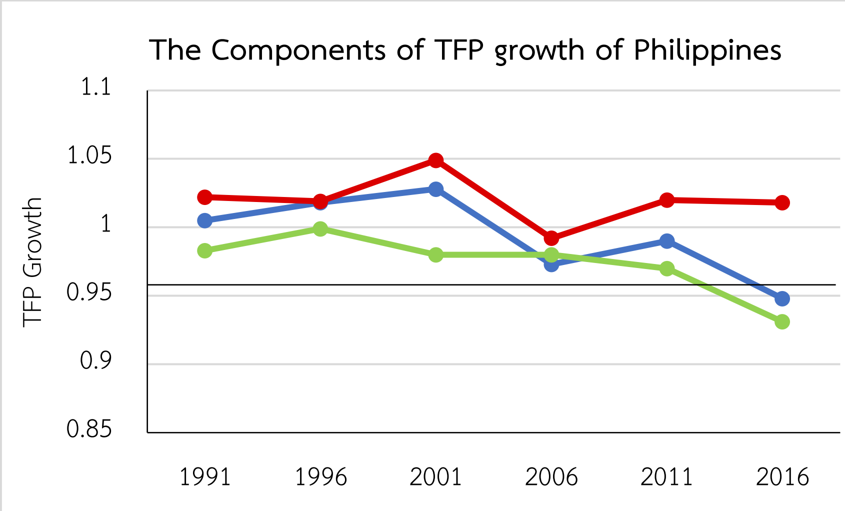

Figure 9 *The Components of TFP growth of Philippines*

Notes: Blue line is TFP represent TFP growth; red line is TC represent technical change; green line is EC represent efficiency change. Figure is five years Geometric Mean.

Another lag behind country is Indonesia, figure 10 shows Indonesia's TFP growth reach a peak in the period from 1996 to 2000 at 1.034 before falling to 0.985 due to exporting declined, but since 2006 TFP increase to 0.992 and remain constant. In addition, Indonesia was arranged as a weak innovation country (Cornell University et al., 2021a) and Indonesia has low innovation capabilities (Basri et al., 2016).

As shown in figure 9 and figure 10, both Philippines and Indonesia have low TFP and no TFP progress in the most of period investigation, even both countries had TFP growth at the beginning, TFP has fallen recently. Therefore, to improve TFP growth, Philippines and Indonesia should intensify the use of knowledge and innovation in economic activities to maintain TFP growth and drive more TC and EC.

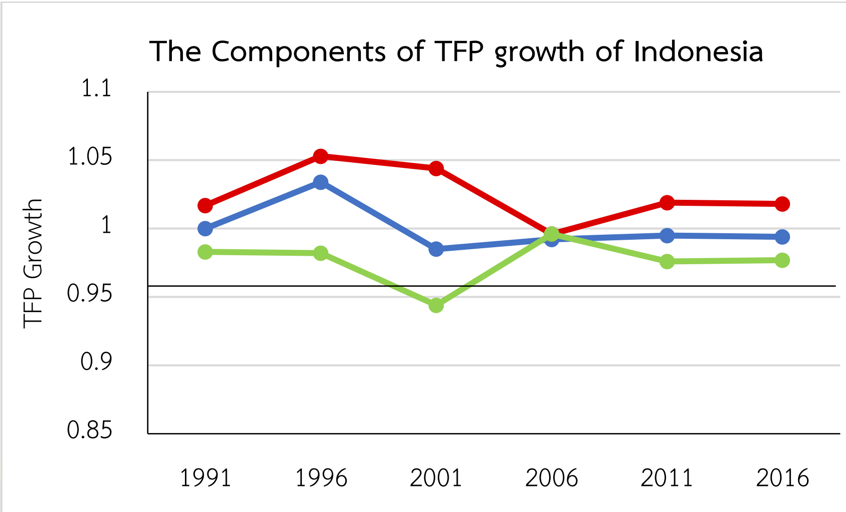

***Figure** 10 The Components of TFP growth of Indonesia*

Notes: Blue line is TFP represent TFP growth; red line is TC represent technical change; green line is EC represent efficiency change. Figure is five years Geometric Mean.

