

Digital Economy's Transformative Impact on Regional Growth: Evidence from ASEAN Countries

(Impak Transformasi Ekonomi Digital terhadap Pertumbuhan Serantau: Bukti dari Negara-negara ASEAN)

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ABSTRACT

This study investigates the impact of digital economy development on regional economic growth. It further determines the role of digital economy in enhancing industrial structures in regional economic growth. Using panel data from ASEAN countries spanning 2011-2019, this study employs the entropy weight method to establish an index system to evaluate the development of digital economy among ASEAN countries. It additionally employs fixed effect model to investigate the relationship between digital economy development and economic growth. Furthermore, a mediation effect model is employed to analyse the indirect effects of digital economy through the advancement of industrial structure in promoting economic growth. This study found that the development of the digital economy contributes to the economic growth of ASEAN countries. It also highlights the digital economy's role in enhancing industrial structures as a mediating factor in this growth, noting a nonlinear relationship where the impact on regional economic growth increases progressively. Simultaneously, this study finds that the development of the digital economy exhibits regional heterogeneity in ASEAN countries, with varying levels of development based on income. This study enriches the evaluation methods and research framework of digital economy research in ASEAN. The entropy weight method is introduced as an evaluation index system for digital economy development in ASEAN countries. Utilizing a two-way fixed effects model and mediation effects model, this study explores the promoting effect of digital economy development on economic growth, revealing the indirect effect of digital economy in promoting industrial structure and economic growth. The findings suggest that ASEAN countries stand to benefit immensely from the burgeoning digital economy, which promises to inject new vitality into regional economic expansion. The study underscores the importance of fostering digital economy advancements to achieve sustained economic development and structural transformation.

Keywords: Digital economy; economic growth; industrial structure; entropy method; fixed-effect model; mediation effect model.

ABSTRAK

Kajian ini menyiasat kesan pembangunan ekonomi digital terhadap pertumbuhan ekonomi serantau. Ia seterusnya menentukan peranan ekonomi digital dalam meningkatkan struktur perindustrian dalam pertumbuhan ekonomi serantau. Kajian ini menggunakan model kesan pengantaraan untuk menganalisis kesan langsung dan tidak langsung kemajuan ekonomi digital terhadap pertumbuhan ekonomi dengan menggunakan data panel dari tahun 2011 hingga 2020. Penyelidikan ini mengesahkan bahawa kemajuan ekonomi digital menyumbang secara signifikan kepada pertumbuhan ekonomi serantau. Ia juga menekankan peranan ekonomi digital dalam meningkatkan struktur perindustrian sebagai faktor pengantara dalam pertumbuhan ini, dengan menyatakan hubungan tidak linear di mana kesan ke atas pertumbuhan ekonomi serantau meningkat secara progresif. Kajian ini memperkenalkan kaedah entropi sebagai sistem indeks penilaian bagi pembangunan ekonomi digital di negara-negara ASEAN, dan menggunakan model kesan tetap dua hala untuk meneroka mekanisme perubahan struktur industri terhadap pertumbuhan ekonomi dengan menonjolkan kesan pengantaraan. Dapatan kajian menunjukkan bahawa negara-negara ASEAN akan mendapat manfaat besar daripada perkembangan ekonomi digital yang berkembang yang menyuntik tenaga baharu ke dalam pengembangan ekonomi serantau. Kajian ini menekankan kepentingan memupuk kemajuan ekonomi digital untuk mencapai pembangunan ekonomi yang mampan dan transformasi struktur.

Kata kunci: Ekonomi digital; pertumbuhan ekonomi; struktur perindustrian; kaedah entropi; model kesan tetap; model kesan pengantaraan.

JEL: O11, O33, O40, O53

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INTRODUCTION

Following the outbreak of the financial crisis, the global economy has not fully recuperated from its aftermath. However, the economy and associated technologies have progressively permeated various sectors of the social economy. While giving rise to new industries and formats, they have also merged with traditional industries, bringing about transformative changes, and injecting renewed vitality into them. The digital economy experienced tremendous growth, increasing from \$30.2 trillion to \$31.8 trillion from 2018 to 2019, with its scale continuing to expand by an additional \$1.6 trillion. The digital economy has transformed into a significant driver of global economic advancement. Additionally, its contribution to the Gross Domestic Product (GDP) has increased from 40.3% in 2018 to 41.5% in 2019 (World Bank 2023), indicating a gradual uptick in the digital economy's share and providing crucial backing for its continued expansion.

