

Green Growth or Digital Divide? Examining the Relationship Between Technology Adoption, CO₂ Emissions, and Sustainable Development in Asean Countries

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Abstract: Digital transformation and development sustainable are two interconnected processes related however No always in harmony. In the ASEAN region, the differences level adoption technology, structure energy and capacity institutional cause question whether digitalization push green growth or precisely strengthen digital divide and pressure environment. Research This aim analyze connection between adoption digital technology, consumption energy, CO₂ emissions, and development economy in ASEAN countries. Research This use approach qualitative through analysis content against secondary data scale big from Our World in Data and reports international. Analysis focused on patterns cross- country use energy per capita, GDP per capita, internet and telephone penetration mobile, as well as CO₂ emissions per capita. Research result show that improvement digitalization Not yet in a way consistent lower CO₂ emissions. In many ASEAN countries, digitalization walk along with improvement consumption energy and emissions carbon consequence domination energy fossils and increasing activity digital economy. Countries with policy environment and capacity more institutional strong relatively more capable control emission compared to countries with limitations infrastructure and the digital divide. Contribution study This is integration draft green growth and digital divide in analysis development sustainable ASEAN and affirmation that technology No solution automatic for sustainability. Limitations study This lies in the approach qualitative and indicators technology that is still aggregate. Research furthermore recommended combine method quantitative, input variables energy renewable and quality institutions, as well as test non-linear relationship for deepen understanding about role digitalization in push development inclusive sustainability.

Keywords: Digital transformation, Green growth, Digital divide, CO₂ emissions, Sustainable development, ASEAN

Introduction

Transformation and development agenda sustainable are two currents large which is simultaneous form direction global development of the 21st century. In one side, adoption digital technologies such as the internet, intelligence artificial intelligence, big data, and technology information and communication (ICT) is seen as the main motor growth economy green (*green growth*) through improvement efficiency energy, innovation friendly environment, as well as optimization management source power nature. On the other hand, the digitalization process is not evenly potential widen *digital divide*, namely gap access and utilization technology between countries and intergroup social, which ultimately can hinder achievement development sustainable. In the context of ASEAN countries, the dilemma This become the more relevant remember area This face growth rapid economy, level adoption diverse technologies, as well as pressure improved environment, especially related emission carbon dioxide (CO₂). Therefore that, question fundamentals that emerge is whether adoption technology in the ASEAN region is more play a role as driver *green growth* or precisely strengthen impactful *digital divide* negative to quality environment and development sustainable.

A number of study previously has explore connection between adoption technology, CO₂ emissions, and development sustainable with mixed results. Initial studies about connection growth economy and environment, such as hypothesis *Environmental Kuznets Curve* (EKC), shows that improvement income at the stage beginning development tend increase degradation environment, but at the stage carry on can lower it through adoption more technology clean and policy a better environment strict (Grossman and Krueger, 1995; Dinda, 2004). In the context digitalization, some study find that improvement internet penetration and ICT are capable lower CO₂ emissions through efficiency energy, reduction cost transactions, as well as optimization chain supply (Salahuddin, Alam and Ozturk, 2016; Danish et al., 2020). Other studies show that digital technology can support development sustainable with push innovation green and improve productivity source Power (Balsalobre-Lorente et al., 2021; Ren, Hao and Wu, 2021).

However Thus, the literature also reveals side paradox from adoption technology. Some studies show that improvement use digital technology in fact can increase consumption energy and emissions carbon consequence growth data center, devices electronics, and activities economy intensive digital-based energy (Belkhir and Elmeli, 2018; S Lange, Pohl and Santarius, 2020). In addition, inequality in access and quality inter-country digital infrastructure develop can make things worse gap development and weaken contribution technology to sustainability environment (Billon, Marco and Lera-Lopez, 2009; Chakravarty and Chaturvedi, 2017). In the ASEAN context, research empirical Still show inconsistent results, where some countries obtained benefit environment from digitalization, while other countries are actually experience improvement CO₂ emissions along with with growth

technology and industrialization (Shahbaz et al., 2021; Le, Chang and Park, 2023).

Although literature about digitalization, emissions carbon, and development sustainable keep going developing, still there is a number of gap significant research. First, some big studies previously focused on developed countries or global country groups such as the OECD and BRICS, while study specifically to examine the dynamics of ASEAN countries are still relatively limited. Second, many study only review bilateral relations between technology and CO₂ emissions or between growth economy and environment, without integrate it in a way comprehensive in framework development sustainable. Third, the approach empirically used generally assume effect homogeneous between countries, even though level development economy, digital readiness, and structure energy in ASEAN is very diverse. Fourth, the role of *digital divide* as factor moderation or mechanism transmission between adoption technology and performance environment still seldom explored in a way systematic in context area develop.

