

HOW THE DIGITAL ECONOMY AFFECTS GDP ACROSS ASEAN COUNTRIES

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ABSTRACT

This study investigates the effects of the digital economy on GDP growth in nine ASEAN countries from 2004 to 2023. The digital economy is measured using three commonly applied indicators: mobile technology penetration, fixed broadband subscriptions, and the share of the population using the Internet. Data were obtained from the World Bank's World Development Indicators database and analysed using a dynamic panel model estimated through the System Generalized Method of Moments (System GMM). The findings demonstrate that the digital economy has a positive and statistically significant influence on GDP growth across ASEAN countries, although the magnitude of this effect differs among the selected indicators. The proportion of Internet users represents the most influential channel through which digitalisation contributes to economic growth, followed by mobile technology penetration. By contrast, the impact of fixed broadband subscriptions is comparatively limited. The results also show that government expenditure and trade openness make important contributions to economic growth, while the effects of capital investment and foreign direct investment depend on specific economic conditions. This study contributes to the literature by identifying the relative importance of different dimensions of the digital economy in promoting GDP growth in ASEAN. It also highlights that the productive and effective use of digital technologies is more important for economic performance than the mere availability of digital infrastructure.

Keywords: *Digital economy, Economic growth, GDP, System GMM, ASEAN countries*

1. INTRODUCTION

Over the past several decades, the global economy has undergone profound transformation as a result of rapid advances in digital technologies. The expansion of the Internet, mobile technologies, and broadband networks has fundamentally altered patterns of production, distribution, and consumption. At the same time, it has reshaped the structure and principal drivers of economic growth across countries. Against this background, the digital economy has become an important foundation for stimulating economic growth, improving productivity, and strengthening national competitiveness (Bukht & Heeks, 2017; Xia et al., 2023).

International organizations, particularly the OECD and the World Bank, have repeatedly em-

phasized the central role of digital connectivity and technology adoption in this transformation. The Digital Progress and Trends Report 2025 describes connectivity as the “gateway” through which countries can participate more effectively in the digital economy and benefit from emerging technologies. The report introduces the “4Cs” framework Connectivity, Compute, Context, and Competency and identifies connectivity as a necessary condition for digital technologies to produce meaningful economic and social benefits (World Bank, 2025).

Despite the continuous growth of Internet usage and mobile subscriptions worldwide, substantial digital disparities persist across countries. High-income economies are approaching saturation in terms of Internet access, whereas many middle and low-income countries continue to face challenges associated with affordability, connection quality, digital skills, and effective technology use (Hunady et al., 2025). According to the World Bank (2025), the economic value of digitalization depends not merely on access to digital infrastructure but, more importantly, on the extent to which individuals, businesses, and public institutions use digital technologies productively. Effective Internet use is therefore essential for converting digital investment into productivity improvements and sustained economic growth.

Mobile technology has been one of the most important drivers of digital inclusion over the past two decades, particularly in developing economies where fixed broadband infrastructure remains underdeveloped. The expansion of mobile subscriptions and mobile broadband services has lowered connectivity costs and extended Internet access to rural and remote communities. This development has supported the growth of e-commerce, digital financial services, online education, and electronic government services (Marjohan et al., 2026). By contrast, fixed broadband infrastructure, particularly fiber-optic networks, remains essential for more advanced digital activities that require high-speed, reliable, and stable connections.

These developments are consistent with previous empirical studies that use Internet penetration, mobile subscriptions, and fixed broadband subscriptions as key indicators of the digital economy in economic growth models (Myovella et al., 2020). However, the effects of these indicators are not necessarily uniform. Internet usage is frequently found to have a stronger and more immediate influence on GDP growth than the mere availability of broadband infrastructure. This finding highlights the importance of actual technology adoption and productive utilization, rather than infrastructure provision alone, in generating economic benefits (Habibi & Zabardast, 2020; Gomes et al., 2022).

Nevertheless, empirical findings concerning the relationship between the digital economy and economic growth remain mixed, particularly in developing economies (Aumeboonsuke & Caplanova, 2026). Some studies identify a positive and statistically significant effect of digital technologies on economic growth (Röller & Waverman, 2001; Czernich et al., 2011), whereas others argue that the magnitude of this effect depends on complementary factors such as the level of economic development, human capital, institutional quality, and technological readiness (Niebel, 2018). This inconsistency raises an important research question: Does the digital economy function as a universal engine of economic growth, or is its effectiveness shaped by country-specific conditions and particular dimensions of digital development?

The ASEAN region offers an appropriate empirical setting for addressing this question. ASEAN member states differ considerably in their levels of economic development, digital readiness, institutional capacity, and technological infrastructure. The region includes relatively advanced economies with well-developed digital systems, as well as lower-middle-income countries that remain at earlier stages of digital transformation. This diversity provides an opportunity to assess both the magnitude of the digital economy’s contribution to GDP growth and the channels through which this contribution occurs.

A further research gap relates to the dynamic and potentially endogenous relationship between digitalization and economic growth. Digital development may promote GDP growth, but stronger economic performance may also increase investment in digital infrastructure and accelerate technology adoption. This bidirectional relationship can create endogeneity and estimation bias if it is not adequately addressed. Although the World Bank and the OECD have emphasized the strategic importance of digital connectivity, relatively few empirical studies have applied dynamic panel-data techniques to investigate this relationship within the ASEAN context.