In recent years, the increasing research on the digital economy draws more attention to the interplay between the digital economy and regional economic dynamics. However, there remains a paucity of research addressing the intricate relationships among digital economy development, regional economic growth, and industrial structures. While commonly held viewpoints frequently ascribe regional economic expansion mainly to adjustments in industrial structure, it's crucial to acknowledge that, during regional economic progress, the optimization and enhancement of industrial structures play pivotal roles (Su & Fan 2022). In consequence this necessitates a concerted effort to enhance the effectiveness of regional economic growth amidst the backdrop of sustainable digital economy development. Thus, it becomes important to study the manifold impacts between them, elucidating both the direct and indirect promotional effects.

Viewing the production in various fields and operational activities through a lens of digital economy, it becomes apparent that the digital economy not only facilitates economies in attaining a requisite scale but also substantively curtails the average long-term developmental costs across industries, effectively fostering economic growth across diverse regions (Pang et al. 2022). Furthermore, the surge of major network platforms and the booming user base on digital platforms signify an explosive trend in digital economy development, particularly prominent in Southeast Asia due to its immense potential and market (Li et al. 2020). Major enterprises, experiencing an uptick in their own internet user base, witness accelerated scale expansion, resulting in heightened actual production benefits and average profits, thereby realizing the scale effect of economic regionalization development (Menon & Fink 2019). In this developmental path, the digital economy employs additional profits, termed *peripheral products*, upon various enterprises in different regions, harnessing regional economic benefits and facilitating rapid growth and development (Sturgeon & Kawakami 2011).

Beyond the augmentation of the growth of enterprises in diverse regions, the digital economy engenders technological transformations, giving rise to advanced emerging industries, thereby posing a formidable challenge to traditional industries (Ahmedov 2020). Consequently, traditional industries, influenced by the principles of the digital economy, face challenges in a phased transitioning from outdated to modern energy sources. This transition fosters the rejuvenation and enhancement of industrial structures for businesses that were formerly deemed outdated. Meanwhile, emerging sectors within the digital economy, such as the software service industry and ICT, have matured and were displaying a competitive trajectory. This development requires regional enterprises to take the lead in integrating new information technologies into their business models. This strategic alignment is crucial for shaping a new industrial paradigm within the actual developmental process of the economy (Hao et al. 2022). The prevailing trend of gradually upgrading industrial structures among traditional industries signifies an optimization process wherein production factors within enterprises shift from lower to higher added-value departments. This transformative process allows for relevant personnel to allocate labor, production, and capital factors within enterprises, enhancing actual production efficiency and quality of various resources, thereby expediting the rapid and effective growth of the social economy (Su et al. 2021).

It can be posited that the digital economy, through its optimization and upgrading of industrial structures, assumes a pivotal role in fostering regional economic growth. In consequence, various regions need to accelerate the transformation and enhancement of their industrial structures, leveraging their inherent strengths to amplify their positive impact within the framework of digital economy development. This approach empowers the digital economy to assume a crucial role in optimizing and elevating industrial structures, the caliber and effectiveness of economic growth at the regional level.

In 2020, the digital economy in Southeast Asia will account for 35% of the GDP of the United States and 16% of the GDP of China, but only 7% of the GDP of Southeast Asian countries (World Bank 2019). However, we should also note that the digital economy is playing an increasingly important role in the development of Southeast Asian countries. From 2018 to 2020, the number of digital consumers in Southeast Asia increased by 60 million, with a compound annual growth rate of 12% (Herbert & Loudon 2020). Southeast Asia will become the fastest growing digital market in the world (Li 2022). Despite these strides, it is imperative to recognize that the digital economy's developmental stage in Southeast Asia remains nascent. The current academic discourse on the digital economy in Southeast Asia predominantly gravitates towards two overarching levels of analysis. On the macro level, existing literature primarily explores the digital economy through qualitative methods (Avirutha 2021; Tran & Nguyen 2022; Jauhari et al. 2023). Conversely, at the micro level, prevailing research tends to focus on assessing the digital economy's developmental status within individual Southeast Asian countries, such as Indonesia and Vietnam (Trinugroho et al. 2022; Nguyen et al. 2022). Alternatively, it explores aspects, including the development of 5G technology and cross-border e-commerce within the context of Southeast Asia (Koe & Sakir 2020; Priyono & Moin 2020). The ongoing shift in the economic landscape of the region is attributed to the rise of the digital economy, driven by the significant involvement of artificial intelligence, the Internet, and other

contemporary information technologies. A critical question in this context is whether the digital economy can significantly impact economic growth in the ASEAN region. Furthermore, there is a need to understand the extent to which the digital economy can influence economic structures and subsequently contribute to overall economic growth. The complex nature of these inquiries emphasizes the necessity for a thorough investigation into the mechanisms and pathways through which the digital economy can bring about these effects. Moreover, it is crucial to recognize potential regional disparities in the mechanisms and the pathways through which the digital economy shapes the economic landscape. These questions remain open for further academic exploration and analysis.