Based on gap said, research this offer a number of novelty that distinguishes it from studies previously. First, research this in a way explicit test dilemma between green growth and digital divide with integrate adoption technology, CO₂ emissions, and development sustainable in one framework analysis complete empirical data. Second, the focus on ASEAN countries allows greater understanding contextual about how digitalization interact with challenge environment and development in the region heterogeneous development. Third, research this no only measure adoption technology in a way quantitative, but also considerate implications digital inequality between countries as influencing factors effectiveness technology in support sustainability. Fourth, from side methodological, research this adopt approach panel econometrics capable catch dynamics term short and long term long, and accommodate heterogeneity across countries, so that produce more robust and relevant estimates for formulation policy.

With Thus, focus main study This is analyze connection between adoption technology, CO₂ emissions, and development sustainable development in ASEAN countries in framework green growth versus digital divide. Research objectives This is: (1) testing influence adoption technology to CO₂ emissions; (2) analyze role technology in push or hinder development sustainable; and (3) evaluate whether digital inequality is strengthening or weaken contribution technology to performance environment. Based on objective said, the question proposed research includes: (a) whether adoption technology in ASEAN contributes to the decline or improvement CO₂ emissions?; (b) how connection between digital technology and indicators development sustainable?; and (c) to what extent is the *digital divide* influence connection between technology and sustainability environment. For answer question said, research this using panel data of ASEAN countries with period observation certain and apply method dynamic panel econometrics, such as *panel cointegration* and *dynamic panel regression*, in order to identify connection causal and dynamic term long between variables. Research

results expected can give contribution theoretical for literature economy environment and digitalization, as well as recommendation relevant policies for ASEAN countries within designing inclusive and sustainable development strategies.

Literature Review

Draft green growth and digital divide represents two paradigms main in development contemporary mutually related, but no always synergize. Green growth emphasize utilization technology and innovation for push growth economy low emissions, efficient source power, and sustainability, at the same time contribute to the decline CO₂ emissions and increase quality life term long (OECD, 2011; UNESCAP, 2018). On the other hand, the digital divide refers to the gap access, use and utilization digital technology between group public or country, which has an impact on inequality capacity economy and capabilities adoption technology proceed (van Dijk, 2006; Hilbert, 2011). In the literature development, digital divide no only understood as limitations access infrastructure, but also gaps literacy and skills utilization technology, which becomes obstacle main for development inclusive and sustainable. Because limit adaptation to growing digital economy rapidly (Bank, 2021).

The role of digital technology is also becoming attention main in context green growth. Technology information and communication (ICT) is seen as *enabler* important in increase efficiency energy, pushing green innovation, as well as optimizing economic processes so that potential lower intensity carbon (Sun, 2022). Digital technology makes it possible efficiency chain supply, reduction waste source power, as well as acceleration adoption practice low carbon through system better monitoring and management good. However, digital infrastructure that is energy-intensive, such as data center and network communication, also contributes to emission carbon if No supported by energy clean (Belkhir and Elmeligi, 2018). Therefore that, the relationship between green growth and digital divide is issue policy real that requires an integrative strategy in development modern technology.

Study international about connection digital technology and emissions carbon show findings diverse empirical. A number of studies find that digital economy has potential lower CO₂ emissions through improvement efficiency energy, utilization technology smart technology, and industrial restructuring (Jin, Gao and Wang, 2021). In addition, ICT has been proven to speed up diffusion innovation green and supportive management higher emissions effective (Zhang et al., 2020). However, other literature confirms that expansion digital infrastructure can increase consumption energy and emissions carbon, especially when dependence on materials burn fossil still high, so that cause significant carbon *footprint* (Belkhir and Elmeligi, 2018). Further study indicates that connection digitalization and emissions is non-linear, where adoption beginning technology can increase emission before the stage carry on produce decline emission along improvement efficiency and penetration technology (Shahbaz

et al., 2021). Findings This confirm that digital technology is not solution single for sustainability, but rather must integrated with policy energy clean and reduction strategies comprehensive carbon.

Other studies also show that digitalization contribute to the achievement *Sustainable Development Goals* (SDGs) (Lei et al., 2024). In the context of Asia, especially China, digitalization proven push innovation green that accelerates growth sustainable and pressing pressure environment through development technology low carbon (Zhang, Liu and Yang, 2024). However, the study cross- country shows that impact digitalization is highly contextual and condition-dependent socio-economic, policy national, readiness institutional, as well as capacity public in utilise technology (Lei et al., 2024). Uncontrolled digitalization balanced policy strong environment potential widen gap development and improvement pressure to source Power natural (Banks, 2021). In the ASEAN region, proof empirical show that digital economy can lower intensity emission carbon through restructuring industry, improvement capability technology and change structure consumption energy.

