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THE ROLE OF ICT DEVELOPMENT IN PROMOTING ASEAN REGIONAL ECONOMIC CONVERGENCE

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ABSTRACT

Economic growth convergence is one of the economic targets that ASEAN countries aim to achieve through various initiatives and regional cooperation. To realize economic convergence, technology and information play a crucial role in accelerating economic growth in each country or region. As there has not been much research discussing the economic convergence in the context of technology and information among Southeast Asian countries, this study aims to uncover how technological innovation acts as a catalyst for economic growth convergence among ASEAN-5. The study uses secondary data from five ASEAN countries (ASEAN-5) from 2000 to 2020, sourced from the World Bank. The Generalized Method of Moments (GMM) is used to estimate the influence of technological and information developments on economic growth in ASEAN countries. The analysis results indicate that mobile phones have extensively penetrated ASEAN countries. This includes various social and economic groups, including communities in rural or remote areas without stable internet access. Mobile phones, especially basic phones (feature phones), remain the primary tool for communication and information access in many developing countries, including those in ASEAN.

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1. INTRODUCTION

Economic integration is one of the goals pursued by ASEAN countries through various initiatives and regional cooperation. In this regional economy, significant disparities still exist between member countries. For instance, data from the World Bank in 2023 shows that the GDP per capita of Singapore is much higher compared to Myanmar's GDP per capita. This indicates a significant economic gap between the two countries. The discourse surrounding the capacity of developing countries to catch up with developed nations has been widely discussed by economists and academics (Ghatak & De, 2021; Piketty et al., 2019). This discussion covers various aspects, including economic policies, foreign investment, improving the quality of education and skills, as well as infrastructure development. Therefore, an analysis of economic convergence is crucial to discuss.

Economic convergence refers to the process by which poorer or less-developed countries experience faster economic growth compared to wealthier countries, thus reducing the per capita income gap between them. A deeper understanding of the factors that drive or hinder economic convergence can assist ASEAN countries in designing more effective strategies for achieving more equitable and sustainable development across the region. Furthermore, efforts to accelerate economic convergence can enhance social and political stability, reduce poverty, and improve the welfare of people throughout ASEAN.

The theory of convergence stems from neoclassical economic thinking, which assumes that developing countries can catch up with developed countries when institutional quality and technological development are considered equal. The core premise of this theory is that countries with lower per capita income will experience faster economic growth compared to already-developed countries, as they have more room for technology adoption and efficiency improvements (Solow, 1956). Therefore, over time, developing countries are expected to catch up. Regional convergence, in this context, refers to the ability of a region or area to close its development gap compared to more developed regions. The effects of convergence in a region could potentially reduce disparities between regions, which in turn can support social and political stability and improve the overall welfare of society (Abreu et al., 2019).

This process involves not only economic growth but also improvements in various development indicators such as education, health, and infrastructure. For example, increased access to education and healthcare in underserved areas can have long-term positive impacts on labor productivity and, ultimately, economic growth. Additionally, adequate infrastructure development, such as roads, bridges, and transportation facilities, can enhance connectivity between regions and stimulate the flow of goods, services, and labor, all of which contribute to more inclusive economic growth. Thus, reducing disparities within a region can serve as an accelerator for sustainable development efforts. More equitable development can reduce migration pressures from poorer areas to more developed regions and promote a fairer distribution of income. Furthermore, policies that support convergence, such as investments in education, health, and infrastructure, along with institutional reforms to improve efficiency and transparency, can play a crucial role in accelerating this process (Mendez & Santos-Marquez, 2021). Ultimately, successful economic convergence can create more favorable conditions for sustainable and inclusive growth that benefits the entire region.