Current research focuses on the study of a single ASEAN country or different evaluation systems. For example, Tran Nguyen (2022) evaluated the development of the digital economy in ASEAN countries based on the *Network Readiness Index 2021 report*. This approach however lacks comprehensiveness and the selected time span is too brief, thus resulting in limited applicability. Using dynamic panel data, Jing & Ab-Rahim (2020) investigated the relationship between ICT and economic growth in ASEAN-5 countries spanning 2003-2018. The study however did not include a digital economy evaluation system thus making it difficult to verify the relationship with economic growth. In addition, Nurdiana et al. (2023) tested the impact of digitalization on economic growth from the perspective of foreign direct investment and consumers, but did not elucidate the indirect effects of digital economy on industrial structures.

Based on existing research, this study uses entropy weight method to evaluate the development of digital economy in major ASEAN countries. On this basis, it adopts a fixed effect model to test the impact of digital economy on economic development in major ASEAN countries from 2011 to 2019. The results show that the development of digital economy has promoted the economic growth in ASEAN countries. Additionally, this paper uses the mediation effect model to reveal the fact that the digital economy promotes economic development by improving the industrial structure.

The study contributes to the extant literature in several areas: Firstly, the study establishes an evaluation index system for the development of the digital economy, considering multiple dimensions for ASEAN countries. Utilizing panel data from six ASEAN countries spanning 2011 to 2019, the study examines the impact of digital economy development on economic growth. Secondly, through the use of a two-way fixed effects model, it elucidates the influence of mechanisms and pathways through which changes in industrial structure impact on economic growth. The study specifically emphasizes the exploration of the mediation effect between these factors. Finally, considering the differences of regional economic bases, the study additionally explores the interaction between digital economy development and changes in industrial structure in both developed ASEAN countries and low and middle-income countries. It conducts a comparative analysis to examine the differences in the effects of digital economy development on the pathways of industrial structure changes in these nations.

The rest of the paper is organized in the following sections: Literature Review includes relevant studies, empiric literature and hypothesis, the model construction and variable description are in the Methodology, and the final part comprises Results and Conclusions.

LITERATURE REVIEW

Previous research has consistently demonstrated the positive impact of the digital economy on both national and regional economic advancement. Honohan (2004) identified the digital economy as a catalyst for promoting overall national economic advancement. Tranos et al. (2020) discovered that the growth of the digital economy correlates with increased productivity, thereby contributing to overall economic development. Using China's provincial panel data from 2010 to 2019, Xiang et al. (2022) similarly revealed the role of digital economy in driving regional economic growth, particularly noting its substantial impact on economic growth in lower quantiles compared to its weaker effect in higher quantiles. Moreover, Salahuddin & Alam (2016) conducted an analysis using OECD panel data spanning 1985 to 2012 to explore the relationship between internet technology adoption, economic growth, and electricity consumption. Their findings indicate that the adoption of internet technology and economic growth have led to increased electricity consumption, ultimately fostering economic growth in both short and long-terms. In a more specific context, Guo et al. (2023) utilized a DID (difference-in-difference) model to examine how the digital economy impacts the development of high-quality urban economies in China. Their analysis revealed that the digital economy positively impacts urban economic development by enhancing human capital, driving innovation in green technology, and mitigating the adverse effects of overcrowding in already developed areas, such as in the eastern regions and major cities. These observations highlight the complex and significant influence of the digital economy on economic advancement across different levels. Empirical research conducted by Li & Wang (2022) further revealed that the digital economy not only fosters upgrades in industrial structure but also contributes to their rationalization. Ren et al. (2023) affirmed the contribution of the digital economy in driving the evolution of industrial structures. Additionally, the empirical study from Liu et al. (2021) underscores its significant role in fostering structural transformation and enhancements.