4.1.4 Catch-up growth country's TFP growth and its component

The catch-up growth country is Vietnam because this country has slightly TFP growth at the beginning period, however, TFP increase in the recent period because EC increase. According to figure 11, the TFP growth of Vietnam was mainly due to the EC and from 2011 to 2015, Vietnam had TFP growth 1.025 higher than Thailand (0.999), Malaysia (0.978), Indonesia (0.995) and Philippines (0.990) as a result from rapidly economic growth of Vietnam. From 1987 to 1995, Viet Nam create a new legal framework for science and technology (S&T)-based development, and nowadays Vietnam has many policies to support the country's economic growth, such as tax reduction for foreign firms, increase preferential access to credit, trade promotion, education and training, information support, market development, and R&D (Tri et al., 2018).

However, over the period from 2016 to 2018, TFP drop to 0.972 from 1.025 in the previous period due to export decline from less demand from a trade partner, which is China faces economic growth declined and in 2016 there was many of natural disaster which negatively affect to Vietnam's economy then TFP decrease. Moreover, Vietnam was classified in Learning phase of innovation policy (Bobowski and Dobrzanski, 2019). So, Vietnam needs to improve technological development.

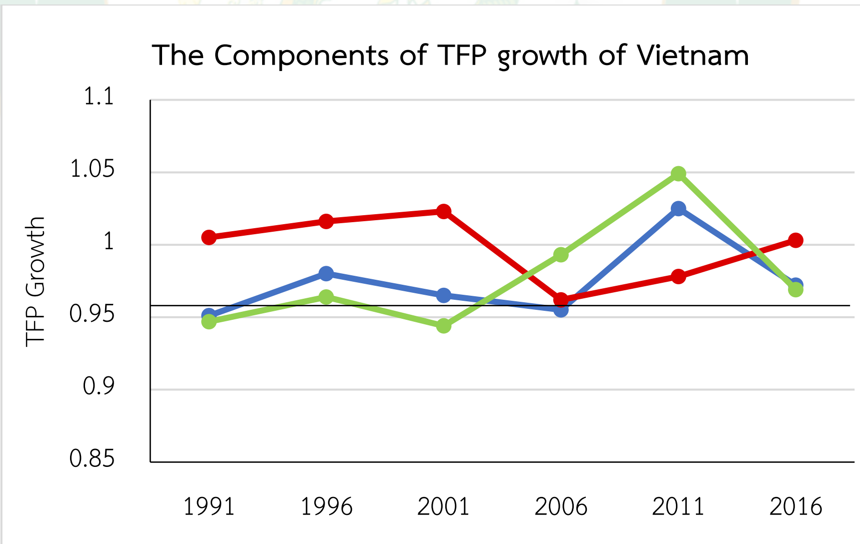

Figure 11 The Components of TFP growth of Vietnam

Notes: Blue line is TFP represent TFP growth; red line is TC represent technical change; green line is EC represent efficiency change. Figure is five years Geometric Mean.

4.2 THE DETERMINANTS OF TOTAL FACTOR PRODUCTIVITY

After we measured TFP growth of each country, then from the objective, we estimated the impact of Research and Development (R&D) capital on Total Factor Productivity (TFP) growth of selected countries in the ASEAN region using the Panel Estimated Generalized Least Squares (EGLS) period weight method.