Motivated by these theoretical debates and empirical gaps, this study examines the impact of the digital economy on GDP growth in ASEAN countries. In line with the World Bank's framework, the digital economy is measured using three widely adopted indicators: the proportion of the population using the Internet, mobile cellular subscriptions, and fixed broadband subscriptions. By examining these dimensions separately, the study seeks to provide robust empirical evidence on their relative importance and to clarify the channels through which digitalization contributes to economic growth across the ASEAN region.

2. LITERATURE REVIEW

The concept of the digital economy is widely used in academic research and policymaking. Nevertheless, no universally accepted definition has yet been established. Existing definitions differ according to countries' levels of technological development, economic structures, and institutional environments (Murthy et al., 2021).

In its earliest interpretation, the digital economy referred primarily to economic activities directly associated with information and communication technologies, including the production of computer hardware, software, and telecommunications services (Tapscott, 1996). This approach treated core digital industries as a distinct sector of the economy. However, the rapid expansion of the Internet, big data, cloud computing, digital platforms, and related technologies has substantially broadened the scope of the concept. More recent studies define the digital economy as an interconnected ecosystem in which digital technologies permeate production, distribution, and consumption while simultaneously transforming traditional industries and economic activities (Bukht & Heeks, 2017; Murthy et al., 2021).

One of the most widely adopted conceptualisations is the three-layer framework, which distinguishes among: (i) the digital core, (ii) the digital economy in the narrow sense, and (iii) the digitalised economy. This framework provides a more comprehensive representation of both the scope and intensity of digital transformation. It is particularly relevant to developing economies, where the adoption and use of digital technologies remain uneven across sectors, regions, and population groups (Bukht & Heeks, 2017; Duc et al., 2024).

International organisations have also contributed significantly to the conceptual development of the digital economy. The OECD (2024) views it as an integrated system in which connectivity infrastructure, the intensity of digital technology use, digital skills, and the institutional environment jointly determine an economy's capacity to create value. Similarly, the World Bank (2025) identifies digital connectivity as a minimum requirement for participation in the digital economy and for the effective application of emerging technologies, including big data and artificial intelligence.

From a theoretical perspective, the relationship between the digital economy and GDP growth can be explained through endogenous growth theory. This framework assigns a central role to technological progress, innovation, and knowledge accumulation in promoting long-term economic growth by increasing total factor productivity (Romer, 1990; Aghion et al., 1998). As a highly diffusive form of technological progress, digitalisation can enhance the productivity and efficiency of conventional factors of production.

Digital technologies can reduce transaction costs, improve the speed and quality of information flows, strengthen market connectivity, and increase the efficiency of resource allocation. These mechanisms can lead to higher productivity and stronger economic performance (Brynjolfsson & Hitt, 2000). In addition, the digital economy stimulates innovation, supports the development of new business models, facilitates access to wider markets, and creates new opportunities for firms and consumers, thereby contributing to GDP growth (Murthy et al., 2021; Gomes et al., 2022).

However, theoretical and empirical research indicates that the growth effects of the digital economy are neither automatic nor uniform across countries. The extent to which economies benefit from digitalisation depends on complementary conditions, including their level of development, human capital, institutional quality, regulatory capacity, and technological readiness. In the short term, the high costs associated with investment in ICT infrastructure may constrain economic performance, particularly in lower-income countries. The long-term benefits of such investment may emerge only after an economy has reached a sufficient level of technological absorptive capacity (Niebel, 2018; Habibi & Zabardast, 2020).

This argument is also reflected in the OECD (2024) and World Bank (2025) reports, which distinguish between the availability of digital infrastructure and its productive use. Digital infrastructure represents a necessary condition for digital development, whereas the effective adoption and application of digital technologies constitute the conditions through which sustainable economic benefits are generated.

2. 1. MEASUREMENT OF THE DIGITAL ECONOMY

Measuring the digital economy remains a significant challenge in empirical research. Because detailed and internationally comparable statistics on digital activities are often unavailable, most studies rely on indirect measures based on digital infrastructure, connectivity, and access to digital technologies. The indicators most frequently used include the proportion of the population using the Internet, mobile cellular subscriptions, and fixed broadband subscriptions (Myovella et al., 2020; Abendin & Duan, 2021; Gomes et al., 2022; Wu & Yu, 2022).

The OECD (2024) identifies digital infrastructure and access indicators as important measures of an economy's readiness for digital transformation, particularly in cross-country comparative studies. The World Bank (2025) similarly argues that Internet usage and mobile subscriptions capture the diffusion of digital technologies throughout society more directly than measures based exclusively on ICT investment. These indicators reflect the fundamental conditions required for the emergence and development of the digital economy. They are particularly suitable for developing economies, where comprehensive data on digital production, digital services, and platform-based activities remain limited.

An important distinction highlighted by both the OECD (2024) and the World Bank (2025) concerns the difference between access to digital technology and its actual use. Fixed broadband subscriptions primarily indicate the availability and coverage of digital infrastructure, whereas the proportion of Internet users reflects the extent to which individuals and organisations actively employ digital technologies in economic and social activities. Consequently, Internet usage may provide a more direct measure of the realised economic effects of digitalisation than infrastructure availability alone.

2. 2. EMPIRICAL LITERATURE

A substantial body of empirical research has examined the effects of the digital economy on economic growth using indicators of digital infrastructure, connectivity, and technology

adoption. Most studies employ cross-country, national, or regional panel datasets and apply either static or dynamic econometric methods to account for growth persistence, unobserved heterogeneity, and potential endogeneity.