The ASEAN countries have conducted research to elucidate the connections among economic growth, digital economy, and industrial structure. For instance, Haefner & Sternberg (2020) have highlighted the potential benefits of widespread internet infrastructure and digital initiatives for future economic growth. They suggest that digitalization will not only impact the economic and creative outcomes of businesses but will also have far-reaching effects on social and institutional conditions. For example, Sau-Rong et al. (2020) investigated the impact of information and communication

technology (ICT) on Malaysia's economic growth spanning 1984-2018, and employed a variety of economic tests including unit root, cointegration, VECM, and Granger Causality. Their results indicate the significant and positive relationships between mobile cellular subscriptions, individual internet usage and Malaysia's GDP, thus emphasizing the crucial role of ICT in economic enhancement.

The digital economy as a new economic form, and using data as a key element, profoundly affects regional economic development through modern information network and digital technology. In terms of its impact mechanism, it firstly generates novel industries and elements through digital technology, which seamlessly integrate into diverse aspects of human life and production, and foster more employment opportunities for regional residents, improve employment levels, and consequently promotes regional economic growth. Secondly, by closely engaging with traditional industries, the digital economy has revolutionized the production methods and sales channels within these sectors. It has introduced innovation in the operational modes of enterprises, enhanced their operational efficiency, and contributed to reducing the marginal cost of businesses. This, in turn, boosts the vitality and effectiveness of enterprise production. Additionally, the digital economy can improve resource allocation and enhance the effectiveness of enterprise management, the smooth exchange of information and technology between regions, thus stimulating regional economic growth through encouraging technological innovation within enterprises and promoting the digital transformation and development of businesses. The evolution of the digital economy can furnish new momentum for regional economic growth, and given this understanding, the following hypothesis is formulated:

H_a The advancement of the digital economy has the direct capacity to boost regional economic growth.

Many scholars have earlier explained the influence of digital economy on industrial structure. A key factor is the role of the Internet of Things (IoT) technology within the context of the digital economy, specifically in its application in the manufacturing sector, given that it has the capacity to drive significant adjustments in industrial structure (Giudice 2016). Empirical research conducted by Li & Wang (2022) has revealed that the digital economy not only facilitates upgrades in industrial structure but also contributes to their rationalization. Ren et al. (2023) further validate the digital economy's contribution to driving the transformation of industrial structures, while empirical findings by Liu et al. (2020) emphasise its substantial impact on promoting structural transformation and upgrades. Additionally, several studies focused on how the digital economy influences residents' income. The advancement of the digital economy is observed to reduce the digital inequality among residents, leading to a positive impact on income levels, especially in terms of their wage income improvement (Jiang et al. 2022). By cultivating digital skills and strengthening regional digital infrastructure, the income gap can be effectively narrowed (Yu & Wang 2021). Liu & Zhou (2023) however pointed out that the advancement of digital economy may exacerbate income inequality between rural and urban areas. Furthermore, the development of the digital economy creates additional employment prospects for residents, leading to a significant increase in wage income (Liu et al. 2023). Simultaneously, the progress of the digital economy contributes to the optimization of human capital structure, thereby fostering the advancement of residents' skills and enhancing their employability (Su et al. 2021). Lastly, the digital economy's evolution exerts a broader societal impact through optimizing the social production environment. This may effectively reduce production costs for enterprises, invigorating the vitality and efficiency of micro-individual production, and ultimately contribute to the improvement of income levels for residents (Song et al. 2022).

The advancement of the digital economy optimizes the efficiency of allocating production factors, accelerates the upgrading of industrial structures, and stimulates economic growth. Furthermore, it reinforces the exchange of means of production between different regions, facilitates the unrestricted movement of production factors and is conducive to their marketization process, enhances the level of industrial correlation between regions, and promotes the optimization and upgrading of industrial structures. The digital economy improves the level of intelligence and informatisation levels of production, which assist in transforming the production modes of enterprises and promoting their transformation and upgrading. The progress of the digital economy dismantles information and technology barriers, leading to effective information sharing among industries and reducing the hidden costs for enterprises. This, in turn, supports the digital innovation of enterprises, raises the technical content of products, and facilitates the transformation and enhancement of industrial structures. In terms of consumer demand, the evolution of the digital economy transforms human consumption habits and patterns, necessitating enterprises to deliver higher-quality and more cost-effective products and services. This transformation caters to diverse and personalized consumer needs, compelling enterprises to modify production methods and directing the evolution of industrial structures from a demand-oriented standpoint. The resulting improvement in industrial structure significantly enhances the effectiveness of resource allocation and utilization, thereby contributing to the promotion of regional economic growth. With these considerations, we formulate the subsequent hypotheses:

H_b The digital economy has the potential to indirectly stimulate regional economic growth by facilitating the upgrading of industrial structures.

