The Impact of Technological Changes on Partial Factor Productivity of the Asean-5: A Panel Regression Analysis

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Abstract: ***This study examined the impact of technological changes on partial factor productivity represented by labor productivity in the ASEAN-5 from 1997 to 2016. The technological changes is represented by gross expenditures on Research and Development (R&D), access to mobile phones, access to internet and patent applications.***

The study employed the quatitative research design to determine the cause and effect relationship between the explanatory variables and the explained variable.

Based on the fixed effect model regression results, gross expenditures on R&D with first lag was acceptable and statistically significant at 5% level of significance. On the other hand, changes in access to mobile phones, access to internet and patent applications although reflected the expected sign of coefficient were found to be insignificant. Furthermore, 99% of the variations in labor productivity is explained by the variations in gross expenditure on R&D, access to mobile phones, access to internet and patent applications. Based on the findings, the paper recommends for strong government commitment through the Department of Science and Technology to increase gross expenditures on R&D to at least 1% of GDP and encourage more patent applications. The Department of Information and Communications Technology should look into the underlying Information and Communications Technology development plan of Malaysia and Singapore in terms of access to mobile phones and access to internet.

Keywords: ***Gross Expenditures on R&D, Access to Mobile Phones, Access to Internet, Patent applications, Labor productivity***

I. INTRODUCTION

Technological change is a process of invention, commercialization, and improvement of technology. In economics, technological change is an increase in the efficiency of a product or process that results in an increase in output, without an increase in input. In other words, someone invents or improves a product or process, which is then used to get higher output for the same amount of work. Some of the common results from technological change are productivity, where tools allow people to produce more in an hour of work; knowledge, where tools help people to create, manage and share knowledge, such as the internet; health-medicine, medical devices and other technologies that treat or prevent disease; transportation tends to become faster and safer with time; and, technology that directly or indirectly changes societies such as social media.

These technological changes are getting more intense with the shaping of the Fourth Industrial Revolution or Industry 4.0 which brought technological changes that are unprecedented, rapid, transformative, and resulted in an irreversible changes to the way people produce, work, live and interact. Governments, businesses, and individuals are migrating their activities to the internet at an increasing pace. More households in developing countries own mobile phones than have access to clean water. Technology is now making it possible to complete transactions, deliver products and services and make payments faster, more efficient, and at lower prices (Box & Lopez-Gonzales, 2017).

Some of the big opportunities from Industry 4.0 brought by technologies are the possibility to expand internationally and create new products and services. Industries also benefit from technological changes through improved productivity and efficiency, risk reduction, reduction in inventories, thereby, reducing capital costs, advanced quality control, improved understanding of customer demand, and reduction in time to market, and improved and more affordable services or after sales. Fostering productivity is a cornerstone of many countries' national economic policies. Taking this into consideration as well as the shaping of Fourth Industrial Revolution and in addition to the current state of science, technology, research and development, and labor productivity in the Philippines compared to other Association of South East Asian nationa (ASEAN) member states, it is necessary and timely to study the impact of technological changes on partial factor productivity (labor productivity) of the ASEAN-5.

II. THEORETICAL FRAMEWORK

Solow's neoclassical growth model, proposes productivity, capital accumulation, and population growth as the main sources of economic growth. This has been modified by later authors to include research and development as a determinant of growth (Romer, 1990). Griliches (1979) introduced the idea that productivity growth is the consequence of expenditures on R&D.

Manuscript received on February 15, 2020.
Revised Manuscript received on February 20, 2020.
Manuscript published on March 30, 2020.

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In endogenous growth theory, research and development spending is likely to lead to growth through its positive effect on innovation and total factor productivity (Romer, 1990). This theory regards new technology not only as an exogenously produced input good that the company utilizes but also new technology which can be created within the company. In endogenous growth theory, investments in research and development can provide long-term growth and lead to rising returns to scale. This is because previous research and development investments that were made to generate specific knowledge do not need to be made again. The replication of previous production does not, therefore, have to bear the burden of any research and development costs.