Information and communication technology (ICT) plays a key role in achieving regional economic convergence. Technological development allows for the dissemination of knowledge between advanced and developing regions. Kijek and Matras-Bolibok (2020) found that technology plays a role in helping developing countries catch up with developed countries in Western and Eastern Europe. Meanwhile, Inegbedion (2021) studied the Asia and Europe regions, indicating technological convergence between these regions, as evidenced by the rapid growth in internet usage in countries that were less advanced in digital technology. A well-developed digital ecosystem can support convergence across regions and, in turn, help reduce disparities between countries within a region (Memood & Azim, 2013; Verico, 2023; Zhou & Sotiriadis, 2021). In the context of ASEAN, technology plays a crucial role. Charutawephonnukoon et al. (2021) and Sapuan and Roly (2021) have highlighted that technology and innovation are two variables that have significant impact to fosters economic growth**.** Referring to data from ASEAN (2022), internet access in ASEAN is quite uneven. The highest internet access is found in Singapore, followed by Malaysia, as shown in the table below:

Table 1. Internet Access in ASEAN

ICT Services	Year	Indonesia	Malaysia	Singapore	Philippines	Thailand
Internet Subscription/Users per 100 persons	2017	54.8	80.1	82.3	-	58.1
	2018	64.8	81.2	87.2	-	70.0
	2019	73.7	84.2	88.9	75.4	68.7
	2020	73.7	89.6	95.0	-	70.2
	2021	77.0	96.8	96.9	75.4	70.2

Source: ASEAN Statistical Yearbook (2022)

Based on these conditions, this research aims to analyze the impact of technological development and convergence performance among ASEAN countries. The research fills gaps in previous studies by analyzing the phenomenon of convergence in the ASEAN region, focusing more on the role of technological innovation. This study explores the role of ICT development in promoting ASEAN regional economic convergence using a holistic approach, considering aspects such as ICT infrastructure, policies, and implications for achieving ASEAN regional economic convergence.

2. RESEARCH METHODS

This study focuses on analyzing the impact of technology development in the ASEAN-5 region since the ASEAN-5 nations represent some of the fastest growing economices and play an integral role in East Asian regionalism (Maneejuk & Yamaka, 2021). The aim of this research is to explore how the development of information and communication technology (ICT) can affect economic growth and reduce economic disparities among ASEAN countries. The stages of this research begin with data collection from relevant sources, followed by data analysis using appropriate methods. This study uses secondary data obtained from reliable sources such as the World Bank Database, covering the period from 2000 to 2020.

The main variable used is Gross Domestic Product (GDP) per capita as the dependent variable, which serves as a general indicator for measuring the level of economic well-being and standard of living of a country. In addition, the independent variables include Internet Penetration and Mobile Cellular Usage, which are used as proxies to measure the development of information and communication technology in ASEAN countries. The details of the variables used and their operational definitions are listed in the following table:

Table 2. Variables and Data Sources

Variables	Operational Definition
GDP Per capita (current US$) (GDP)	The total value added produced by all producers within an economy, plus product taxes (minus subsidies), divided by the mid-year population
Individual Using Internet (% Population) (INTERNET)	Individuals who have used the internet in the last three months
Mobile Cellular Phone Subscription (Per 100 people) (MOB)	Subscriptions to public mobile cellular services providing access to the Public Switched Telephone Network (PSTN) using mobile technology
Foreign Direct Investment (FDI)	Net inflows of investment to acquire lasting management interests (10% or more of voting shares) in a company operating in an economy other than that of the investor
Government expenditure for education (GOVEDU)	Government spending on the education sector
Trade (TRADE)	Net exports = Exports - Imports
Government Final Consumption (GFINC)	The total transactions in a country's national income accounts that represent government expenditure for goods and services used to meet individual (individual consumption) or collective (collective consumption) needs
Government Expenditure (GOVEX)	Government spending

Source: Processed Data (2024)

This study employs the Generalized Method of Moments (GMM) dynamic panel regression method. GMM is an econometric method used to estimate parameters in models that involve endogenous variables, serial correlation or heteroskedasticity (Hansen, 2010). GMM method is widely used in panel data analysis for its robust and efficient estimations under minimal assumptions. This research uses GMM method, with the following general form:

$$\ln Y_{it} = \beta_{0it} + \beta_1 \ln Y_{it-1} + \beta_2 \ln X_{1\,i,t} + \beta_3 \ln X_{2\,i,t} + \beta_4 \ln X_{3\,i,t} + \beta_5 \ln X_{4\,i,t} + \beta_6 \ln X_{5\,i,t} + \beta_7 \ln X_{6\,i,t} + u_{i,t} \quad (1)$$

Description :

$\ln Y_{it}$: The natural logarithm of GDP per capita for country *i* at time *t*, indicating the economic wellbeing of a country.