METHODOLOGY

MODEL CONSTRUCTION

To explore the impact of digital economy development on regional economic growth, we construct the following econometric model:

$$eco_{it} = \alpha_0 + \alpha_1 dige_{it} + \alpha_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Where i represents a country, t represents time, eco_{it} represents economic development level of country i at time t , $dige_{it}$ represents digital economic development level of country i at time t , X_{it} represents control variables, λ_t is the time effect, μ_i is the individual effect, ε_{it} is the error term, α_1 is the regression coefficient of digital economy, which represents the influence of the digital economy on regional economic growth.

Equation (1) indicates the direct impact of digital economy on regional economic growth. To explore the internal impact mechanism of the digital economy, industrial structure upgrading and regional economic growth, a mediation variable (med) is introduced, and a mediation effect model is established with reference to Marsh et al. (2004). An examination is conducted into the indirect impact mechanism through which the digital economy promotes economic growth. The following models are established:

$$med_{it} = \beta_0 + \beta_1 dige_{it} + \beta_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

$$eco_{it} = \gamma_0 + \gamma_1 dige_{it} + \gamma_2 med_{it} + \gamma_3 X_{it} + \nu_i + \xi_t + \varepsilon_{it} \quad (3)$$

Among them, med_{it} is the mediation variable of country i at time t , ν_i is time effect, ξ_t is individual effect, ε_{it} is error term. γ_1 is the direct impact of digital economy on economic growth, and $\gamma_2 * \beta_1$ represents the indirect impact of digital economy on economic growth.

VARIABLES

In this study, the dependent variable is regional economic growth (eco) with GDP per capita as proxy to measure the economic development level of each region. The explanatory variable is the level of development of the digital economy ($dige$). With reference to Pan et al. (2022), this paper measures the development level of the digital economy in each country using four indicators: *Fixed broadband subscriptions per 100 inhabitants*, *Mobile cellular subscriptions per 100 inhabitants*, *Financial Institution Depth Index*, *Financial Institution Access Index*, *ICT Product Export*. The entropy weight method is used to assess the development level of digital economy in each country. The process is as follows: Initially, if the data span k years, n samples and m indices, then $x_{\theta ij}$ represents the j index of country i in θ year. Subsequently, to address differences of dimension and value among data indices, this study employs standardization. It undertakes dimensionless, positive, and normalization treatments on the data, accounting for both extremely large and extremely small indices.

$$\hat{x}_{\theta ij} = \frac{x_{\theta ij} - x_{minj}}{x_{maxj} - x_{minj}} \quad (4)$$

$$\hat{x}_{\theta ij} = \frac{x_{maxj} - x_{\theta ij}}{x_{maxj} - x_{minj}} \quad (5)$$

Where $\hat{x}_{\theta ij}$ represents the normalized value of $x_{\theta ij}$, and x_{maxj} , x_{minj} are the maximum and minimum values of j_{th} index.

By computing index information redundancy, weighting of the index is applied, resulting in more rational outcomes in the analysis. The main steps are as follows; calculating probability matrix, calculating index information, calculating information utility degree by entropy, deriving entropy weight, and finally calculating score.

$$P_{\theta ij} = \frac{\hat{x}_{\theta ij}}{\sum_{\theta=1}^h \sum_{i=1}^n \hat{x}_{\theta ij}} \quad (6)$$

$$e_j = -\frac{1}{\ln(n \times \theta)} \times \sum_{\theta=1}^h \sum_{i=1}^n P_{\theta ij} \ln(P_{\theta ij}) \quad (7)$$

$$d_j = 1 - e_j \quad (8)$$

$$W_j = \frac{d_j}{\sum_{j=1}^m d_j} \quad (9)$$

Where $P_{\theta ij}$ represents the proportion of the j th index in the θ th region of year i ; e_j d_j W_j denotes the information entropy, information utility degree and entropy weight of the final index respectively.

Based on the preceding analysis, industrial structure upgrading has an indirect impact on regional economic growth promoted by the digital economy. Consequently, industrial structure upgrading (str) is chosen as a mediating variable. The proportion of added value from secondary and tertiary industries to regional GDP is used to gauge industrial structure upgrading.