Findings This confirm potential digitalization in support green growth, especially If in harmony with transformation energy and innovation friendly environment. However, the impact the no homogeneous between ASEAN countries, considering difference level development economy, capacity fiscal, and resources available power (Elfaki and Ahmed, 2024). Bibliometric and empirical studies also reveal that gap infrastructure and access technology Still become challenge major in ASEAN, especially in countries with level development more low, which shows limitations investment and adoption technology tall (Banks, 2021). Another study regarding *digital inclusive finance* show that impact digitalization to development sustainable is non-linear and sectoral; in condition certain, especially in quantiles low, digital expansion is actually can increase CO₂ emissions due to domination effect growth economy (Wang and Guo, 2022).

Although literature has study connection between digital technology, emissions carbon, and development sustainable, still there is a number of research gap. First, some big studies focused on developed countries or area certain such as China and the G-20, with study comprehensive ASEAN which is still limited (Jiang et al., 2024). Second, the digital divide seldom positioned as variables moderation or mediation, even though gap technology is very important effectiveness digital adoption (van Dijk, 2006; Hilbert, 2011). Third, the mechanism transmission like role structure industry, policy energy and capacity institutional still not enough explored in a way deep (Shahbaz et al., 2021). Fourth, a lot studies Still use linear approach, while connection digitalization and emissions is non-linear and dynamic. Research This offer novelty with integrate green growth and *digital divide* in One framework analysis theoretical and empirical. Digital divide positioned as variables moderation main influencing factors connection between digital technology and CO₂ emissions. In addition, research this use dynamic panel analysis for catch heterogeneity between countries and long-term non-linear relationships long. In terms of practical, study this give proof

relevant empirical for maker ASEAN policy regarding How adoption technology and digital inequality affect emission carbon and development sustainable.

Based on literature, framework study built on three element main: (1) adoption digital technology, (2) CO₂ emissions and intensity environment, and (3) indicators development sustainable. Adoption technology assumed influence emission in a way direct through efficiency technology and in a no direct through restructuring industry as well as innovation green, with digital divide as moderator variables. This model also includes factor control like level development economy, capacity institutional and policy energy, which is proven important in literature (OECD, 2011; UNESCAP, 2018).

Method

This Study apply type study qualitative with approach analysis content qualitative because objective main studies this no for test connection causal in a way statistics, but rather for understand in a way deep patterns, tendencies, and meanings behind connection between adoption digital technology, CO₂ emissions, and development sustainable development in ASEAN countries. Analysis content qualitative relevant used when researchers make an effort interpret phenomenon complex socio-economic and environmental, cross-national, and influenced by context diverse structural and policy. This method allows exploration thematic against secondary data scale big in a way systematic and transparent, so that researchers can identify pattern narratives, contradictions, and dynamics that are not always caught through approach quantitative pure. In literature methodology, analysis content qualitative viewed effective For examine longitudinal and comparative data, especially in studies development and environment that emphasizes interpretation context and process (Krippendorff, 2022; Mayring, 2014; Schreier, 2024).

Along with increasing availability of large-scale data big in study social and environmental research this also adopts qualitative big data approach. Approach this no interpreted as analysis statistics towards big data, but rather as a qualitative strategy for interpret large, diverse, and cross-sectional data sets time with focus on patterns, trends, and meaning substantive. Qualitative big data allows researchers combine riches information from global dataset with logic interpretive typical study qualitative, such as coding thematic and analysis comparative cross cases. Some studies methodological confirm that analysis qualitative towards important big data for avoid reductionism number as well as give understanding contextual to dynamics social and policy background to quantitative data (Venturini et al., 2018). In the study this, qualitative big data approach used for interpret dynamics digital transformation and emissions carbon in ASEAN in general holistic, with put researchers as instrument main in the process of interpretation and synthesis findings.

Primary data source study This originate from Our World in Data (OWID), an open database global scale developed by the Global Change Data Lab works the same

with the University of Oxford. OWID provides standardized and documented data with good about various indicator development, including CO₂ emissions, consumption energy, GDP per capita, internet usage, and penetration telephone mobile sourced from institution international reputable such as the World Bank, the International Energy Agency, and the Global Carbon Project. In the research in this case, OWID data is treated as text and context empirical analysis in a way qualitative through longitudinal reading and comparison across ASEAN countries. The data used For identify pattern narrative about relatedness between digitalization, growth economy, and pressure environment, as well as for interpret how difference structure energy and level development influence direction connection the use of OWID as qualitative data sources secondary considered valid and reliable Because transparency the methodology as well as its area temporal and geographic coverage, which is much recommended in studies across countries regarding development sustainability and change climate (Sebestyén and Abonyi, 2021).