Table 5 The panel regression results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
logRD	0.012	0.006	2.002	0.047**
logHDI	0.105	0.049	2.146	0.034**
logFDI	0.002	0.005	0.335	0.738
C	0.756	0.160	4.716	0.000
R-squared	0.550			
Adjusted R-squared	0.451			
DW	1.698			
F:	5.580			

Note: The estimate is based on Panel EGLS (Period weights) and Fixed Effect estimation for six ASEAN countries in the period 1991-2018. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels of significance, respectively. The dependent variable is TFP. The independent variables are RD is R&D capital, HDI is Human Development Index, and FDI is FDI capital.

As can be seen in table 5, the result shows the coefficient of R&D capital (RD) is positive and statistically significant at 5 percent level, this finding is similar as Bernini et al. (2017); (Park, 2012; Xiong et al., 2020), these studies found that R&D capital is positive affect to TFP significantly because R&D capital is the well-organized process that cause the creation and application of knowledge in the production, and R&D capital is also the necessary input innovation use to produce or develop new technology and innovation output of the production.

Moreover, the R&D capital can increase TFP through higher efficient in the production and increase product quality by technological progress or Technical change (TC) which is the source of TFP growth, TC indicates the capacity to keep up with the largest technologies, if there are highly use of technology and innovation through the R&D capital in the production, then the aggregate productivity or TFP will increase, and if there is no R&D capital, it is difficult to develop or create new technology product. Therefore, this study found that R&D capital is the key factor in promoting TFP as the previous study by Huang et al. (2019); (Tsamadias et al., 2018).

The Human Development Index (HDI), which is the represent of the human capital has a positive coefficient and statistically significant at 5 percent as the previous studies found that the human capital has a positive impact on TFP (Kim and Park, 2018; Lee and Narjoko, 2015) because these previous study reveal the low educational attainment of labor or low human capital is lead to low productivity and TFP.

Furthermore, human capital increases productivity in the production and TFP through the ability of highly skilled labor, qualification or educational attainment, and the experience of labor on absorbing or adopt innovative technology and innovation product at a high level of technology on production. Then, human capital accumulation is another important key to contributing the TFP growth (Bandyopadhyay et al., 2019).

The coefficient of FDI capital (FDI) is a positive affect to TFP but statistically insignificant because FDI capital has contribute to TFP through boosting capital investment, creating jobs for the host country, and spillover effect of technology from higher technology country or parent MNEs to affiliates in the host country which includes knowledge, skilled labor via training, technology transfer from parent MNEs to the affiliates in production (Papaioannou and Dimelis, 2018; Pietrucha and Żelazny, 2020; Stojčić and Orlić, 2020).

However, in ASEAN member countries which is developing countries where the absorptive capacities are not efficient as high as high-income countries and the lack of high level of technology capacities similar result as Li and Tanna (2019); (Su Dinh and Nguyen, 2020) reveals the TFP growth of developing countries depend on the absorptive capacity of the labor in the host country and suggest the high skilled labor has the ability to utilise new external technology for TFP growth.

Therefore, as the table 5, R&D capital is a significantly positive effect on TFP, and for catching up with the leader country (Singapore) and overcome the middle income trap like Singapore, other countries should improve the TC or Technical change, represent technological progress through support more on R&D capital in term of the R&D policy improvement like Singapore, which has the development a lot of R&D activity both in public and private sectors, such as the public structure that support to innovation activity and effective knowledge flows and network links among key actors in the cluster between universities, public research institutes, and private firms (Dobrzanski and Bobowski, 2020; Lim, 2018).

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study aims to measure the TFP growth of six ASEAN countries and investigate the impact of R&D capital, FDI capital, and human capital on TFP growth. Based on the DEA result we can categorize the ASEAN countries into four groups including Leader country (Singapore), Steady growth country (Thailand and Malaysia), Lag behind country (Philippines and Indonesia), and Catch-up growth country (Vietnam), we found only the leader country, which is Singapore has TFP growth every year and it was mainly driven by TC, moreover, we found that there is the gap of TFP growth and TFP growth components (TC and EC) between groups because the capacities and budget to drive TFP growth are different (Caselli, 2005).