Following the methodology employed by Liu & Chen (2021), this study incorporates relevant control variables: (1) Urbanization Rate (urb), which is defined as the ratio of the urban population to the total population in each region. (2) The degree of government intervention (exp), which is expressed by the proportion of public financial expenditure to regional GDP. (3) Labour participation rate (lab), which represents the number of persons in the labour force as a percentage of the working-age population. (4) Foreign direct investment (fdi), which refers to foreign direct investment as a percentage of nominal GDP. (5) Patent applied (pat), which denotes the total number of patents applied by residents and non-residents in one year. The source of each variable is shown in Table 1. Table 2 presents the statistical description of all variables.

TABLE 1. Data source

Data Name	Source
Urbanization Rate	CEIC Database
Government Financial Expenditure	CEIC Database
Labour participation rate	CEIC Database
Foreign direct investment	CEIC Database
Patent Applied	World Bank
Fixed broadband subscriptions per 100 inhabitants	World Bank
Mobile cellular subscriptions per 100 inhabitants	World Bank
Financial Institution Depth Index	CEIC Database
Financial Institution Access Index	CEIC Database
ICT Product Export	CEIC Database
Industrial Structure	World Bank

TABLE 2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
urb	54	0.599	0.219	0.314	1
exp	54	0.196	0.044	0.097	0.285
lab	54	0.686	0.044	0.61	0.777
fdi	54	0.061	0.076	0.005	0.298
pat	54	7102.556	2655.626	2994	14136
str	54	0.873	0.058	0.745	0.949
eco	54	3.847	0.467	3.292	4.825
$dige$	54	0.429	0.213	0.112	0.734

RESULT

TABLE 3. Index system for digital economy development

Primary Index	Secondary Index	Data	Weight
	Infrastructure	Broad Subscription	0.2854
		Mobile Subscription	0.0916
Digital Economy	Financial Index	Financial institution access index	0.3210
		Financial institution depth index	0.1837
	ICT Index	ICT Product Export	0.1183

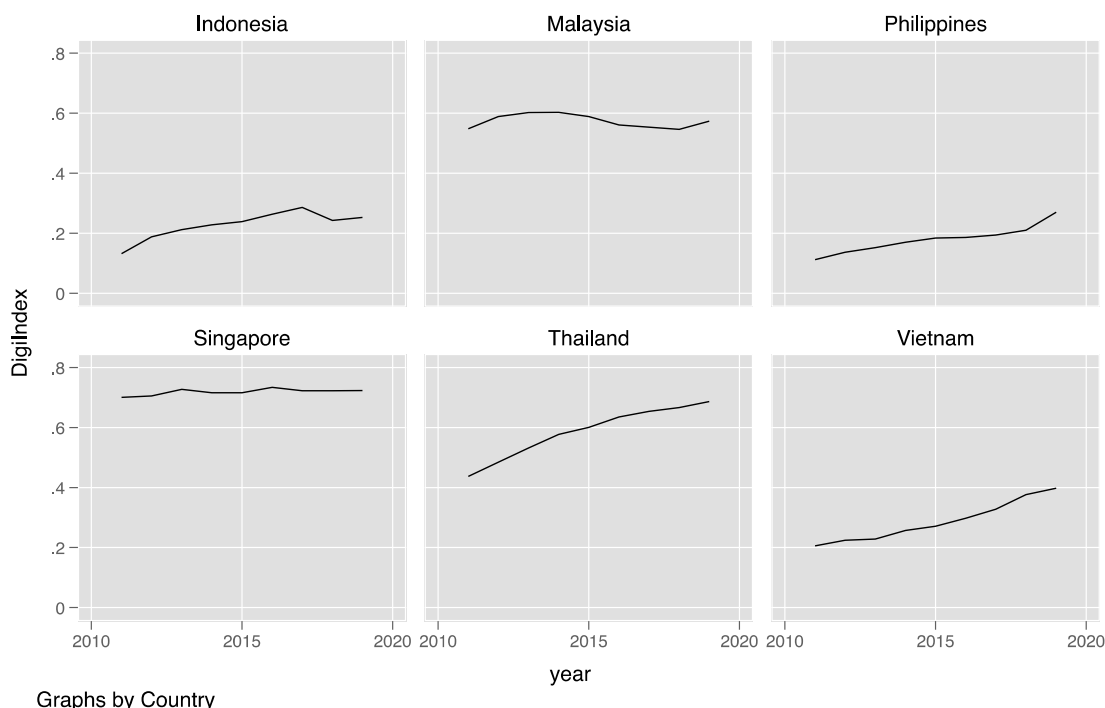


FIGURE 1. Digital economy development distribution

Table 3 presents the weights of each indicator for measuring digital economy index, while Figure 1 displays the trend of development of digital economy in each country. It is evident from the figure that the digital economy index remains stable and well-developed in Singapore, whereas in other countries, it displays a steady upward trend.