Results

Results section study this serve findings empirical data obtained from analysis content qualitative against secondary data scale large source from *Our World in Data*. Results compiled for give description comprehensive about dynamics adoption digital technology, growth economy, consumption energy, and CO₂ emissions in ASEAN countries in perspective development sustainable. Presentation results no intended as testing causality statistics, but rather as effort interpretive For identify patterns, trends, and differences cross-country that reflects connection complex between digital transformation and pressure environment. Findings study organized in a way thematic and comparative, with put indicator use energy per capita, GDP per capita, penetration digital technology, as well as CO₂ emissions per capita as base analysis. Approach This allows greater understanding contextual about How digitalization and growth economy develop in a way No uniform in the ASEAN region, as well How variation the implications to potential green growth and strengthening digital divide. With thus, the part this functioning as runway empirical for discussion critical on the part next, which relates results findings with framework theoretical and literary development sustainable.

Per Capita Energy Use Patterns

Analysis results show existence very significant disparity in use energy per capita between countries in the Southeast Asian region. Singapore and Brunei Darussalam are consistent occupy position top as a country with consumption energy per capita highest throughout period observation.

Singapore noted trend improvement use energy per capita from range around 110,000 kWh per person in the early 2000s to more from 180,000 kWh per person in the years last.

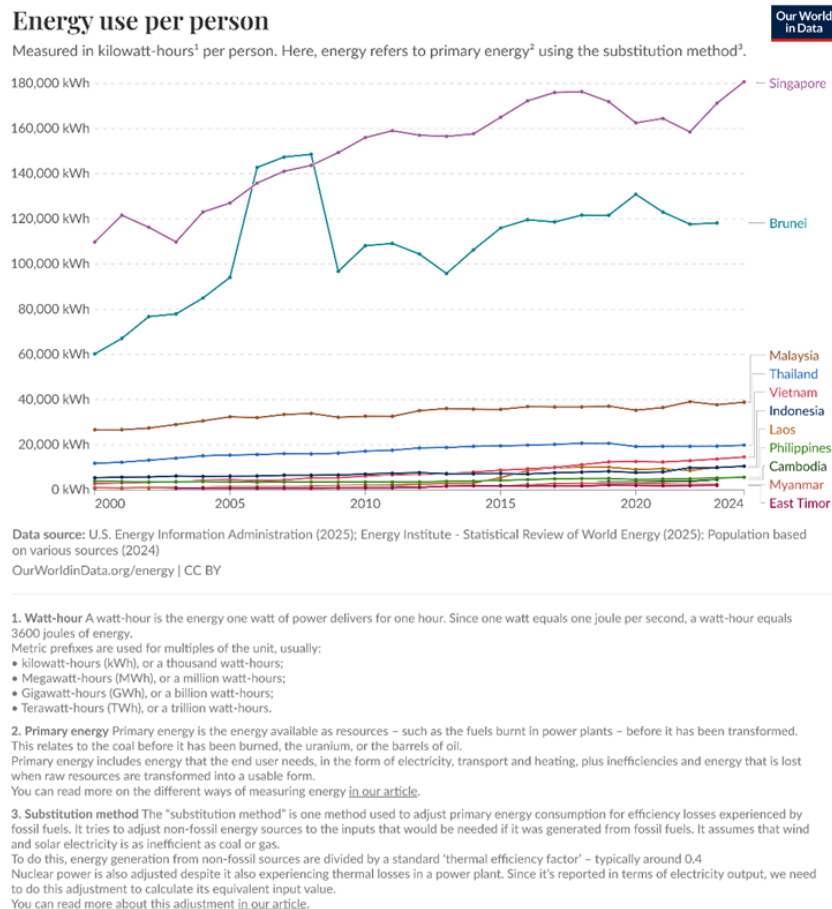


Figure 1. Data usage energy per capita of ASEAN countries

The height consumption energy this reflect characteristics Singapore's economy is based on industry, services finance, logistics, and level very high urbanization. Brunei Darussalam also shows level consumption relative energy per capita high, even though with more fluctuations big compared to Singapore. In the mid- 2000s, consumption Brunei's energy per capita is experiencing surge significant, then down, and back increase after 2015. This pattern related close with dependence Brunei's economy in the sector oil and natural gas, which are very sensitive to dynamics production and prices global energy.

On the other hand, developing countries such as Indonesia, Vietnam, the Philippines, and Thailand are in the group medium with consumption energy per capita is far more low. Indonesia, for example, shows trend gradual increase of around 5,000 kWh per capita in early period become approaching 9,000–10,000 kWh per capita in the years last. Increase This indicates improvement activity economy and access energy, although still relatively low