$\beta_1 \ln Y_{it-1}$: The lagged value of GDP per capita, representing the previous period's GDP to capture dynamic effects.

$\ln X_{1\,i,t}$: Natural logarithms of internet penetration

$\ln X_{2\,i,t}$: Natural logarithms of mobile phone usage

$\ln X_{3\,i,t}$: Natural logarithms of foreign direct investment

$\ln X_{4\,i,t}$: Natural logarithms of government education expenditure

$\ln X_{5\,i,t}$: Natural logarithms of trade

$\ln X_{6\,i,t}$: Natural logarithms of government consumption

This method is used to analyze the relationship between ICT development and GDP per capita in ASEAN countries, and to calculate the Beta convergence of economic growth caused by the influence of technological development. There are two types of Beta convergence: absolute and conditional convergence. This study uses conditional Beta convergence due to the different stationary conditions in each region. The following is the panel regression model with conditional Beta convergence:

$$\Delta \ln GDPit = \beta_{0it} + \beta_1 \ln GDP_{it-1} + \beta_2 \ln INT + \beta_3 \ln MOB + \beta_4 \ln FDI + \beta_5 \ln GOVEDU + \beta_6 \ln TRADE + \beta_7 \ln GFINC + \beta_8 \ln GOVEX + u_{i,t} \quad (2)$$

Description :

$\Delta \ln GDPit$: The growth rate of GDP per capita, capturing economic progress over time.

$\ln INT$: Logarithms of internet penetration

$\ln MOB$: Natural logarithms of mobile phone usage

$\ln FDI$: Natural logarithms of foreign direct investment

$\ln GOVEDU$: Natural logarithms of government education expenditure

$\ln TRADE$: Natural logarithms of trade

$\ln GFINC$: Natural logarithms of government consumption

$\ln GOVEX$: Natural logarithms of government consumption

Where β_{0it} represents the constant or intercept and β_1 represents the convergence coefficient. The beta convergence calculation is calculated using the coefficient value PDB_{it-1}, which can be symbolized by b. Thus, we obtain the equation $b = 1 + \beta_1$, with the parameters used to determine the convergence speed are – ln(b)

3. RESULTS AND DISCUSSION

3.1. RESULTS

This study uses secondary data obtained from the World Bank Database from 2000 to 2020. Table 3 presents the descriptive summary of the data for the variables under investigation.

Table 3. Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
GDP Growth	105	0.0581429	0.0848337	-0.15	0.32
GDP Per Capita	105	8.584476	1.217954	6.5	11.11
INTERNET	105	38.76952	27.56724	0.93	92
MOB	105	96.6519	48.95728	1.71	181.77
FDI	105	5.671143	7.67587	-2.76	29.76
GOVEDU	105	3.659905	1.130527	2.33	7.66
TRADE	105	9.02219	11.02933	-12.08	31.27
GFINC	105	11.42305	2.53787	6.53	17.8
GOVEX	105	91.1339	11.05909	67.05	112.08

Source: Processed Data, (2024)

The columns in the table provide descriptive statistics for each variable, including the number of observations, mean, standard deviation, minimum, and maximum values. All variables have a total of 105 observations. First, the average GDP growth rate from 2000 to 2020 is 0.058% with a standard deviation of 0.084. The lowest growth rate recorded is -0.15, while the highest is 0.32%. Second, the average GDP per capita is 8.58% with a standard deviation of 1.22%. The lowest GDP per capita is 6.5%, while the highest is 11.11%. Third, the average value for the "Individual Using Internet" variable (INTERNET) is 38.77% with a standard deviation of 27.57%. The minimum value is 0.93%, and the maximum is 92%. Fourth, the "Mobile Cellular Phone Subscription" (MOB) has an average of 96.65% with a standard deviation of 48.96%. The minimum is 1.71%, and the maximum is 181.77%.