TABLE 4. Statistical results between digital economy development and economic growth

	<i>eco</i>	<i>eco</i>
<i>dige</i>	0.7357*** (0.1607)	0.8182*** (0.0267)
<i>_cons</i>	4.1054*** (0.635)	2.995*** (0.1086)
Hausman Test		0.7230654*** [0.0003]
Time Controlled	Yes	Yes
Country Controlled	No	Yes
Observations	54	54
R ²	0.8304	0.6333

(1) Standard errors are in parentheses; (2) P-Value are in square brackets.

*** $p < .01$, ** $p < .05$, * $p < .1$

In this study, Equation 1 is employed to assess the impact of digital economy development on economic growth. Based on Hausman test results, the fixed-effect model is selected, controlling for fixed effects of regions and years independently and simultaneously. Table 4 indicates that in the time fixed-effect regression, the digital economy development index, yields a digital economy regression coefficient of 0.7357, indicating that each unit increase in digital economy contributes to a regional economic growth boost of 0.7357 units. In the next column showing two-way fixed-effect regression, each increase in digital economy significantly promotes regional economic advancement by 0.8182 units. Both fix-effect models collectively demonstrate a notably positive influence of the digital economy on regional economic growth, thus confirming Hypothesis a.

TABLE 5. Estimation of mediation effect of digital economy development on economic growth

	<i>eco</i>	<i>str</i>	<i>eco</i>
<i>dige</i>	0.8*** (0.051)	0.226*** (0.021)	0.573*** (0.089)
<i>str</i>			1.002*** (0.332)
<i>_cons</i>	2.876*** (0.14)	1.437*** (0.057)	1.436*** (0.494)
Sobel Test			0.227** (0.0779)

Ratio of total effect that is mediated			0.28343
Observations	54	54	54
R-squared	0.994	0.937	0.995

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

Theoretical analysis explores the indirect influence mechanism of the digital economy on regional economic growth from the perspective of industrial structure upgrading. The constructed mediation effect model is verified in Table 5 and Bootstrap tests results in Table 6 corroborate the conclusion. Table 4 confirms that the advancement of the digital economy notably enhances industrial structure upgrading. Specifically, if the digital economy is upgraded by one unit, the industrial structure will be upgraded by 0.226 units. Furthermore, both digital economy and industrial structure upgrading show significantly positive coefficients on regional economic growth at the 5% level, thus supporting Hypothesis b. According to the last column of the results, the estimated coefficient for the relationship between the number of unemployed laborers and the industrial employment structure is 1.002, which is significant at the 1% level. This implies that the digital economy's development has a mediation effect on the industrial employment structure through the number of unemployed laborers, which constitutes 28.34% of the total effect. Therefore, we can conclude that the digital economy development primarily drives regional economic advancement mainly through direct effects, supplemented by the indirect effect of industrial structure upgrading.

TABLE 6. Bootstrap results

	Observed coefficient	Bootstrap std. err.	z	P>z	Normal-based [95% conf. interval]
_bs_1	0.227	0.102	2.230	0.026	0.027-0.426
_bs_2	0.573	0.105	5.480	0.000	0.368-0.778

HETEROGENEITY TEST

To investigate potential regional disparities in the influence of digital economy development on regional economic growth, a regional heterogeneity test is conducted across the developed and developing regions, with the regression outcomes presented in Table 7.

The impact of digital economy development on economic advancement varies depending on the level of marketization and regional resource endowment, resulting in diverse marginal contributions of the digital economy to economic growth across regions. According to the results of the regional regression analysis, digital economy development in developing countries contributes to enhancing regional economic growth. However, in Singapore, it fails to effectively elevate the level of regional economic development, as indicated by the non-significant regression coefficient for Singapore. This pattern of regional economic growth driven by the digital economy aligns with the trend that developing countries surpass Singapore, which is consistent with the findings from Zhou et al (2020). In recent years, the digital economy development in developing countries in Southeast Asia has experienced steady growth, boasting a substantial market and considerable development potential. Conversely, Singapore's digital market is highly developed and mature, characterized by a limited domestic market and a predominantly export-oriented economy. Therefore, the marginal benefits of digital economy development do not significantly impact its economic growth.