From the investigation of the relationship between TFP and its determinants, this study found the positive impact of R&D capital, FDI capital, and human capital on TFP, further, the finding indicates R&D capital is the most important factor to achieve TFP growth because R&D capital improves the technological progress or TC which increase TFP through the technology and innovation capacity. Furthermore, the technological progress is the ultimate source of sustained productivity growth and thus increases living standards in the long run (Bakker et al., 2019).

In addition, the Leader country which is Singapore has driven the economy by a knowledge-based economy, intensive technology, and innovation capacities, and continuously increase R&D expenditure for a long time, then Singapore overcomes MIT and obtain high-income economy status. Therefore, the Steady growth country, Lag behind country, and Catch-up growth country need to improve their source of TFP which is technical change (TC) by government support more in the technology and innovation expenditure and innovative capacities to induce innovation to promote productivity.

5.2 POLICY RECOMMENDATIONS

The finding of this study is directly important to policy implication for MICs or developing countries to overcome the middle-income trap because R&D capital is the main source for improving technical change or technological progress of the country and R&D can result in better TFP growth as the leader country, which has the success of innovative knowledge-based development and R&D investment.

Therefore, the policymakers of Malaysia, Thailand, Philippines, Indonesia, and Vietnam should encourage public expenditure on R&D in terms of highly promoting the technology and innovation sector. First, Malaysia can support innovation policies whether there is no lack of R&D incentives and grants for R&D, the government should increase the strengthening links between the university as the public research agency and industry to increase the opportunity and the platform to disseminate information quickly and efficiently (Narayanan and Lai, 2018).

Second, Thailand should increase the public investment in R&D and increase the spending of public funds and public money to encourage private investment in R&D and should improve R&D human resources, such as support the university student through the scholarship for internationalization education (Rattanakhamfu and Tangkitvanich, 2018). Third, Philippines should support the various form of cooperation and relate to sector-specific characteristics of firms, the government need to ensure that intellectual property in the Philippines is protected is also essential and the government should foster an innovation ecosystem and support higher encourage of R&D (Francis et al., 2018) especially should support new researchers because one of the strengths of Philippines is the high population of young labor forces.

Fourth, the government of Indonesia should support more spending on R&D activities, financing mechanisms, and infrastructure, such as public laboratories to support innovation activity. Finally, Vietnam, which had been a rapid economic development country since 1986 and Vietnam is showing a strong effort to improve institutions for the market economy, macroeconomic stabilization, and integration into the regional and global economies, however, Tri et al. (2018) suggest for achieve a more effective innovation policy, Viet Nam should improve coordination between research organizations and industry for state management, allocate sufficient funding for support human resources especially the research personnel, and support training partnerships between vocational education providers, universities, foreign-invested enterprises, and domestic firms.

5.3 RECOMMENDATIONS FOR FURTHER STUDIES

In addition, further study can apply the sample of study more especially on high income, middle-income, and low-income countries, and able to adapt more explanatory variables to more explain diverse factors that impact TFP.

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APPENDIX

Descriptive Statistics data of Singapore

	TFP Growth	*HDI*	*FDI capital*	*R&D capital*
Mean	1.065	0.850	1.87E+11	2.16E+10
Median	1.043	0.858	1.53E+11	1.89E+10
Minimum	0.930	0.728	3.1E+10	3.29E+09
Maximum	1.594	0.935	4.71E+11	4.74E+10
Std. Dev.	0.114	0.067	1.32E+11	1.45E+10
Sample Variance	0.013	0.005	1.74E+22	2.09E+20
Kurtosis	18.345	-1.257	-0.58618	-1.24584
Skewness	3.871	-0.269	0.679816	0.358118
Range	0.664	0.207	4.4E+11	4.41E+10
Sum	29.828	23.793	5.24E+12	6.05E+11
Observations	**28**	**28**	**28**	**28**