Early studies provide evidence that investment in telecommunications and ICT infrastructure contributes positively to economic growth. Röllner and Waverman (2001) demonstrate that telecommunications infrastructure has a significant positive effect on economic performance in OECD countries. Czernich et al. (2011) similarly find that the expansion of broadband networks contributes to higher GDP growth in developed economies.

Evidence from developing countries suggests that mobile and Internet technologies are particularly important drivers of economic growth. Using panel data for African countries, Myovella et al. (2020) show that both mobile penetration and Internet usage have positive and statistically significant effects on GDP growth. They argue that mobile technologies reduce information and transaction costs, improve access to financial services, and support the activities of small and medium-sized enterprises.

Habibi and Zabardast (2020) examine developing economies and find that Internet penetration positively affects economic growth. However, the magnitude of this effect is greater in countries characterised by stronger institutional quality. Their findings therefore indicate that institutions play an important complementary role in transforming digital investment and technology adoption into measurable economic benefits.

A considerable proportion of the recent literature focuses on China and provides more detailed evidence regarding the transmission mechanisms of the digital economy. Jiao and Sun (2021) find that digital development promotes urban economic growth and produces positive spatial spillover effects. Zhang et al. (2021) show that the digital economy contributes to economic growth and productivity by encouraging industrial upgrading and technological innovation. In the case of Vietnam, Duc et al. (2024) estimate the contribution of the digital economy to GDP and conclude that the core digital sector plays an important role in supporting economic expansion.

Other studies extend the analysis beyond GDP growth to productivity, innovation, environmental performance, and sustainable development. Wang et al. (2025) find that the digital economy improves energy productivity in China. Similarly, Zhang et al. (2022) and Ma et al. (2024) conclude that digitalisation contributes to green and sustainable development through technological innovation, improved resource efficiency, and the upgrading of industrial structures.

Overall, the literature provides substantial evidence that the digital economy, when measured through digital infrastructure, connectivity, and access to technology, contributes positively to GDP growth and productivity. Nevertheless, several important limitations remain.

First, a large share of the existing research focuses on China or advanced economies, while evidence relating specifically to ASEAN countries remains comparatively limited. Second, although previous studies employ various indicators of digital development, relatively few systematically compare the magnitude and significance of the effects associated with Internet usage, mobile subscriptions, and fixed broadband subscriptions. Third, some studies do not adequately address the dynamic and potentially endogenous relationship between digitalisation and economic growth.

These limitations underline the need for an ASEAN-focused study based on long-term panel data and an econometric methodology capable of controlling for growth persistence, country-specific effects, and endogeneity. By separately examining Internet usage, mobile technology penetration, and fixed broadband penetration, the present study seeks to clarify the relative contribution of each dimension of the digital economy to GDP growth in ASEAN countries.

2. 3. RESEARCH HYPOTHESES

Based on the theoretical arguments and empirical evidence reviewed above, the following hypotheses are proposed:

H₁: *The digital economy has a positive and statistically significant effect on GDP growth in ASEAN countries.*

H₂: *Mobile technology penetration has a positive and statistically significant effect on GDP growth in ASEAN countries.*

H₃: *Fixed broadband penetration has a positive and statistically significant effect on GDP growth in ASEAN countries.*

H₄: *Internet usage has a positive and statistically significant effect on GDP growth and exerts a stronger growth-enhancing effect than mobile technology penetration and fixed broadband penetration.*

3. METHODOLOGY

3. 1. ECONOMETRIC MODEL

In dynamic panel-data research, selecting an appropriate estimation technique is essential for obtaining consistent and reliable empirical results. Economic growth models commonly include a lagged dependent variable to capture growth persistence and the adjustment process over time. However, the inclusion of this variable creates an endogeneity problem because the lagged dependent variable is correlated with the transformed error term. Consequently, conventional estimators, including Ordinary Least Squares, fixed-effects, and random-effects models, may generate biased and inconsistent coefficient estimates (Arellano & Bond, 1991).

To address this methodological challenge, the present study applies the Generalized Method of Moments framework, which is widely used in dynamic panel-data analysis. More specifically, it employs the System Generalized Method of Moments estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). Unlike Difference GMM, which estimates only the first-differenced equation, System GMM jointly estimates equations in first differences and levels. It uses lagged levels as instruments for the differenced equation and lagged differences as instruments for the level equation, subject to the relevant moment conditions.

By combining these two sets of equations, System GMM can improve estimation efficiency and reduce the weak-instrument problem that may arise under Difference GMM, particularly when the variables are highly persistent or when the number of time periods is limited (Blundell & Bond, 1998; Roodman, 2009). Its validity, however, depends on the appropriateness of the selected instruments and the absence of invalid serial correlation in the idiosyncratic errors.

System GMM is suitable for the present analysis because the empirical model contains a lagged dependent variable and several regressors that may be endogenous or predetermined, including indicators of the digital economy, foreign direct investment, and trade openness. These variables may influence GDP growth, while economic growth may simultaneously affect investment, openness, and the adoption of digital technologies. Such reciprocal relationships create the possibility of reverse causality and simultaneity bias.

Within the System GMM framework, appropriately lagged values of endogenous and predetermined variables can be used as internal instruments. This enables the model to address endogeneity without relying exclusively on external instruments. Nevertheless, the classification of each explanatory variable as endogenous, predetermined, or strictly exogenous must be theoretically justified and clearly specified.