Grossman and Helpman (1994) argue that technological progress has been the main driver of growth in the world, where most technological progress requires, at least at some stage, an intentional investment of profit-seeking firms or entrepreneurs. Thus, under this view, industrial innovation resulting from research and development investment is the chief engine of economic growth. Moreover, a large investment of resources is required in order to reap benefits from the development of scientific ideas. Firms have an incentive to invest in research and development if there is an opportunity for them to increase profits. Therefore, if the profitability of R&D is raised (for example, through policy that promotes investment) and more investment goes into private-sector research and development, the innovation process accelerates, resulting in higher productivity.

Several empirical studies supports the postulations in the existing literature and revealed significant and positive relationship between research and development expenditures, ICT infrastructure (access to mobile phones and internet), innovation (patent applications), and labor productivity. Hence, an increase in research and development expenditures will result to a corresponding increase in labor productivity. While, some of the studies discussed in this section derived varied results. In the study of Castellani, Piva, Schubert and Vivareli (2016), they found out that the positive relationship between R&D expenditures and labor productivity both in the US and EU firms are with larger coefficients in the US firm because it is characterized with high-tech industry which has better ability to translate research and development investments into productivity gains. On the other hand, in the study on research and development expenditures and labor productivity in OECD countries they found out that while the level of research and development expenditure growth is found to affect labor productivity growth negatively, its lag has a positive effect and is statistically significant on the first lag. This indicated that, the positive impact of R&D activities on productivity occurs with a delay (Erdil, Cilasun and Eruygur, 2013).

Lastly, there is positive relationship between innovation and labor productivity. Kurt and Kurt (2015) used patent applications of non-residents, patent applications of residents, internet users per 100 people as innovation variables and GDP per person employed as labor productivity variable. Likewise, Bosco and Brugnoli (2010) found out that labor productivity change is positively correlated to patents. The correlation supports the idea that a large innovation contribute to labor productivity growth, therefore, those regions that register more patent application, should also register a higher labor productivity growth.

III. METHODOLOGY

This research study employed the quantitative descriptive-causal research design. Since the study was concerned in determining the behavior of the each of the variables, gross expenditure on research and development, access to mobile phones, access to internet and patent applications and labor productivity. The data were examined through analysis of dependence relationship between the said variables. A panel regression model was employed to measure the relationship between the explanatory variables and the explained variable.

A. Econometric Model

The model was estimated using the ordinary least squares (OLS). The estimating equation expressed labor productivity (LABPR) as a function of gross expenditure on R&D (GERD), access to mobile phones (MOB), access to internet (INT) and patent registration (PAT). The model is thus presented below:

$$\mathrm{LABPR} = \beta_0 + \beta_1\mathrm{GERD} + \beta_2\mathrm{MOB} + \beta_3\mathrm{INT} + \beta_4\mathrm{PAT} + \varepsilon_i \quad (1)$$

Where, β_0 as the intercept, β_1, β_2, β_3, and β_4 are coefficients of elasticity, and ε_i as the stochastic error term. LABPR is expected to be positively related to GERD, MOB, INT and PAT.

The three (3) approaches in panel regression analysis were employed to provide answers to specific problems of this study.

B. Pooled Least Square Model

The pooled least square model assumes that coefficients are constant across time and individuals. This is the simplest approach as it disregards the space and time dimensions of the pooled data and just estimates the usual ordinary least square regression. In econometric model it is represented as:

$$\mathrm{LABPR} = \beta_0 + \beta_1\mathrm{GERD}_{it} + \beta_2\mathrm{MOB}_{it} + \beta_3\mathrm{INT}_{it} + \beta_4\mathrm{PAT}_{it} + \varepsilon_{it} \quad (2)$$

Despite its simplicity, pooled regression may distort the true picture of the relationship of LABPR and changes in GERD, MOB, INT and PAT, across ASEAN-5 countries.

C. Fixed Effect Model (FEM)

The FEM is used between individual effects and if the explanatory variables are correlated:

$$\mathrm{LABPR} = \beta_0 + \beta_1\mathrm{GERD}_{it} + \beta_2\mathrm{MOB}_{it} + \beta_3\mathrm{INT}_{it} + \beta_4\mathrm{PAT}_{it} + \sum_{i=1}^{5} A + \varepsilon_{it} \quad (3)$$

Where, LABPR is the Labor Productivity, GERD is the Gross expenditure on R&D, MOB is the Access to mobile phones, INT is the Access to internet, PAT is the Patent registration, ε is the Error term, i is the Specific ASEAN-5 country, t is the Specific time, and A is the Dummy variable for ASEAN5 country.