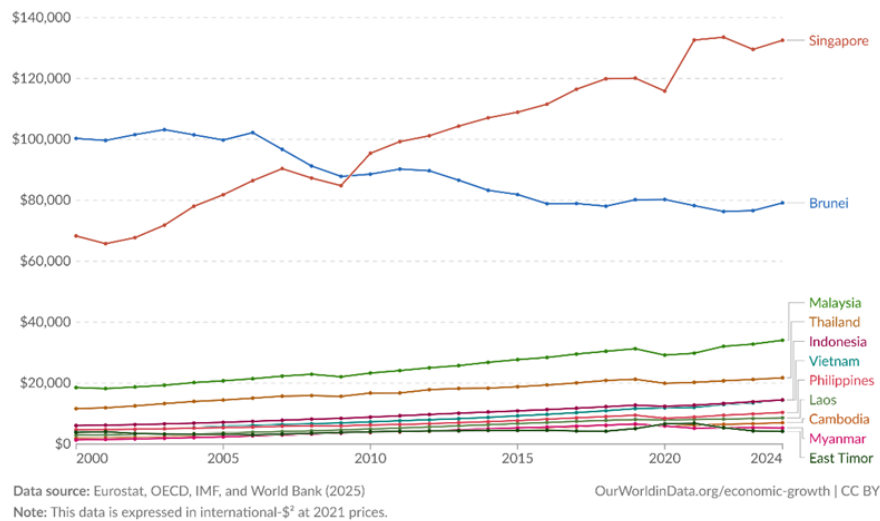
compared to low-income countries high in the area. Countries with level development economy more low such as Laos, Cambodia, Myanmar, and Timor Leste recorded consumption the lowest energy per capita. Although thus, the entire country in group This show trend increase, which reflects the process of electrification, development infrastructure basic, and improvement welfare public in a way gradually.

Development Product Gross Domestic Product (GDP) per Capita

GDP per capita data show gap sharp economic growth among Southeast Asian countries. Singapore is consistent record GDP per capita highest, with trend strong increase from around USD 65,000 in the early 2000s to more from USD 130,000 (in dollar international constant) in the period latest. This is confirm Singapore's position as a country with level income height and structure mature economy. Brunei Darussalam is ranked secondly, although show relative trend stagnant and even decreased in some period.

GDP per capita

GDP per capita is a country's gross domestic product¹ divided by its population. This data is adjusted for inflation and differences in living costs between countries.



1. **Gross domestic product** Gross domestic product (GDP) is a measure of a country's economic performance. It represents the total monetary value of all final goods and services produced within its borders over a specific time period, typically annually or quarterly. GDP includes consumption, government spending, investments, and net exports (exports minus imports). It can be measured in current prices (nominal GDP) or adjusted for inflation to reflect GDP in constant prices (real GDP). GDP is used to gauge the health of an economy, with increases indicating growth and decreases signaling contraction. Policymakers, economists, and analysts use GDP to make informed decisions, track economic trends, and make comparisons between countries.

2. **International dollars** International dollars are a hypothetical currency that is used to make meaningful comparisons of monetary indicators of living standards. Figures expressed in constant international dollars are adjusted for inflation within countries over time, and for differences in the cost of living between countries. The goal of such adjustments is to provide a unit whose purchasing power is held fixed over time and across countries, such that one international dollar can buy the same quantity and quality of goods and services no matter where or when it is spent. Read more in our article: [What are international dollars?](#)

Figure 2. GDP per capita of ASEAN countries

The decline in Brunei's GDP per capita after 2014 indicates vulnerability high economy to fluctuations sector energy, in particular oil and gas. Malaysia and Thailand are in the group medium above, with GDP per capita increasing in a way stable throughout period observation. Malaysia shows improvement from around USD 18,000 to more from USD 33,000, while Thailand increased from around USD 12,000 to more from USD 21,000. These two countries reflect the process of industrialization and diversification relative economy succeed.

Indonesia, Vietnam, and the Philippines are in the group medium below, however show trend consistent growth. Vietnam shows rate relative growth fast, so that GDP per capita distance with Indonesia and the Philippines increasingly narrowing. Condition This indicates transformation structural Vietnam's economy is supported by the sector manufacturing and exports. Countries such as Laos,

Cambodia, Myanmar, and Timor Leste are still is at a low GDP per capita level, even though in a way general show improvement from time to time. Improvement This signify existence progress economy, but at a time confirm challenge big in chase backwardness from other countries in the region.

Subscription Levels Telephone Mobile

Indicator subscriber telephone cellular per 100 inhabitants show acceleration rapid digital transformation across Southeast Asian countries. Almost all countries experience improvement sharp since early 2000s, with part large countries reach more of 100 subscriptions per 100 inhabitants in mid until late 2010s. This figure indicates that the average individual own more from One card or device mobile.

Mobile phone subscriptions per 100 people, 2000 to 2023

This number can get over 100 when the average person has more than one subscription to a mobile service.