Fifth, the average value for Foreign Direct Investment (FDI) is 5.67% with a standard deviation of 7.68%. The lowest FDI is -2.76%, while the highest is 29.76%. Sixth, government expenditure on education (GOVEDU) averages 3.66% with a standard deviation of 1.13%. The lowest recorded expenditure is 2.33%, and the highest is 7.66%. Seventh, ASEAN's net exports (TRADE) during the 21-year period averaged 9.02% with a standard deviation of 11.03%. The lowest value is -12.08%, and the highest is 31.27%. Eighth, government final consumption (GFINC) has an average of 11.42% with a standard deviation of 2.54%. The lowest value is 6.53%, and the highest is 17.8%. Finally, government expenditure (GOVEX) averages 91.13% with a standard deviation of 11.06%. The lowest expenditure recorded is 67.05%, and the highest is 112.08%. The Generalized Method of Moments (GMM) analysis method requires several conditions to be met, namely instrument validity, consistency, and unbiasedness. Instrument validity can be assessed through the Sargan test that can be seen in Table 4.

Table 4. Sargant Test

chi2(84)	100.1087
Prob > chi2	0.1109

Source: Processed Data, (2024)

The null hypothesis (H0) is accepted if the probability value is greater than 5%. Based on the Sargan test results, the probability value obtained is 0.1109, which is greater than the alpha level of 0.05. Therefore, H0 is accepted, and it can be concluded that the instruments used are valid.

To assess the consistency of the Generalized Method of Moments (GMM) estimator, the Arellano-Bond test for autocorrelation is employed. This test examines whether the idiosyncratic error term exhibits serial correlation in the first-differenced errors. To meet the consistency test criteria, the Arellano-Bond test can be used. The estimator will be consistent if the probability value for the second-order test is not significant or if H0 is not rejected (i.e., the p-value must be > 0.05).

Table 5. Arellano-Bond Test

Order	Z	Prob > z
1	-2.233	0.0255
2	-0.43498	0.6636

Source: Processed Data, (2024)

According to the Arellano-Bond test results presented in Table 5, the probability value for the second-order autocorrelation test is 0.6636, which exceeds the 0.05 significance level. This indicates that the null hypothesis of no second-order autocorrelation cannot be rejected, thereby satisfying the consistency requirement of the estimator.

The third condition in GMM is unbiasedness. The unbiasedness of the System Generalized Method of Moments (SYS-GMM) estimator is evaluated by comparing its coefficients to those obtained from the Fixed Effects (FE) and Pooled Least Squares (PLS) models. Typically, the FE estimator is considered downward-biased, while the PLS estimator is upward-biased. An estimator is deemed unbiased if its coefficients fall between those of the FE and PLS estimators.

Table 6. Unbiasedness Test

Variables	fe	fgdmm	sysgmm	pls
LNPDBT1	-0.25140167***	-0.32575011***	-0.1118253***	-0.08403961**
INTERNET	-0.00132675	-0.00056716	-0.00034164	-0.00064429
MOB	0.00276794***	0.00307445***	0.00122222*	0.00087517*
FDI	0.00789416**	0.00861924**	0.00597954	0.00429494
GOVEDU	-0.00762443	-0.01757167	0.00324728	-0.00098812
TRADE	-0.00335415	-0.0059341	0.00398772	-0.00064608
GFINC	-0.02129019*	-0.01296602	-0.01849934*	-0.00545832
GOVEX	-0.00389807	-0.00563289	-0.00200924	-0.00614819
LNPDBT1	-0.25140167***	-0.32575011***	-0.1118253***	-0.08403961**

Source: Processed Data, (2024)

In Table 6, the SYS-GMM estimator's coefficients are consistently situated between those of the FE and PLS estimators. For instance, the coefficient for LNPDBT1 is -0.1118 for SYS-GMM, which lies between the FE coefficient of -0.2514 and the PLS coefficient of -0.0840. Similar patterns are observed for other variables, such as INTERNET, MOB, FDI, GOVEDU, TRADE, GFINC, and GOVEX. This alignment supports the unbiasedness of the SYS-GMM estimator. Therefore, based on the unbiasedness test results, the SYS-GMM model is identified as the most appropriate for this analysis, as it satisfies all necessary assumption test criteria.