D. Random Effect Model (REM)

To determine if there is random individual effect of the entities, the REM is effective if the explanatory variables are not correlated, the model is:

$$LABPR = \beta_0 + \beta_1 GERD_{it} + \beta_2 MOB_{it} + \beta_3 INT_{it} + \beta_4 PAT_{it} + U_{it} + \mu_{it} \quad (4)$$

This research run the regression model by using E-Views 7.0 and conducted various statistical tests.

Except for the test for stationarity using the Levin, Lin and Chu procedure and the Hausman test, all the other statistical tests were used in this study were gathered from the book of Gujarati (2003).

IV. STATISTICAL RESULTS

A. Behavior of Labor Productivity

Table 1 shows the data on labor productivity represented as output per employed person of ASEAN-5 from 1997 to 2016. Singapore consistently recorded the highest labor productivity per person employed with an annual average of 121,378. Whereas, the lowest labor productivity per person employed was recorded in the Philippines with an annual average of 15,025.Second to Singapore is Malaysia with an average labor productivity per person employed of 51,668, followed by Thailand and Indonesia with an average labor productivity per person employed of23,466 and 19,057, respectively. It may be observed that there was a decline in the average labor productivity in the ASEAN-5 from 1997 to 1998. In the said period, output per employed person recorded a decrease in Singapore from 101,266 to 96,326, Malaysia from 45,117 to 41,650, Indonesia from 16,468 to 14,205, Thailand from 18,462 to 17,585, and Philippines from 12,725 to 12,525.

Table –I: Labor Productivity of ASEAN-5

Year	Singapore	Thailand	Philippines	Malaysia	Indonesia
1997	101,266	18,462	12,725	45,117	16,468
1998	96,326	17,585	12,525	41,650	14,205
1999	102,653	18,394	12,394	43,012	14,133
2000	107,422	18,663	13,077	44,566	14,668
2001	102,772	19,006	12,669	44,376	15,040
2002	108,637	19,788	12,736	45,859	15,573
2003	114,842	21,034	13,119	46,906	16,112
2004	123,742	21,801	13,564	49,536	16,758
2005	127,414	22,572	13,904	51,660	17,668
2006	130,113	23,684	14,489	53,324	18,347
2007	130,648	24,467	15,022	55,269	18,638
2008	121,200	24,439	15,403	57,280	19,513
2009	117,252	23,956	15,148	55,182	19,979
2010	130,810	25,561	15,863	54,339	20,598
2011	134,001	25,359	15,932	55,122	21,577
2012	134,146	27,022	16,813	56,011	22,643
2013	135,444	27,890	17,756	55,503	23,487
2014	135,592	28,869	18,587	57,532	24,262
2015	135,715	29,766	19,186	59,494	25,346
2016	137,574	30,993	19,586	61,629	26,127

B. Behavior of Gross Expenditure on Research and Development

Table 2 shows historical data on gross expenditure on research and development from 1997 to 2016 by ASEAN5. The behavior of gross expenditure on research and development is somewhat similar with the behavior of labor productivity in terms of ranking. Rank 1, rank 2, rank 3, rank 4, and rank 5 are Singapore, Malaysia, Thailand, Indonesia, and Philippines, respectively. From 1997 to 2016, Singapore always had the highest expenditure on research and development with an average of 4,135 million US Dollar (USD). Whereas, Philippines has the least expenditure on research and development with an average of 215 million USD which is only 5 percent of what Singapore spent on research and development on the average.

Second highest ranking is Malaysia with average expenditure on research and development of 1,974 million USD. Followed by Thailand with an average expenditure on research and development of 957 million USD.

