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Digital Transformation Pathways in Southeast Asia: A Temporal-taxonomic Study

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DIGITAL TRANSFORMATION PATHWAYS IN SOUTHEAST ASIA: A TEMPORAL-TAXONOMIC STUDY

Abstract

This paper offers a comprehensive assessment of digital transformation pathways across Southeast Asian (ASEAN) countries between 2017 and 2022. Drawing on data from the International Telecommunication Union (ITU), we introduce a novel temporal–taxonomic methodological framework that enables a more refined analysis of digital development. Through expert-guided variable selection, we construct a composite synthetic indicator (CMG) and several partial indicators to capture the multidimensional nature of digitalization. A taxonomic clustering approach is then applied to identify structural patterns among the ten ASEAN countries.

Our analysis reveals significant disparities in digitalization levels, which align closely with broader socio-economic differences across the region. Specifically, three distinct clusters emerge, each reflecting different stages of digital advancement. Countries exhibiting higher levels of GDP, industrialization, and social development are consistently found in the most digitally advanced cluster.

The study contributes to filling a recognized research gap by providing a comparative, data-driven perspective on digital transformation in emerging economies. It offers actionable insights for policymakers and development agencies seeking to reduce digital inequality and foster inclusive technological growth in Southeast Asia. Furthermore, the methodological framework developed here may serve as a basis for future research in digital transformation and socio-economic forecasting.

Keywords: Digital Transformation; ASEAN; ICT Indicators; Taxonomic Clustering; Synthetic Indicator; Regional Development

1. Introduction

Changes observed in the world economy since 2013[1] are called the fourth industrial revolution or digital revolution. In this context, the term "Economy 4.0" which is based on the development and broad application of digital technologies, is characterized by the networked interconnection of participants in social and economic life and the so-called datafication – i.e., the integration of data derived from these networks. At the same time, profound transformation of business models and strategies are observed (Siuta-Tokarska et al. 2023). The revolution 4.0 is not only a grass-roots business-industrial initiative but a revolution requiring the integration of horizontal and vertical linkages across value chains and production systems (Gótz 2018). However, the foundations of its functioning and development are closely linked to the enabling environment provided by the State.

In this scope, the "State" has a special place as one of a distinctive features of the region it concerns, combining political, social and economic phenomena that integrate – in the light of understanding the idea of the state – three fundamental components (Klima 2009): territory, law or government, embodying authority and power, population (society).

In this paper, the research was undertaken to identify factors enabling the development of digitalization of economies in ASEAN countries, currently creating the "world's largest free trade area", and constituting a group of 10 countries with a population exceeding 600 million people and an estimated USD 100 billion in revenues from the digital economy in 2023, which

[1] In 2013 the final report of the working group operating in Germany was published, dealing with, among others, the preparation of recommendations in the field of intelligent industry. The term industry 4.0 (German: "Industrie 4.0") comes from the high technology strategy project of the German government and was first used during the international Hannover Messe fair in 2011.
This author of the research (Yu 2024) confirms the existence of three sets of factors influencing the development of digitalization of the economies of ASEAN countries:

1) national factors relating to policy at the national level
2) regional factors relating to other Asian countries, including China, but even outside Asia, such as cooperation with the USA
3) global factors.

Research has confirmed that factors at the national level are decisive because they enable the rapid development of peripheral innovations such as the ASEAN region, while factors at the regional and global levels are of an auxiliary nature.

is growing at 27% CAGR since 2021 (Yu 2024). The clear digital transformation of ASEAN countries is evidenced by data showing that in 2015 the digital economy of this region accounted for 1.3% of ASEAN's GDP and in 2019 already 3.7% with the assumed 8.5% in 2025 (Yu 2024).

Despite these impressive aggregate gains, significant intra-regional disparities persist in the levels and trajectories of digitalization across ASEAN member states. Therefore, the aim of this article is to analyse and assess the heterogeneity in digitalization levels among Southeast Asian countries, identify structural similarities and divergences, and formulate relevant policy and strategic inferences.

This scientific article is divided into several logically interconnected sections, structured according to core principles of scholarly investigation – including analysis and synthesis, deductive and inductive reasoning, comparative evaluation, and generalized inference.

2. The digital economy and digital transformation of ASEAN countries: a literature review

The digital economy includes all economic processes, transactions, interactions, and activities based on digital technologies (Schilirò 2022). It is an ecosystem where consumers, businesses, and governments exist within a digital society, engaging and creating value that benefits all stakeholders. The transformation towards economy 4.0, i.e. a digitalized economy, requires both bottom-up and top-down actions (Recommendations 2013):

1. Establishing a regulatory and legal framework that considers data protection, legal liability, and trade restrictions;
2. Standardization and reference architecture for interoperability;
3. Ensuring security and reliability in products, workplaces, and data transmission;

4. Building appropriate infrastructure, such as broadband networks;
5. Managing complex systems using appropriate models and tools;
6. Designing and organizing work with evolving real-time digital tasks;
7. Supporting continuous training and skill development;
8. Promoting resource efficiency in the context of the 4th Industrial Revolution.

Digital infrastructure forms the backbone of both the digital economy and digital society (Kovac et al. 2024; Siuta-Tokarska et al. 2025). The digital economy is also defined as the contribution of digital products and industries to GDP (Asian Development Bank 2021).