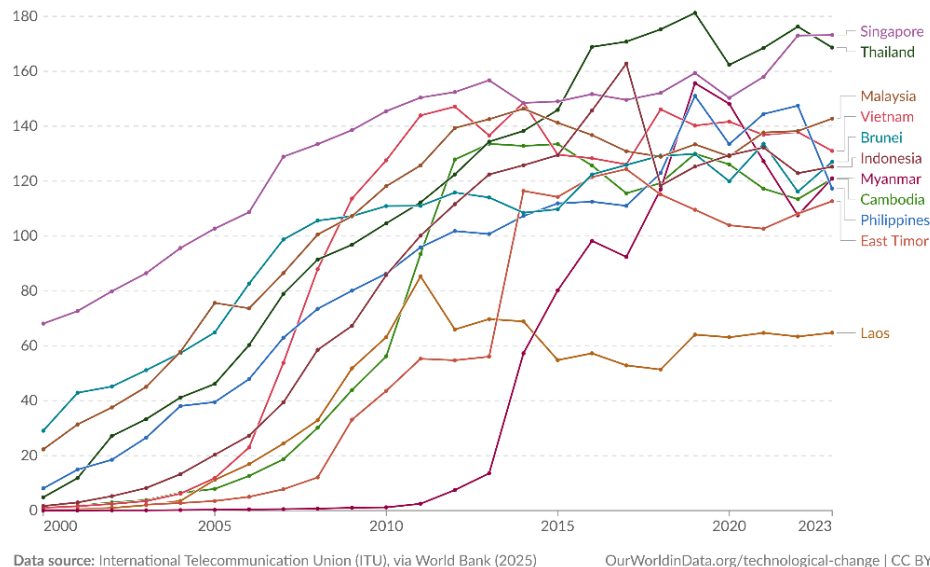


Figure 3. Subscription cellular per 100 people in ASEAN countries

Singapore, Thailand, Malaysia and Vietnam recorded level penetration highest, with close numbers or even exceeding 150 subscriptions per 100 inhabitants. The high penetration This reflect telecommunications market maturity, level relative income high, and need intensive communication in activity economic and social. Indonesia and the Philippines also show significant improvement, although with level little penetration more low compared to those countries. However thus, the increasing trend in a way consistent confirm role important technology mobile as means main communication and access information. Countries with level development more low such as Laos, Cambodia, Myanmar, and Timor Leste also experienced a significant spike, although level penetration still relatively more low. This is show that technology mobile play a role as a

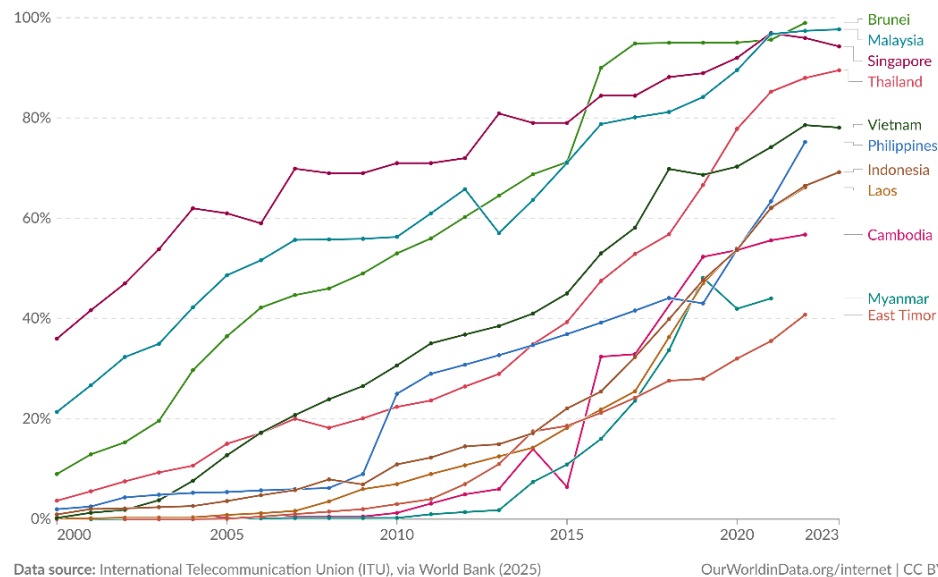
“leap technology (leapfrogging) that enables developing countries access service communication without must through stages development infrastructure still expensive.

Internet Use by Residents

Analysis results internet usage shows consistent pattern with level development digital economy and infrastructure. Singapore, Brunei Darussalam, and Malaysia recorded level highest internet usage, with proportion resident internet users approaching or exceeding 90 percent in recent years last. Condition This reflect availability adequate digital infrastructure, high digital literacy, and integration technology information in life daily.

Share of the population using the Internet

Share of the population who used the Internet¹ in the last three months.



1. Internet user The International Telecommunication Union defines an Internet user as anyone who has accessed the Internet from any location in the last three months. This can be from any type of device, including a computer, mobile phone, personal digital assistant, games machine, digital TV, and other technological devices.