The study employs the two-step System GMM estimator with Windmeijer-corrected standard errors. Although the two-step estimator is asymptotically more efficient than its one-step counterpart, its conventional standard errors may be downward biased in finite samples. Windmeijer's finite-sample correction reduces this bias and improves the reliability of statistical inference, particularly in panels with a limited number of cross-sectional units (Windmeijer, 2005).

The validity of the estimated model should be assessed using the Arellano–Bond tests for first- and second-order serial correlation and the Hansen or Sargan test of overidentifying restrictions. In addition, the number of instruments should be carefully controlled to avoid instrument proliferation, especially because the present sample contains only nine ASEAN countries. Subject to these diagnostic requirements, two-step System GMM provides an appropriate framework for examining the effect of the digital economy on GDP growth while accounting for growth persistence, endogeneity, heteroskedasticity, and within-panel serial correlation.

Based on the above considerations, the empirical model is specified as follows:

$$GDP_{it} = \beta_0 + \beta_1 GDP_{it-1} + \beta_2 DEC_{it} + \beta_3 GCF_{it} + \beta_4 GCE_{it} + \beta_5 FDI_{it} + \beta_6 EOP_{it} + \eta_i + \varepsilon_{it}$$

where:

i denotes the country index ($i = 1, 2, 3, \dots, N$).

t denotes the time index ($t = 1, 2, 3, \dots, T$).

GDP_{it} represents GDP per capita growth of country i in year t .

GDP_{it-1} is the one-period lagged dependent variable.

DEC_{it} denotes the set of independent variables representing the digital economy.

GCF_{it} , GCE_{it} , FDI_{it} and EOP_{it} are control variables.

η_i captures unobserved country specific fixed effects.

ε_{it} is the random error term.

Table 1. Description of variables and data sources

Variables	Symbol	Measurement	Data source
Dependent variable			
GDP per capita	GDP	GDP per capita growth (annual %)	WDI
Explanatory variables			
Digital economy	DEC	MER; FER; IER	
Mobile subscriptions	MER	Mobile cellular subscriptions (per 100 people)	WDI
Broadband subscriptions	FER	Fixed broadband subscriptions (per 100 people)	WDI
Internet users	IER	Individuals using the Internet (% of population)	WDI
Control variables			
Domestic investment capital	GCF	Gross capital formation (% of GDP)	WDI
Public consumption expenditure	GCE	General government final consumption expenditure (% of GDP)	WDI
Foreign direct investment	FDI	Foreign direct investment, net inflows (% of GDP)	WDI
Economic openness	EOP	Natural logarithm of the sum of exports and imports of goods and services (% of GDP)	WDI

Source: Worldbank and author's calculation

The explanatory variables used to represent the digital economy (DEC) comprise three widely applied indicators that capture distinct dimensions of digital development: mobile penetration

(MER), fixed broadband subscriptions (FER), and Internet usage (IER). These indicators are frequently employed in empirical research because they provide internationally comparable measures of digital infrastructure, connectivity, and technology adoption. They are particularly appropriate for developing economies, where comprehensive and consistent statistics on the digital economy remain limited (Myovella et al., 2020; Habibi & Zabardast, 2020; Abendin & Duan, 2021; Gomes et al., 2022).

Conceptually, the selected indicators can be divided into two dimensions. The first concerns digital infrastructure and connectivity and is represented by mobile penetration and fixed broadband subscriptions. MER is measured as the number of mobile cellular subscriptions per 100 inhabitants and reflects the accessibility and diffusion of mobile communication networks within an economy. Mobile connectivity is especially important in developing countries because it provides relatively rapid and affordable access to digital services, including mobile banking, e-commerce, online education, and electronic government services.

FER, measured by the number of fixed broadband subscriptions, captures the availability of high-speed and reliable Internet infrastructure. Such infrastructure is particularly important for data-intensive economic activities, business digitalisation, cloud computing, remote working, and the provision of advanced digital services. Compared with mobile connectivity, fixed broadband generally offers greater stability and capacity, although its expansion often requires substantial investment in physical infrastructure.

The second dimension concerns the actual use of digital technologies and is represented by Internet usage. IER is measured as the percentage of the population using the Internet. Unlike MER and FER, which primarily indicate the availability and reach of digital infrastructure, IER reflects the extent to which individuals actively use digital technologies in their economic and social activities. It may therefore be regarded as a more direct measure of digital participation, integration, and technology adoption within an economy.

This distinction is consistent with the approaches adopted by the OECD (2024) and the World Bank (2025), both of which emphasise that digital infrastructure is a necessary foundation for digital transformation, whereas effective technology use is the principal mechanism through which digital investment generates productivity gains and economic growth. Connectivity creates access to digital opportunities, but the extent to which firms, households, and public institutions use digital technologies determines whether these opportunities translate into greater innovation, efficiency, inclusion, and market participation.

In addition to the digital economy indicators, the empirical model incorporates several control variables that are widely regarded as important determinants of economic growth. These include foreign direct investment (FDI), gross capital formation (GCF), government expenditure (GCE), and economic openness (EOP).