Table –II: Gross Expenditure on Research and Development

Year	Singapore	Thailand	Philippines	Malaysia	Indonesia
1997	1,681.63	220.42	117.14	604.66	334.03
1998	2,028.79	203.60	116.46	560.17	290.18
1999	2,247.00	517.62	120.05	594.55	292.48
2000	2,453.06	532.74	125.35	763.08	306.87
2001	2,691.43	567.69	128.98	767.03	223.03
2002	2,864.48	551.13	183.65	1,124.11	233.07
2003	2,937.71	628.42	182.26	1,189.18	244.21
2004	3,342.59	649.39	194.47	1,166.88	256.49
2005	3,689.91	621.48	174.74	1,229.10	456.96
2006	3,961.78	693.22	183.90	1,321.28	482.10
2007	4,743.23	630.37	193.04	1,404.50	512.69
2008	5,408.98	649.30	201.06	1,900.40	543.52
2009	4,427.56	744.82	211.21	2,397.17	591.93
2010	4,764.44	800.78	227.33	2,643.58	604.08
2011	5,412.79	1,244.07	242.56	2,774.08	641.35
2012	5,251.99	1,334.18	258.78	3,095.47	680.02
2013	5,535.11	1,674.89	327.04	3,240.77	759.62
2014	6,279.75	1,853.91	347.13	3,956.32	753.75
2015	6,420.48	2,471.66	368.19	4,285.41	790.50
2016	6,574.38	2,552.80	393.51	4,466.25	830.29

C. Behavior of Access to Mobile Phones

Table 3 shows the 20-year data on access to mobile phones, per 100 persons of the ASEAN5 from 1997 to 2016. On the average, Singapore posted the highest average access to mobile phone with annual average of 105 mobile phones access. Next to Singapore is Malaysia which recorded an average mobile phone access of 82 and recorded its highest in the year 2014 with a value of 148. Following the rank of Singapore is Thailand with an average of 71. It can be noted, however, that starting 2015 to 2016 Thailand recorded its highest access to mobile phones in 2016 at 173 which surpassed the record of Singapore and Malaysia.

Table –III: Gross Expenditure on Research and Development

Year	Singapore	Thailand	Philippines	Malaysia	Indonesia
1997	19.59	1.82	1.88	8.4	0.053
1998	26.01	1.65	2.37	8.9	1.07
1999	45.7	1.87	3.81	12	1.24
2000	59.02	5.04	8.44	22	1.8
2001	69.09	3.89	15.6	31.4	2.5
2002	77.7	2.6	19.35	37.7	5.5
2003	83.06	34.57	27.77	44.41	8.6
2004	92.65	42.98	39.85	57.12	13.63

2005	99.79	48.47	41.3	75.17	21.06
2006	105.37	60.5	49.29	75.45	28.3
2007	122.46	80.2	64.75	87.92	41.57
2008	131.01	93	75.28	100.77	59.83
2009	137.48	98.6	81.96	107.85	67.08
2010	143.57	106.6	90.05	119.22	88.08
2011	149.61	114.6	98.13	127.04	102.49
2012	151.86	125.18	104.49	140	114.89
2013	156.28	137.51	103.46	143.6	125.89
2014	146.9	141.42	110.03	148.47	126.5
2015	146.5	152.7	115.8	143.9	132.6
2016	146.9	172.6	109.2	141.2	149.1

In 2014, the number of people purchasing mobile technology on a regular basis vastly increased in Thailand, this is supported with statistics obtained by Pew Research Center Report that there are a staggering 97 million mobile subscriptions in the country. Overall, smart phone penetration has increased by 5 percent since the 2014 survey cited above, with the total number of mobile users predicted to reach 50 percent by 2019. Although this might seem rather low, this actually puts Thailand amongst the top 10 of the 32 developing nations polled in the survey for owning a smart phone device (Websell, 2016). On the average, the Philippines ranked 4th and Indonesia ranked 5th with access to mobile phones of 58 and 55, respectively.

C. Behavior of Access to Internet (per 100 Persons)

Table 4 shows a twenty year data on access to internet from 1997 to 2016, per 100 persons of the ASEAN-5. The highest access to internet is observed in Singapore in 2014 with a value of 82.