Figure 4. Internet usage in ASEAN countries

Thailand and Vietnam show very rapid increase, especially after 2010. Vietnam, in particular, experienced surge significant in One decade lastly, so that approach level Internet use in more countries forward. This is show success policy expansion internet access and penetration digital devices. Indonesia and the Philippines are at the level medium, with trend steady increase. Although however, the digital divide still exists visible, especially between urban and rural areas. The level of internet usage continues to increase increase show potential big digital economy, but also emphasizes the need policy for ensure equality access. Countries such as Laos, Cambodia, Myanmar, and Timor Leste demonstrate level more internet use low, although with rate sufficient growth fast. Improvement This indicates phase beginning digital transformation, which is still face challenge

in the form of limitations infrastructure, costs access, and digital literacy.

Internet Use by Residents

Analysis CO₂ emissions per capita show existence close relationship between level consumption energy, structure economy, and pressure environment. Brunei Darussalam and Singapore took note CO₂ emissions per capita highest in the region. Brunei even reach more from 20 tonnes of CO₂ per capita in some year, which reflects domination sector energy fossils and industry based oil and gas. Singapore, although has a very high GDP per capita, indicating relative CO₂ emissions per capita more low compared to Brunei, however still is in the range high.

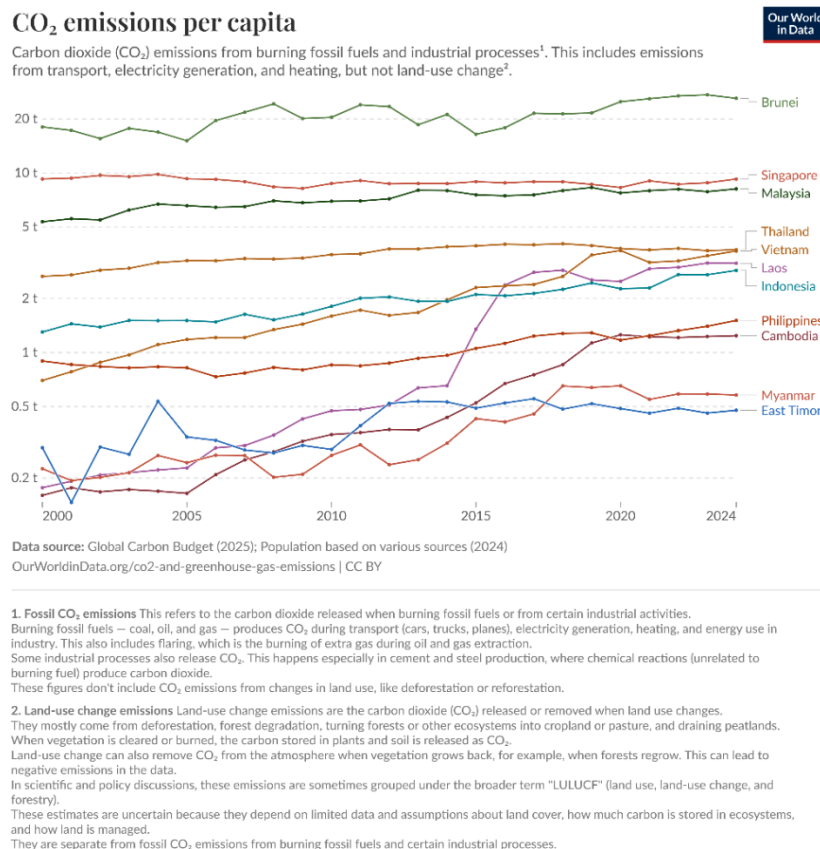


Figure 5. Emini Co2 per capita in ASEAN countries

This is show existence effort efficiency energy and management environment, although challenge emission still significant. Malaysia and Thailand are at the level emission medium, with trend relative increase stable. Indonesia and Vietnam show higher CO₂ emissions per capita low, but with trend increase along with growth economy and industrialization. Increase This confirm dilemma development faced by developing countries, namely between push growth economy and maintain sustainability environment. Countries such as the Philippines, Cambodia, Laos, Myanmar, and Timor Leste have recorded low per capita CO₂ emissions. Although thus, the trend improvement still visible, which shows that transition going to development low carbon become issue important to front, before pattern emission tall lock track development they.

Discussion

Findings study this show that connection between adoption digital technology, growth economy, consumption energy, and CO₂ emissions in ASEAN countries are complex and not uniform between countries. Increase in GDP per capita in a way general walk along with increasing consumption energy per capita, especially in countries with level income tall such as Singapore and Brunei Darussalam. This pattern in line with view classic in economy energy that places energy as the main input in the production and improvement process welfare economy (Wang *et al.*, 2019).

In context this, the result study confirm that growth the economy in ASEAN is still very dependent on consumption energy, some of which big sourced from energy fossil.