Descriptive Statistics data of Malaysia

	TFP Growth	*HDI*	*FDI capital*	*R&D capital*
Mean	1.012	0.738	56078667856	9391215776
Median	1.004	0.733	54373047541	6502504783
Minimum	0.901	0.652	17947127570	1621510015
Maximum	1.536	0.804	85750749112	26541856563
Std. Dev.	0.113	0.046	17019115132	7926169484
Sample Variance	0.013	0.002	2.8965E+20	6.28242E+19
Kurtosis	18.011	-1.028	0.062790226	-0.319483687
Skewness	3.848	-0.201	-0.173496367	0.971781986
Range	0.636	0.152	67803621542	24920346548
Sum	28.345	20.666	1.5702E+12	2.62954E+11
Observations	**28**	**28**	**28**	**28**

Descriptive Statistics data of Thailand

	TFP Growth	*HDI*	*FDI capital*	*R&D capital*
Mean	1.025	0.680	50932978961	5029622944
Median	1.009	0.688	58811631953	3799112648
Minimum	0.099	0.057	24526617623	4522815016
Maximum	0.010	0.003	6.01555E+20	2.04559E+19
Std. Dev.	12.725	-1.295	-1.355869292	2.601382834
Sample Variance	3.226	-0.200	-0.507916757	1.673287156
Kurtosis	0.524	0.182	69302949246	18007093141
Skewness	0.923	0.583	10889291502	815844938.4
Range	1.448	0.765	80192240747	18822938079
Sum	28.708	19.034	1.42612E+12	1.40829E+11
Observations	28	28	28	28

Descriptive Statistics data of Philippines

	TFP Growth	*HDI*	*FDI capital*	*R&D capital*
Mean	0.998	0.651	16789960610	1753088731
Median	0.984	0.655	15570091122	1640554265
Minimum	0.058	0.037	8339497341	466837327.9
Maximum	0.003	0.001	6.95472E+19	2.17937E+17
Std. Dev.	0.210	-1.165	0.888691158	1.165362658
Sample Variance	0.776	0.052	0.725698124	1.325849001
Kurtosis	0.243	0.119	35199831857	1722779136
Skewness	0.890	0.593	3087086195	1212977963
Range	1.133	0.712	38286918053	2935757099
Sum	27.950	18.240	4.70119E+11	49086484458
Observations	28	28	28	28

Descriptive Statistics data of Indonesia

	TFP Growth	*HDI*	*FDI capital*	*R&D capital*
Mean	1.002	0.628	44696470959	3411829395
Median	0.989	0.631	33640877056	2438380748
Minimum	0.057	0.055	38065603939	2567470736
Maximum	0.003	0.003	1.44899E+21	6.59191E+18
Std. Dev.	4.984	-1.082	-0.477823329	3.759795206
Sample Variance	1.923	-0.242	0.882794232	2.030542183
Kurtosis	0.272	0.177	1.24793E+11	10407693614
Skewness	0.913	0.530	1607430434	1086896330
Range	1.185	0.707	1.264E+11	11494589944
Sum	28.052	17.577	1.2515E+12	95531223072
Observations	28	28	28	28

Descriptive Statistics data of Vietnam

	TFP Growth	*HDI*	*FDI capital*	*R&D capital*
Mean	0.977	0.605	32663330223	1336060105
Median	0.969	0.614	24060907659	966223303.8
Minimum	0.068	0.065	19464362241	1066145767
Maximum	0.005	0.004	3.78861E+20	1.13667E+18
Std. Dev.	3.347	-1.124	-0.840945319	1.035219079
Sample Variance	1.236	-0.353	0.506382307	1.378794271
Kurtosis	0.316	0.209	68058843300	3781369885
Skewness	0.863	0.484	4487479426	301738708.5
Range	1.179	0.693	72546322725	4083108594
Sum	27.357	16.950	9.14573E+11	37409682946
Observations	28	28	28	28

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