Table –IV: Access to Internet by ASEAN-5

Year	Singapore	Thailand	Philippines	Malaysia	Indonesia
1997	19.59	1.82	1.88	8.4	0.053
1998	26.01	1.65	2.37	8.9	1.07
1999	45.7	1.87	3.81	12	1.24
2000	59.02	5.04	8.44	22	1.8
2001	69.09	3.89	15.6	31.40	2.5
2002	77.70	2.60	19.35	37.70	5.5
2003	83.06	34.57	27.77	44.41	8.6
2004	92.65	42.98	39.85	57.12	13.63
2005	99.79	48.47	41.3	75.17	21.06
2006	105.37	60.5	49.29	75.45	28.3
2007	122.46	80.2	64.75	87.92	41.57
2008	131.01	93	75.28	100.77	59.83
2009	137.48	98.6	81.96	107.85	67.08
2010	143.57	106.6	90.05	119.22	88.08
2011	149.61	114.6	98.13	127.04	102.49
2012	151.86	125.18	104.49	140	114.89
2013	156.28	137.51	103.46	143.6	125.89
2014	146.9	141.42	110.03	148.47	126.5
2015	146.5	152.7	115.8	143.9	132.6
2016	146.9	172.6	109.2	141.2	149.1

On the other hand, the lowest access to internet was recorded by Indonesia with a value of 0.025 in 1997 and 1998. This further means that among ASEAN-5 countries, Indonesia has the slowest growth in the access to internet.

D. Behavior of Patent Applications

Table 5 shows data on patent in total number of applications including non-residents and residents of ASEAN-5 from 1997 to 2016.

Table –V: Patent Applications of ASEAN-5

Year	Singapore	Thailand	Philippines	Malaysia	Indonesia
1997	19.59	1.82	1.88	8.4	0.053
1998	26.01	1.65	2.37	8.9	1.07
1999	45.7	1.87	3.81	12	1.24
2000	59.02	5.04	8.44	22	1.8
2001	69.09	3.89	15.6	31.4	2.5
2002	77.7	2.6	19.35	37.7	5.5
2003	83.06	34.57	27.77	44.41	8.6
2004	92.65	42.98	39.85	57.12	13.63
2005	99.79	48.47	41.3	75.17	21.06
2006	105.37	60.5	49.29	75.45	28.3
2007	122.46	80.2	64.75	87.92	41.57
2008	131.01	93	75.28	100.77	59.83
2009	137.48	98.6	81.96	107.85	67.08
2010	143.57	106.6	90.05	119.22	88.08
2011	149.61	114.6	98.13	127.04	102.49
2012	151.86	125.18	104.49	140	114.89
2013	156.28	137.51	103.46	143.6	125.89
2014	146.9	141.42	110.03	148.47	126.5
2015	146.5	152.7	115.8	143.9	132.6
2016	146.9	172.6	109.2	141.2	149.1

Singapore consistently recorded the highest number of patent applications with an average of 8,922. The Philippines has the least number of patent applications with an average of 3,083. Second to Singapore is Malaysia with an average number of patent applications of 5,996, followed by Thailand and Indonesia with an average number of patent applications of 5,848 and 4,788 respectively.

Over the past 20 years, the patent applications in Singapore generally demonstrated an increasing behavior. This is different with the rest of the country in ASEAN-5 such as Thailand, Philippines, Malaysia, and Indonesia, where patent applications showed a declining behavior.

E. Test of Linear Association

Table 7 shows the correlation matrix between labor productivity and its determinants. The correlation coefficient of 0.8981 suggests that there is a strong positive correlation between labor productivity and gross expenditure on R&D same with access to internet and patent with correlation coefficient of 0.6869 and 0.7754, respectively. This indicates that there is a strong positive correlation between labor productivity and access to internet and patent. On the other hand, there is a moderate correlation between labor productivity and access to mobile phones as shown by 0.4557 coefficient.

Table –VI: Pearson Test of Correlation

	GERD	MOB	INT	PAT
Pearson Correlation	0.89*	0.45*	0.68*	0.77*
p-value	0.0000	0.0000	0.0000	0.0000

Significant at 5% Level of Significance

Since the calculated p-value is less than the 5 percent level of significance. Thus, reject the null hypothesis that there is no significant relationship between labor productivity and each of the independent variables gross expenditure on R&D, access to mobile phones, access to internet, and patent application.

F. Analysis of Regression Results

To test the significance of the hypothesized effects of gross expenditure on research and development, access to mobile phones, access to internet and patent applications on the percentage change in labor productivity, the three approaches in panel regression analysis were performed. This three approaches in panel regression are: pooled least squares, Fixed Effect Model and Random Effect Model.