However thus, the results research also shows variation significant cross- country differences, even among countries with level relative income similar. Difference level consumption energy per capita between Malaysia, Thailand, and Vietnam indicates that structure economy, level efficiency energy, as well as policy national play role important in form connection between growth economy and use energy. Findings This strengthen argument that growth economy No in a way automatic produce pressure the same environment in each country, as also found in studies cross- country by the IEA (2023) and OECD (2022). With thus, the context institutions and policies become factor determinant in direction development sustainable.

From the side digital transformation, improvement penetration telephone the very rapid use of mobile and internet in all ASEAN countries shows that digitalization has become phenomenon cross level development. Income countries medium such as Indonesia, Vietnam, and the Philippines experienced growth fast digital access although GDP per capita level they Still relatively low. Findings This in line with draft *digital leapfrogging*, where developing countries can adopt digital technology in direct without must through stages industrialization long technology (Delera *et al.*, 2022). Literature previously also confirmed that technology information and communication potential increase

productivity, expanding market access, and accelerate growth economy (Kurniawati, 2022).

Although thus, the results study This show that improvement digitalization No always followed by an increase quality environment. In some large ASEAN countries, growth use digital technology in fact walk side by side with increasing consumption energy and CO₂ emissions. Findings This support arguments that state that digitalization own side paradox, where technology can increase efficiency in one side, but also adds request energy through improvement use device electronics, networks telecommunications, and data centers on the other hand (Steffen Lange, Pohl and Santarius, 2020). In other words, digital transformation has not yet fully functioning as driving green growth in this region.

In this regard with CO₂ emissions, results study show that countries with consumption energy high and dependency big on material burn fossil tend own higher per capita emissions high. This pattern consistent with IPAT framework that explains that improvement prosperity and technology based fossil increase pressure to environment (Hunjra *et al.*, 2024). However, the case of Singapore shows a little dynamic different, where the level relative CO₂ emissions more under control compared to with level his income. This is indicates existence role policy environment, efficiency energy, and adoption more technology clean, as also emphasized in literature about developed country capacity in manage impact environment from growth economy (OECD, 2022).

In a way overall, discussion results This confirm that adoption digital technology in ASEAN is not yet fully functioning as drivers of green growth, but rather Still is at in dilemma between push growth economy and enlarge pressure environment. Digital transformation is indeed open opportunity big for improvement productivity and inclusion economy, but without policy energy clean, efficient, and reduced digital divide, digitalization precisely potential strengthen pattern development that is not sustainable. Therefore that, the findings study This strengthen argument that digitalization need integrated in a way strategic with policy energy and the environment to truly contribute to development sustainable development in the ASEAN region.

Conclusion

This Study conclude that connection between adoption digital technology, growth economy, consumption energy, and CO₂ emissions in ASEAN countries are complex, non-linear, and highly heterogeneous between countries. Increase penetration digital technology is reflected from increasing internet and telephone usage mobile no in a way automatic lower emission carbon or strengthen development sustainable. In many ASEAN countries, digital transformation is actually walk along with increasing consumption energy and CO₂ emissions, especially Because structure energy that is still dominated material burn fossils and increasing request energy from the digital infrastructure alone. Income country tall as Singapore shows that emission can relatively controlled through efficiency energy and policy strong environment, while developing countries still is in phase improvement

emission along growth economy. With thus, adoption technology in ASEAN today This more represent dilemma between green growth and digital divide than become driver automatic development sustainable.

Contribution main study This lies in integration the concept of green growth and digital divide in One framework analysis for understand dynamics development sustainable development in ASEAN. This study show that digitalization is not variables neutral, but rather the impact is largely determined by the context structural like policy energy, capacity institutional level development economy and inequality digital access. With positioning the digital divide as moderating factors effectiveness technology, research This enrich literature that has been This tend look at technology as universal solution for problem environment. In general empirical, research This give description comparative across ASEAN countries which shows that the country with digital infrastructure and better policies ripe more capable utilise technology for efficiency, while countries with limitations precisely risky experience improvement pressure environment without benefit commensurate sustainability. With thus, research This give base conceptual and policy that digitalization must accompanied by transition energy clean and reduction strategies digital divide to truly support development sustainable.

Study This own a number of limitations. First, the approach qualitative based analysis content and interpretation of secondary data limit ability for identify connection causal in a way statistics. Second, the indicators technology used Still nature general (internet and mobile penetration) and not yet reflect quality use technology or adoption technology green in a way specific. Third, variation policy national and dynamics political Not yet analyzed in a way deep. Therefore that, research furthermore recommended for combine approach qualitative and quantitative through dynamic panel model or non-linear approach to test connection causal and threshold effects digitalization to emissions. In addition, research advanced can expand analysis with enter variables energy renewable, quality institutions, as well as innovation green for understanding about How digitalization can directed towards inclusive green growth become more comprehensive and operational for formulation policy.

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