Capital represents a fundamental input in the production process and an important source of economic expansion. When domestic savings and investment are insufficient to support production growth and technological upgrading, foreign direct investment can provide an additional source of capital. FDI may promote economic growth through technology transfer, knowledge spillovers, workforce development, improved managerial practices, and productivity enhancement (Pegkas, 2015). On this basis, FDI is generally expected to have a positive effect on GDP growth. However, its impact may depend on domestic absorptive capacity, institutional quality, and the sectoral allocation of foreign investment.

Gross capital formation reflects investment undertaken by both the public and private sectors and contributes to the expansion of productive capacity. Investment in physical infrastructure, machinery, equipment, education, and other productive assets can enhance economic efficien-

cy and support long-term growth. Previous empirical studies have reported a positive association between capital accumulation and economic performance (Solomon & Klyton, 2020; Oyebowale & Algarhi, 2020; Pandey & Bishnoi, 2023; Hadush et al., 2023). Accordingly, the coefficient of GCF is expected to be positive.

Government expenditure may also influence economic growth through investment in education, healthcare, transport, digital infrastructure, and other public services. Productive public spending can improve human capital, reduce transaction costs, strengthen the business environment, and increase labour productivity. Empirical evidence suggests that well-targeted and efficiently managed government expenditure can support economic growth, particularly in developing economies (Solomon & Klyton, 2020; Oyebowale & Algarhi, 2020; Hadush et al., 2023). Nevertheless, the effect may vary according to the composition, efficiency, and financing of public expenditure.

Finally, economic openness is expected to promote growth by expanding access to foreign markets, strengthening competition, facilitating technology transfer, and enabling countries to specialise according to their comparative advantages. Greater openness can improve resource allocation, increase production efficiency, and support the diffusion of knowledge and innovation across borders (Mazurek, 2017; Myovella et al., 2020; Hadush et al., 2023; Mastilo, 2026). Therefore, the estimated coefficient of economic openness is also expected to be positive.

3. 2. SAMPLE AND DATA

The study sample consists of nine ASEAN countries, as presented in Table 2. These countries were selected to capture the considerable heterogeneity of the ASEAN region in terms of economic development, income levels, technological capacity, and the degree of digital integration. This diversity provides an appropriate basis for assessing the effects of the digital economy across economies at different stages of development and digital transformation.

The study relies on secondary data obtained primarily from the World Bank's World Development Indicators database, which provides internationally comparable macroeconomic and digital development indicators. The dataset covers the period from 2004 to 2023, during which ASEAN countries experienced a substantial expansion of information and communication technology infrastructure, increased adoption of digital technologies, and deeper regional economic integration.

Table 2. Classification of ASEAN countries by GDP per capita

Countries	GDP per capita, PPP (constant 2021 \$)	GDP per capita (constant 2015 US\$)	GDP per capita growth (annual %)	Classification
Singapore	132,569	67,707	2.327	High income
Brunei	79,072	29,564	3.204	High income
Malaysia	34,116	11,884	3.830	Upper middle income
Thailand	21,741	6,574	2.591	Upper middle income
Indonesia	14,470	4,368	4.179	Upper middle income
Viet Nam	14,415	4,018	6.417	Lower middle income
Philippines	10,376	3,925	4.823	Lower middle income
Laos	8,600	2,721	2.725	Lower middle income
Cambodia	7,009	2,183	4.684	Lower middle income

Source: Worldbank and author's calculation

According to the World Bank's 2024 income classification based on gross national income (GNI) per capita, the ASEAN countries included in the sample exhibit considerable diversity

in their levels of economic development. Brunei Darussalam and Singapore are classified as high-income economies, reflecting their advanced economic structures and well-developed digital infrastructure. Malaysia, Thailand, and Indonesia belong to the upper-middle-income group, representing economies undergoing rapid structural transformation accompanied by continued industrialisation and digitalisation. Vietnam, the Philippines, Lao PDR, and Cambodia are classified as lower-middle-income economies, where economic growth continues to depend largely on capital accumulation, productivity improvements, and technological upgrading. This variation in income levels and stages of development provides an appropriate setting for examining whether the contribution of the digital economy to economic growth differs across ASEAN countries.

Table 3 reports the descriptive statistics for all variables included in the empirical analysis. The balanced panel dataset comprises 180 observations covering nine ASEAN countries over the period 2004–2023. The descriptive statistics provide an overview of the central tendency, dispersion, and distribution of the variables.

GDP growth has an average value of 3.274%, with a relatively high standard deviation of 3.529 percentage points, indicating substantial variation in economic performance across countries and over time. The minimum value of –10.549% reflects periods of severe economic contraction, likely associated with regional or global economic crises, whereas the maximum value of 14.431% indicates episodes of rapid economic expansion. Such variability is characteristic of emerging and developing economies, where economic growth tends to be more volatile than in advanced economies.

The three indicators representing the digital economy display different levels of development across the sample. Mobile penetration (MER) records the highest average value, at 105.370 mobile subscriptions per 100 inhabitants. Values exceeding 100 indicate that many individuals maintain more than one mobile subscription, a common phenomenon in developing and emerging markets. The relatively large standard deviation (43.483) points to considerable differences in mobile connectivity across countries.

Fixed broadband penetration (FER) exhibits a much lower average value of 7.174 subscriptions per 100 inhabitants, with observations ranging from 0.001 to 28.539. These figures suggest that fixed broadband infrastructure remains relatively underdeveloped and unevenly distributed throughout the region.

Internet usage (IER), measured as the percentage of the population using the Internet, averages 45.337%, with values ranging from 0.300% to 99.000%. This wide dispersion highlights substantial differences in digital adoption among ASEAN countries and reflects the persistence of a digital divide within the region.