TABLE 7. Heterogeneity test results

	Singapore	Other Countries
<i>dige</i>	-12.976 (0)	0.771*** (0.185)
<i>urb</i>		-1.694* (0.917)
<i>exp</i>	10.562 (0)	0.137 (0.43)
<i>lab</i>	1.11 (0)	1.229* (0.639)
<i>fdi</i>	-2.129 (0)	0.738 (0.581)
<i>pat</i>	0 (0)	0 (0)
_cons	11.939 (0)	3.37*** (0.802)
Sobel Test	No Mediation Effect	0.3491*** (0.09376)
Ratio of total effect that is mediated	No Mediation Effect	0.4782
Observations	9	45
R-squared	1	0.845

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

ROBUSTNESS TEST

This study carries out robustness test by replacing the explained variables, in accordance with the methodology outlined in Tao et al., (2022). To mitigate the influence of price factors, the year 2011 is selected as the base period, and the per capita GDP Purchasing Power Parity (PPP) of each country is calculated as the new explained variable for the robustness test. Through analysis, it becomes evident that the regression coefficients of digital economy development remain significantly positive after changing the explained variables and adjusting the corresponding data. This underscores the strong robustness of the regression results. To address potential endogenous problems arising from measurement errors and other factors, this study refers to the approach related by Zhang & Chen (2021) to re-evaluate the development level of the digital economy through principal component analysis. The results were consistent with those of the previous regression findings, which reaffirm the conclusion that the development of digital economy can promote regional economic growth holds true even after conducting endogenous tests.

TABLE 8. Robustness test results

	GDP PPP
<i>dige</i>	0.31*** (0.056)
<i>urb</i>	-1.731*** (0.424)
<i>exp</i>	-0.153 (0.193)
<i>lab</i>	0.635** (0.266)
<i>fdi</i>	0.595** (0.258)
<i>pat</i>	0* (0)
<i>_cons</i>	4.342*** (0.359)
Observations	45
R-squared	0.979

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

CONCLUSION

Based on panel data spanning from 2011 to 2019, this study measures the digital economy development of the ASEAN 6 countries using the entropy method. Through examining the impact of digital economy development on regional economic growth from the perspective of industrial structure upgrading, the paper employs a mediation effect model, and poses the following suggestions: Firstly, the advancement of the digital economy fosters regional economic growth, as validated through robust and endogenous tests. Secondly, the digital economy indirectly stimulates regional economic growth by fostering the mediation effect of industrial structure upgrading. Lastly, regional differences exist in the influence of digital economy development on economic growth, with the most significant effects observed in developing regions.

POLICY RECOMMENDATIONS

The realization of the digital economy's potential in ASEAN underscores its pivotal role in propelling regional economic growth. This is supported by comprehensive analyses, which reveal that advancements in digital infrastructure and policies directly contribute to economic growth. This positive correlation is further substantiated by endogenous testing, demonstrating that a well-developed digital economy is a key driver of regional prosperity. Furthermore, the digital economy plays a crucial role in modernizing industrial structures, indirectly stimulating economic growth through this mediation effect. These findings highlight the transformative power of digital technologies in enhancing productivity and fostering new avenues for economic activities.

The influence of the digital economy on economic growth varies significantly across the region, with developing areas experiencing the most pronounced advantages. This underscores the importance of targeted digital economy policies that acknowledge regional differences, thus indicating a necessity for strategies specifically designed to uplift developing regions within ASEAN. Such policies should focus on bridging digital disparities, enhancing digital literacy, and facilitating the adoption of digital technologies in key sectors. By customising initiatives to the unique needs of each region, ASEAN can guarantee that the benefits of the digital economy are more equitably distributed, thereby maximizing its potential to drive inclusive economic growth.

Considering these findings, ASEAN's policy recommendations should be refined to emphasize the creation of a supportive environment for digital economy growth that considers regional variances. This entails a strategic approach to infrastructure development, focusing on areas with the greatest potential for economic impact, and fostering an ecosystem that encourages the digital transformation of industries. By prioritizing investments in digital literacy and infrastructure in

developing regions, ASEAN can harness the full potential of the digital economy to catalyse economic growth across the board. Such targeted strategies will not only address existing disparities but also unlock the transformative power of digital innovation for all member states, ensuring a cohesive and inclusive path to regional economic enhancement.

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