Table –VI: Panel Regression Results

Variables	PLS		FEM		REM	
	Coefficient	p-values	Coefficient	p-values	Coefficient	p-values
GERD	2.58E-11	0.00	2.56E-11	0.00	1.85E-10	0.14
MOB	0.0006	0.12	0.006	0.16	-0.0049	0.00
INT	0.0001	0.78	0.002	0.62	0.0205	0.00
PAT	3.41E-07	0.87	2.28E-07	0.92	0.0001	0.00
	R^2=0.8048		R^2=0.9989		R^2=0.8048	
	F-Test= 92.8232		F-Test= 8391		F-Test= 92.8232	

Significant at 5% Level of Significance

The Pooled Least Square (PLS) estimation in Table 6 revealed that the coefficient of determination, R^2 is 0.99 which suggests that 99 percent of the variations in percentage change in labor productivity is explained by the variations in gross expenditures on research and development in access to mobile phones, access to internet and patent applications.

The corresponding p-value of 0.0061 for gross expenditure on research and development is less than the 5 percent level of significance. Therefore, reject the null hypothesis that labor productivity is not significantly affected by gross expenditures on research and development. However, access to mobile phones, access to internet and patent application are not statistically significant at 5 percent level of significance.

The F-statistic of 15,535.68 exceeded the F critical value of 2.53 at five percent level of significance. Hence, reject the null hypothesis that labor productivity is not significantly affected by gross expenditures on research and development, access to mobile phones, access to internet, and patent application, when taken collectively. The model is statistically significant, the gross expenditures on research and development, access to mobile phones, access to internet and patent application when treated as an aggregate, affect a percentage change in labor productivity.

The Fixed Effect Model (FEM) estimation revealed that The coefficient of determination, R2is 0.99 which suggests that 99 percent of the variations in percentage change in labor productivity is explained by the variations in gross expenditures on research and development, access to mobile phones, access to internet, and patent applications.

The corresponding t-statistic for gross expenditures on research and development, access to mobile phones, access to internet and patent application were 2.7274, 1.4234, 0.4985 and 0.1027, respectively. The gross expenditures on research and development are greater than the critical value of 1.671 with a corresponding p-value of 0.0078 which is less than the 5 percent level of significance. Therefore, reject the null hypothesis that labor productivity is not significantly affected by gross expenditures on research and development, access to mobile phones, access to internet, and patent applications. However, access to mobile phones, access to internet and patent applications were not statistically significant at five percent level of significance.

The F-statistic of 8391.773 exceeded the F critical value of 2.53 at five percent level of significance. Hence, reject the null hypothesis that labor productivity is not significantly affected by gross expenditures on research and development, access to mobile phones, access to internet and patent applications, when taken collectively. The model is statistically significant, a change in gross expenditures in research and development with first lag, access to mobile phones, access to internet and patent applications, when taken collectively, affect a percentage change in labor productivity.

The regression using Random Effect Model approach indicates that the sign of the coefficient for gross expenditures on research and development reflected the expected sign. However, it was found out not statistically significant at 5 percent level. Access to internet and patent applications reflected were found to be statistically significant at 5% level of significance. Similarly, access to mobile phones was also statistically significant but reflected the unexpected sign of the coefficient. Although the coefficient of determination, R^2, is relatively high at 8 percent, which suggest that 80 percent of the variations in percentage increase of labor productivity was explained by the variations in gross expenditure on research and development with first lag, access to mobile phones, access to internet and patent applications. However, it should be noted that the d-statistic is 0.6249 which is less than the d_L 1.566 and d_U 1.751 and 4-d_U 2.249, there is negative autocorrelation, hence, the regression model is not reliable.

V. CONCLUSIONS AND RECOMMENDATIONS

Gross expenditures on research and development, access to mobile phones, access to internet, and patent applications are correlated with labor productivity. However, only gross expenditure on research and development with first lag has a significant direct relationship with labor productivity but not access to mobile phones, access to internet and patent application. It can be inferred, therefore, that a change in gross expenditures on research and development will lead to a percentage change in labor productivity. This result is consistent with Erdil, Cilasun and Eruygur (2013) which showed that the positive impact of research and development expenditures on labor productivity occurs with a delay.

The regression results derived from the fixed effect model, suggested that, statistically, labor productivity was significantly affected by gross expenditures on research and development with first lag. Among the three approaches of panel regression, fixed effect model is the most appropriate model to use to measure the effects on labor productivity of gross expenditures on research and development, access to mobile phones, access to internet, and patent applications in the ASEAN5.