The control variables display patterns broadly consistent with those typically observed in developing and emerging economies. Gross capital formation averages 27.453% of GDP, indicating relatively high investment rates across the sample. Government expenditure averages 11.875% of GDP, reflecting a moderate level of public-sector involvement in economic activity. Foreign direct investment inflows average 5.874% of GDP but exhibit considerable volatility, as indicated by a standard deviation of 6.676. Negative values (minimum = –1.739%) suggest periods of net capital disinvestment or foreign capital withdrawals in some countries. Finally, trade openness records an average value of 4.738 with relatively limited variation across observations, indicating broadly comparable levels of integration into international trade among the sampled ASEAN economies.

Table 3. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	180	3.274	3.529	-10.549	14.431
MER	180	105.370	43.483	3.532	181.222
FER	180	7.174	8.146	0.001	28.539
IER	180	45.337	30.063	0.300	99.000
GCF	180	27.453	5.371	15.172	41.067
GCE	180	11.875	4.856	4.809	26.477
FDI	180	5.874	6.676	-1.739	33.305
EOP	180	4.738	0.563	3.496	6.081

Source: Author's calculation

4. EMPIRICAL RESULTS

Based on the described dataset, the study conducts a series of diagnostic tests to assess the presence of autocorrelation, heteroskedasticity, and endogeneity in the estimated models. These issues are commonly encountered in dynamic panel data analyses, particularly when the model includes a lagged dependent variable and explanatory variables that may be simultaneously affected by economic growth. To address potential biases arising from these problems, the study applies the two-step SGMM estimator, which effectively handles endogeneity, autocorrelation, and heteroskedasticity through the use of appropriate instrumental variables. This approach also enhances estimation efficiency in settings where the time dimension is relatively short and the number of cross-sectional units is limited. The detailed estimation results of the models are reported in Table 4.

Table 4. Dynamic panel-data estimation, two-step system GMM

Variables	Model 1		Model 2		Model 3	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
l.GDP	0.256	0.005***	0.267	0.018**	0.283	0.006***
MER	0.070	0.039**				
FER			0.027	0.053*		
IER					0.125	0.002***
GCF	-0.305	0.241	0.423	0.509	0.174	0.593
GCE	1.314	0.002***	1.367	0.000***	1.255	0.009***
FDI	0.479	0.460	0.273	0.458	0.366	0.594
EOP	2.273	0.000***	1.908	0.009***	2.069	0.006***
Constant	2.629	0.059	3.021	0.386	2.293	0.318
AR(1) p-value	0.040		0.022		0.037	
AR(2) p-value	0.246		0.160		0.147	
Sargan test p-value	0.203		0.114		0.426	
Hansen test p-value	0.311		0.410		0.708	
F – test p-value	0.000		0.000		0.000	
Number of obs	162		171		175	
Number of groups (countries)	9		9		9	
Number of instruments	8		8		8	

Note: ***p < 0.01, **p < 0.05, *p < 0.1.

Source: Author's calculation

According to the World Bank's 2024 income classification based on gross national income (GNI) per capita, the ASEAN countries included in the sample exhibit considerable diversity in their levels of economic development. Brunei Darussalam and Singapore are classified as high-income economies, reflecting their advanced economic structures and well-developed digital infrastructure. Malaysia, Thailand, and Indonesia belong to the upper-middle-income group, representing economies undergoing rapid structural transformation accompanied by continued industrialisation and digitalisation. Vietnam, the Philippines, Lao PDR, and Cambodia are classified as lower-middle-income economies, where economic growth continues to depend largely on capital accumulation, productivity improvements, and technological upgrading. This variation in income levels and stages of development provides an appropriate setting for examining whether the contribution of the digital economy to economic growth differs across ASEAN countries.

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GDP growth has an average value of 3.274%, with a relatively high standard deviation of 3.529 percentage points, indicating substantial variation in economic performance across countries and over time. The minimum value of –10.549% reflects periods of severe economic contraction, likely associated with regional or global economic crises, whereas the maximum value of 14.431% indicates episodes of rapid economic expansion. Such variability is characteristic of emerging and developing economies, where economic growth tends to be more volatile than in advanced economies.

The three indicators representing the digital economy display different levels of development across the sample. Mobile penetration (MER) records the highest average value, at 105.370 mobile subscriptions per 100 inhabitants. Values exceeding 100 indicate that many individuals maintain more than one mobile subscription, a common phenomenon in developing and emerging markets. The relatively large standard deviation (43.483) points to considerable differences in mobile connectivity across countries.

Fixed broadband penetration (FER) exhibits a much lower average value of 7.174 subscriptions per 100 inhabitants, with observations ranging from 0.001 to 28.539. These figures suggest that fixed broadband infrastructure remains relatively underdeveloped and unevenly distributed throughout the region.

Internet usage (IER), measured as the percentage of the population using the Internet, averages 45.337%, with values ranging from 0.300% to 99.000%. This wide dispersion highlights substantial differences in digital adoption among ASEAN countries and reflects the persistence of a digital divide within the region.