After confirming the unbiasedness of the SYS-GMM model and validating its suitability for the analysis, the next step is to examine the significance of the individual variables within the model. This parameter significance test identifies which variables exert a statistically significant influence on GDP growth, offering insights into the relationships between the dependent and independent variables. Table 7 presents the results of this significance test.

Table 7. Parameter Significance Test Results

Variables	Coef.	Robust Std. Err.	z	P > |z|
GDP Growth	.0768791	.0912828	0.84	0.400
INTERNET	-.0003416	.0006196	-0.55	0.581
MOB	.0012222	.0004813	2.54	0.011
FDI	.0059795	.0033719	1.77	0.076
GOVEDU	.0032473	.0175502	0.19	0.853
TRADE	.0039877	.0037125	1.07	0.283
GFINC	-.0184993	.00904	-2.05	0.041
GOVEX	-.0020092	.0026642	-0.75	0.45
GDP Growth	.0768791	.0912828	0.84	0.400

Source: Processed Data, (2024)

Table 7 presents the results of the parameter significance test. Among all the variables studied, only the Mobile Cellular Phone Subscription (MOB) variable significantly and positively impacts GDP growth in ASEAN. Meanwhile, the Government Final Consumption (GFINC) variable has a significant negative effect on GDP growth. The remaining variables do not significantly affect GDP growth.

After evaluating the significance of the variables, the next crucial aspect of the analysis is to assess the convergence speed of the economic variables, particularly GDP growth, internet usage, and mobile phone subscriptions. The convergence speed provides insights into how long it takes for these variables to stabilize or reach equilibrium across countries. Table 8 presents the results of the convergence speed calculations, highlighting the expected timeframes for each variable to achieve convergence.

Table 8. Convergence Speed Test Results

Variables	Convergence Speed	Half Life of Convergence
GDP Growth	0.56%	123 years
Internet	0.0047%	14.663 years
Mobile Phone Subscription	1.03%	67 years

Source: Processed Data, (2024)

Table 8 shows the convergence speed calculations for GDP growth, internet usage, and mobile phone subscriptions. Based on the table, the convergence speed for GDP growth is 0.56%, which will take 123 years to reach convergence. Internet usage has a convergence speed of 0.0047%, requiring 14,663 years to reach convergence. Lastly, mobile phone subscriptions have a convergence speed of 1.03%, taking 67 years to reach convergence. The estimation results are aligned with past research like Borowiecki et al. (2021) that focuses on digitalization on economic convergence in EU. Meanwhile different results arise from OECD countries, where they experienced partial convergence on RnD budgets and technological aspects between developed economies (Kassouri et al., 2021).

3.2. DISCUSSION

In this study, Information and Communication Technology (ICT) is proxied by the variables Individual Using Internet (INTERNET) and Mobile Cellular Phone Subscription (MOB). The data analysis results show that only Mobile Cellular Phone Subscription (MOB) has a statistically significant positive impact on GDP growth in ASEAN. MOB refers to subscriptions to public mobile cellular services that provide access to the Public Switched Telephone Network (PSTN) using cellular technology. This means that an increase in mobile phone subscriptions has a tangible and beneficial impact on GDP growth in ASEAN countries. This impact can be attributed to several factors.

First, with more people having access to mobile phones, communication becomes faster and more efficient. This facilitates easier communication for individuals and businesses, reduces transaction costs, and boosts productivity. Second, mobile phones often serve as the primary means of accessing digital services, including digital banking, e-commerce, and financial applications in many ASEAN countries.

These findings align with earlier research, such as Aker and Mbiti (2010), who found that mobile phones improve efficiency in the exchange of information and communication, reducing costs in information exchange and enabling two-way communication. This enhances communication flow and facilitates the development of various mobile services, such as mobile banking, which can create business and entrepreneurship opportunities (Aker & Mbiti, 2010). Furthermore, mobile phones can stimulate innovation, build networks, foster businesses, deepen capital, expand labor markets, strengthen market competition, and contribute to broader economic development (Nasution et al., 2022). The study reveals a one-way relationship between mobile phone usage and economic growth in ASEAN, where only economic growth affects mobile phone usage (Aker & Mbiti, 2010; Wahab et al., 2020). Therefore, the increasing use of mobile phones can be considered a positive indicator of economic growth in the ASEAN region.