The cross-section fixed effects generated showed that Thailand, Philippines, Malaysia, and Indonesia are inferior to Singapore in terms of gross expenditure on R&D, access to mobile phones, access to internet and patent application. Singapore consistently leads the other four ASEAN member states under study with highest average labor productivity of 121,378 output per employed person; highest in R&D expenditures with average of 4.135 billion US$ from 1997 to 2016; highest access to mobile phones at 105 per 100 persons, highest average access to internet 50 per 100 persons and highest in patent applications with an average of 8,922.

The Department of Science and Technology should continue its effort in strengthening the research and development activities where research and development expenditure will be invested.

The study recommends the Department of Information and Communications Technology to look into available statistics as well as the underlying ICT development plan or policy of Singapore and Malaysia being at ranked 1 and 2 in terms of access to mobile phones and access to internet, respectively. With the speed of exchange of information in the digital age mobile phones are not only used for communication but as a medium to access a range of services from shopping, entertainment, banking, and access to various government services, among others.

In terms of gross expenditure on R&D, it is worthy to note that there is significant positive correlation with labor productivity. This is consistent with a number of related literature and studies that highly recommend for government to invest in R&D. In addition, according to UNESCO (United Nations Educational, Scientific and Cultural Organization) as part of Sustainable Development Goals, countries have pledged to substantially increase R&D spending. Further, developing countries must spend at least 1% of GDP for R&D (Albert, Yasay and Gaspar, 2016) which is currently being adopted by Malaysia.

Other determinants of labor productivity relative to technological changes as represented by research and development expenditures, access to mobile phones, access to internet and patent applications of the ASEAN5 may be considered in future studies, considering it is one of the limitations of the study.

REFERENCES

1. S. Box and J. Lopez-Gonzalez .2017. "The Future of Technology: Opportunities for ASEAN in the Digital Economy". *Global Megatrends: Implications for the ASEAN Economic Community*.
2. P. Romer. *1990. "The Origins of Endogenous Growth".* The Journal of Economic Perspectives. *8 (1): 3–22.* doi:10.1257/jep.8.1.3.JSTO R 2138148.
3. Z. Griliches. 1998. "R&D and Productivity: The Econometric Evidence". *National Bureau of Economic Research, pages 17-45*.
4. G. Gross and E.Helpman. 1994. "*Endogenous* Innovation in the Theory of Growth" American Economic Review Vol.8 No.1. doi: 10.1257/jep.8.1.23.
5. Castellani, D., Piva, M., Schubert, T., and Vivarelli, M., 2016. "The Productivity Impact of R&D Investment: A Comparison between the EU and the US". *Institute for the Study of Labor (IZA) in Bonn. Discussion Paper No. 9937*.
6. E. Erdil, S. Cilasun and A. Eruygur. 2013. "Do R&D Expenditures Matter for Labor Productivity in OECD Countries? An Unresolved Question". H.Ü. İktisadiveİdariBilimlerFakültesiDergisi, Cilt 31, Sayı 1, 2013, s. 71-82.
7. Kurt, S. and Kurt, U., 2015. "Innovation and Labour Productivity in BRICS Countries: Panel Causality and Co-integration". *Science Direct Procedia Social and Behavioral Sciences 195 (2015) 1295-1302*
8. M.G. Bosco, and A. Brugnoli. 2010, "Regional Efficiency, Innovation and Productivity". Regional Studies Association Annual International Conference Pecs, Hungary.
9. Gujarati, D.N. 2003. *Basic Econometrics* (4th ed.). New York: McGraw-Hill Company.
10. Organization for Economic Cooperation. *https://data.oecd.org/lprdty/multifactor-productivity.htm; https://stats.oecd.org/glossary/detail.asp?ID=309; https://stats.oecd.org/glossary/detail.asp?ID=1698*
11. Websell, J. 2016. "The Growth of Mobile Technology in Thailand". Retrieved from https://tecpartners.co.uk/growth -mobile-technology-thailand.
12. Albert, J.R., Yasay D., and Gaspar, R. 2016. "Examining Processes in Research and Development at the Department of Science and Technology". PIDS Discussion Paper Series No. 2016-04.

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