The control variables display patterns broadly consistent with those typically observed in developing and emerging economies. Gross capital formation averages 27.453% of GDP, indicating relatively high investment rates across the sample. Government expenditure averages 11.875% of GDP, reflecting a moderate level of public-sector involvement in economic activity. Foreign direct investment inflows average 5.874% of GDP but exhibit considerable volatility, as indicated by a standard deviation of 6.676. Negative values (minimum = –1.739%) suggest periods of net capital disinvestment or foreign capital withdrawals in some countries. Finally, trade openness records an average value of 4.738 with relatively limited variation across observations, indicating broadly comparable levels of integration into international trade among the sampled ASEAN economies.

5. DISCUSSION

The results obtained from the two-step System GMM estimation provide evidence that the digital economy contributes positively to economic growth in ASEAN countries. Across the estimated models, the coefficient of the lagged GDP growth variable is positive and statistically significant, indicating a substantial degree of persistence in economic growth. In other words, current economic performance is partly influenced by growth outcomes in previous periods.

This dynamic pattern is broadly consistent with endogenous growth theory, which emphasises the cumulative contribution of technological progress, knowledge accumulation, and innovation to long-term economic development (Romer, 1990; Aghion et al., 1998). Similar findings have been reported by Myovella et al. (2020), Gomes et al. (2022), and Xia et al. (2023), who note that economic growth is inherently dynamic and that ignoring growth persistence may lead to biased estimates. The inclusion of the lagged dependent variable therefore supports the use of a dynamic panel-data estimator. Subject to the validity of the instruments and the relevant specification tests, System GMM provides an appropriate framework for addressing endogeneity, unobserved country-specific effects, heteroskedasticity, and within-panel serial correlation.

The findings further show that the three indicators of the digital economy are positively associated with GDP growth, supporting the general hypothesis that digitalisation promotes economic development. This result is consistent with the argument that digital technologies enhance productivity by reducing transaction and information costs, improving market access, accelerating information flows, and increasing the efficiency of resource allocation (Brynjolfsson & Hitt, 2000; Murthy et al., 2021). Positive growth effects of digitalisation have also been documented in OECD economies (Czernich et al., 2011), African countries (Myovella et al., 2020), developing economies (Habibi & Zabardast, 2020), and emerging markets more generally (Gomes et al., 2022). Taken together, these findings suggest that digital technologies have become an increasingly important component of economic growth across different regional and institutional contexts.

Nevertheless, the estimated magnitude and statistical significance of the effects differ across the three digital indicators. Mobile penetration (MER) has a positive and statistically significant effect on GDP growth, confirming the important role of mobile technologies in developing and emerging economies. This result is consistent with studies showing that mobile connectivity can promote financial inclusion, reduce information barriers, improve access to markets, and support entrepreneurial activity (Myovella et al., 2020; Habibi & Zabardast, 2020).

Mobile technologies are particularly relevant in ASEAN because they enable access to digital services in locations where fixed broadband infrastructure remains limited or costly. Mobile-based applications facilitate electronic commerce, digital payments, online marketplaces, transport services, and access to government and financial services. Through these channels, mobile connectivity can stimulate business activity, increase labour and firm productivity, and broaden participation in the formal economy.

Fixed broadband penetration (FER), by contrast, has a positive but comparatively weaker effect on economic growth. This finding is broadly consistent with Niebel (2018) and Gomes et al. (2022), who argue that investment in digital infrastructure does not necessarily generate immediate economic benefits. The contribution of broadband infrastructure depends on its affordability, quality, coverage, and actual use by households, firms, and public institutions.

In several ASEAN economies, fixed broadband remains concentrated in urban and economically developed areas, while rural and remote communities continue to face limited coverage, high subscription costs, and lower connection quality. Moreover, the productive use of broadband may be constrained by insufficient digital skills, limited business digitalisation, and

unequal access to suitable devices. These factors may explain why the estimated growth effect of fixed broadband is weaker than that of mobile penetration and Internet usage.

The most notable result concerns Internet usage (IER), which demonstrates the strongest and most statistically significant association with GDP growth. This finding suggests that the actual use of digital technologies may be more important for economic performance than the availability of infrastructure alone. Internet usage reflects the extent to which individuals, firms, and institutions actively incorporate digital technologies into commercial, productive, educational, financial, and administrative activities.

This result is consistent with [Myovella et al. \(2020\)](#), [Habibi and Zabardast \(2020\)](#), and [Gomes et al. \(2022\)](#), who emphasise that the economic value of digitalisation depends on the effective adoption and utilisation of digital technologies. It also supports the position of the [OECD \(2024\)](#) and [the World Bank \(2025\)](#), according to which connectivity represents a foundational stage of digital transformation, while measurable economic benefits arise when digital technologies are productively integrated into economic and social processes.

The stronger estimated effect of Internet usage relative to infrastructure-based indicators has important implications for ASEAN countries. It may indicate that many countries in the region have already achieved a minimum level of digital connectivity, while substantial differences persist in the intensity and effectiveness of technology use. More digitally advanced economies, such as Singapore and Malaysia, have achieved high levels of adoption among firms, households, and public institutions. Lower-income ASEAN economies, however, continue to face constraints related to affordability, digital literacy, technological capabilities, and business readiness. The regional digital divide may therefore increasingly reflect differences in effective use and digital capability rather than infrastructure access alone.

The results also indicate that government expenditure and economic openness contribute positively to economic growth. These findings are consistent with previous research highlighting the role of productive public spending and international economic integration in supporting development ([Solomon & Klyton, 2020](#); [Mazurek, 2017](#)). Government expenditure can complement digital transformation through investment in telecommunications infrastructure, education, research, innovation, and public-sector digitalisation. Similarly, greater economic openness can facilitate access to foreign technologies, encourage knowledge diffusion, expand markets, and strengthen participation in global value chains.