On the other hand, the variable Individual Using Internet (INTERNET), which represents the number of individuals using the internet over the past three months, does not have a significant impact on GDP growth in ASEAN. This suggests that although more people are using the internet, it does not necessarily or strongly contribute to the increase in GDP in ASEAN countries. Several factors may explain this. First, the quality of internet use may be suboptimal. Despite increasing internet access, many users may primarily use the internet for entertainment or social activities, which do not directly contribute to economic productivity or GDP growth. For instance, social media use or video streaming may not have the same direct economic impact as internet use for business, trade, or education. Second, the digital divide still exists in ASEAN countries, where access to the internet in rural or underdeveloped areas remains limited. Therefore, despite statistics showing an increase in internet users, the impact on the economy may be constrained by limited infrastructure and the ability to fully leverage digital technologies. Third, internet usage and its integration with economic activities in several ASEAN countries are still not maximized. Internet penetration may not yet be fully integrated into major economic sectors such as agriculture, manufacturing, and services, meaning that the adoption of digital technologies has not significantly impacted productivity or economic output in these sectors. This also indicates that the relationship between internet usage and economic growth in ASEAN is one-way, where only economic growth influences internet usage, not vice versa (Wahab et al., 2020). Therefore, despite increased internet usage, it does not significantly drive GDP growth in ASEAN.

While mobile phones are significantly contributing to economic growth and convergence, the limited impact of internet usage suggests gaps in digital infrastructure, particularly broadband access. Policymakers should prioritize expanding affordable, high-speed internet in rural and underserved areas. Moreover, investment in 5G networks and fiber-optic expansion could enhance productivity and innovation, ensuring that internet access becomes as impactful as mobile phone usage. Thus, ASEAN government should harmonize digital policies across member states to reduce disparities in digital adoption. Strenghtening cross-border e-commerce regulations and data sharing agreements could enhance regional trade efficiency and economic integration.

4. CONCLUSION

This study aims to examine the effects of technological and information development variables on economic growth convergence in ASEAN-5. The analysis employs a dynamic panel data method using the system GMM approach to establish the relationship between the independent variables and the dependent variable. This research provides insights into the role of technological advancements in economic growth across ASEAN-5 countries, highlighting their potential to achieve convergence. Based on the calculations conducted, it was found that under the conditional variable of internet development, which varies significantly among ASEAN-5 countries, the estimated half-life of convergence is 14.663 years. Meanwhile, with the conditional variable of mobile phone subscriptions, characterized by broader and more equitable usage, the estimated half-life of convergence is 67 years.

The system GMM estimation results reveal that only the mobile phone subscription variable has a positive and significant effect on economic growth in the ASEAN-5 region. These findings align with previous studies suggesting that mobile phone usage enhances efficiency in various activities, including economic activities. On the other hand, the impact of internet usage on economic growth is not statistically significant. This indicates that increased internet access does not necessarily contribute to a country's GDP. In other words, the results reflect a lack of quality internet use in productive activities. Therefore, an essential focus of this study is the need to optimize the use of technology and information.

To strengthen ASEAN regional digital integration, national transformation strategies should be aligned with the ASEAN digital masterplan 2025, ensuring coordinated progress across member states. Public-private partnerships (PPPs) should also be encouraged to foster technology transfer and innovation sharing within the region. Given the significant role of mobile technology in economic growth, leveraging mobile-based services such as mobile banking and digital financial inclusion can help enhance economic participation, particularly in underserved communities. While mobile phone penetration has contributed to economic growth, achieving long term technological convergence requires policy-driven interventions to ensure that internet access translates into tangible productivity gains. Strengthened cooperation among ASEAN countries is essential to foster a more integrated digital economy, reducing disparities and accelerating regional economic convergence.

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