By contrast, gross capital formation and foreign direct investment do not display statistically significant effects in the estimated models. These results suggest that the volume of investment alone may be insufficient to generate stronger economic growth. The effectiveness of domestic and foreign investment may depend on its sectoral composition, technological content, productivity, institutional environment, and alignment with national development priorities. In the case of FDI, positive spillovers are more likely to emerge when recipient countries possess sufficient human capital, technological absorptive capacity, efficient institutions, and strong linkages between foreign and domestic firms.

Policy Implications

The findings imply that ASEAN governments should move beyond policies focused primarily on expanding digital infrastructure and adopt a broader strategy aimed at strengthening the productive use of digital technologies.

First, continued investment in digital infrastructure remains necessary, particularly in rural, remote, and underserved areas. Expanding mobile and broadband coverage, improving network reliability and speed, and reducing connectivity costs are essential for ensuring more inclusive

participation in the digital economy. Infrastructure policies should also seek to reduce disparities in access between urban and rural populations.

Second, greater policy attention should be directed towards digital adoption and effective technology use. Governments should expand digital literacy programmes, strengthen education and vocational training in digital skills, and encourage firms to integrate digital technologies into production, management, marketing, and distribution. Particular support should be provided to small and medium-sized enterprises, which often face financial, technical, and organisational barriers to digital transformation.

Third, ASEAN countries should promote the development of comprehensive digital ecosystems. This includes encouraging e-commerce, digital financial services, cloud computing, artificial intelligence, digital entrepreneurship, and technology-based innovation. Regulatory frameworks should support innovation while providing adequate safeguards for cybersecurity, consumer rights, competition, and personal data protection. Public–private partnerships may also help mobilise investment and expertise for large-scale digital transformation initiatives.

Fourth, reducing the digital divide should remain a central policy objective. Differences in digital access, affordability, skills, and usage persist both within and between ASEAN countries. Targeted subsidies, affordable connectivity programmes, community access initiatives, and investment in digital education can help ensure that the benefits of digitalisation are distributed more broadly across regions and social groups.

Finally, stronger regional cooperation is needed to support digital integration within ASEAN. Greater harmonisation of digital regulations, improved interoperability of payment and identification systems, stronger cross-border data governance, and the facilitation of digital trade could expand regional markets and increase the returns generated by digital investment. Enhanced regional cooperation may also help less digitally developed member states benefit from knowledge transfer, shared infrastructure, and coordinated capacity-building programmes.

6. CONCLUSION

This study examines the impact of the digital economy on per capita GDP growth in ASEAN countries over the period 2004–2023. Digital development is represented by three indicators: mobile technology penetration (MER), fixed broadband subscriptions (FER), and Internet usage (IER).

The empirical findings show that the digital economy has a positive effect on economic growth across the ASEAN region, confirming the growing importance of digital transformation as a driver of regional development. Nevertheless, the magnitude of this effect differs across the three dimensions examined. Internet usage has the strongest influence on per capita GDP growth, followed by mobile technology penetration, whereas the contribution of fixed broadband subscriptions is comparatively modest. These results indicate that the expansion of digital infrastructure is a necessary foundation for digital transformation, but that the productive adoption and effective use of digital technologies are more important for converting digital resources into measurable economic benefits.

This study makes three main contributions to the literature. First, it provides additional empirical evidence for ASEAN, a region characterised by substantial differences in income levels, digital readiness, institutional capacity, and technological development, but one that remains less extensively studied than China and OECD economies. Second, the study distinguishes between digital connectivity and actual technology use by examining three separate indicators of the digital economy. The stronger effect of Internet usage relative to infrastructure-based indicators supports the argument advanced by the [OECD \(2024\)](#) and the [World Bank \(2025\)](#) that the economic value of digital transformation depends not only on access to infrastructure but

also on the extent to which digital technologies are actively integrated into economic and social activities. Third, the study applies the two-step System Generalized Method of Moments estimator to account for the dynamic nature of economic growth and to address potential endogeneity, heteroskedasticity, and within-panel serial correlation.

Despite these contributions, several limitations should be recognised. The selected indicators primarily capture digital connectivity, infrastructure, and general technology adoption. They do not fully represent more advanced dimensions of the digital economy, including digital platforms, artificial intelligence, cloud computing, digital entrepreneurship, and innovation ecosystems. Moreover, the analysis does not explicitly assess whether the effects of digitalisation differ across ASEAN countries according to income level, institutional quality, or stage of digital development. The empirical specification also assumes a linear relationship between digital development and economic growth, although the effects may be nonlinear or dependent on particular development thresholds.

Future research could address these limitations by constructing broader digital economy indices that incorporate infrastructure, usage, skills, innovation, and institutional dimensions. Nonlinear, threshold, or panel quantile models could also be applied to determine whether the growth effects of digitalisation vary according to countries' levels of income, connectivity, or technological readiness. Further studies may extend the analysis to other outcomes, including labour productivity, innovation performance, green growth, financial inclusion, and sustainable development. Finally, examining the moderating roles of human capital, institutional quality, innovation capacity, and regulatory effectiveness would provide deeper insight into the conditions under which ASEAN economies can fully realise the long-term benefits of digital transformation.

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