In contemporary literature, ASEAN has emerged as a dynamic region for digital transformation. Comprising ten member states with a collective GDP of nearly USD 3.2 trillion and a population exceeding 680 million, ASEAN is positioned as a global economic force (Isono and Prilliadi 2023; ASEAN 2022). Projections show it becoming the world's fourth-largest economy by 2030 (Lee 2024).

In 2022, manufacturing remained the primary contributor to ASEAN's GDP, but regional differences persist. While Singapore and Malaysia lead in high-tech sectors, Cambodia and Lao PDR are still dominated by agriculture. Brunei is heavily reliant on extractives, while the Philippines is trade-driven (ASEAN Statistical Brief 2024).

Digitalization efforts in ASEAN date back to ASEAN Vision 2020. The rapid expansion of digital natives and improving ICT infrastructure are key growth enablers (Murphy 2022; Aryani et al. 2022). A study by Google et al. (2022) indicates that ASEAN had 460 million Internet users in 2022, with 100 million added in just three years.

Digital transformation, as a concept, involves the systemic integration of digital technologies across business and governance, altering operations and value delivery. It is often explained in a progression: digitization (conversion of analog data), digitalization (integration

of digital tools into processes), and digital transformation (strategic digital reconfiguration) (Kraus et al. 2022; Verhoef et al. 2021).

ADB (2021) projects an additional USD 1 trillion GDP boost from digitalization in ASEAN by 2025. However, achieving this potential requires investments in infrastructure, skills, and governance. As Tobing (2022) noted, firms like Grab, Netflix, and Go-Jek are scaling at rates far surpassing traditional industries.

The COVID-19 pandemic accelerated digital transitions (Srisathan and Naruetharadhol 2022), spurring innovation and startup growth despite a subsequent funding slowdown (Marsan 2022). Yet, a significant challenge remains: the digital divide.

The digital divide in ASEAN manifests across access, usage, and performance dimensions (Aissaoui 2021; Cruz-Jesus et al. 2012). While Singapore leads with 211.36 Mbps average speed, Myanmar and Cambodia lag significantly (Speedtest 2022). Internet use ranges from 95% in Brunei to just 33.8% in Lao PDR (World Bank 2021). Similarly, disparities exist in patent filings and digital skills (Ing and Markus 2023).

Wati et al. (2024) documented digital skill gaps within Indonesia, linking them to regional economic indicators. These findings stress the need for standardized assessments and longitudinal tracking of digital readiness.

Efforts like the ASEAN Digital Integration Framework aim to harmonize policy and technological growth (Isono and Prilliadi 2023). Strategic priorities include legal alignment, digital innovation, cybersecurity, and sustainability-oriented tech adoption (Hendratmoko 2023).

A thematic review of recent literature further consolidates understanding in five dominant areas:

(1) **Theoretical frameworks of digital transformation:** The literature illustrates a strong conceptual foundation built around the evolution from digitization to digitalization and

finally to digital transformation. This sequence reflects increasing degrees of technological integration, from basic data conversion to strategic shifts in organizational structures and business models. Scholars such as Kraus et al. (2022) and Verhoef et al. (2021) underscore the importance of understanding digital transformation as an enterprise-wide reorientation driven by technology.

(2) **ICT infrastructure in ASEAN:** Multiple studies recognize digital infrastructure as a foundational driver for digital economy readiness in ASEAN countries. Broadband penetration, internet speed, and connectivity quality are frequently cited as critical determinants of digital competitiveness. Research has emphasized the enabling role of infrastructure in facilitating e-commerce, financial inclusion, and innovation ecosystems across the region.

(3) **Digital divide and disparities:** The digital divide is consistently portrayed as a multi-layered challenge, spanning access to digital technologies, their use, and the capacity to derive meaningful benefits. This divide is observed not only between ASEAN countries but also within them – across urban and rural divides and socio-economic groups. Recent studies, including those by Wati et al. (2024), delve into sub-national disparities in digital literacy and ICT access.

(4) **Measurement methodologies:** There is a growing body of work that explores innovative ways to quantify digital progress. Recent literature emphasizes the value of composite indicators, taxonomic approaches, and clustering algorithms for comparing national digital transformation trajectories. These methods offer more granular and structured ways of interpreting multidimensional digital development, addressing some of the limitations of traditional indices.

(5) **Governance and policy frameworks:** Studies increasingly stress the pivotal role of regulatory and institutional structures in shaping the digital future of ASEAN countries.

Research discusses the fragmented nature of digital governance in the region and calls for harmonized digital regulations, investment in digital public goods, and coordinated capacity-building initiatives. The role of supranational frameworks like the ASEAN Digital Integration Framework is highlighted as essential for regional coherence.

These thematic insights reflect both the maturity of the field and its evolving contours. They point to significant conceptual contributions and methodological developments, while also revealing persistent empirical gaps. Importantly, they highlight the need for comparative studies that combine temporal assessments with structural classification to offer actionable insights for policy and practice.

Despite advances, regulatory fragmentation persists, which may hinder cohesive digital development. More studies are needed on structural similarities and taxonomic groupings within ASEAN digitalization to inform policy. Suranto et al. (2023) and Wati et al. (2024) highlight the lack of granular comparative research.

This paper addresses that gap by employing synthetic indicators and taxonomic clustering to map ASEAN digital transformation trajectories from 2017-2022, thus contributing to the empirical literature on regional digital economy analysis.

3. Methodology

3.1. The research procedure and assumptions of the scientific work

The implementation of scientific research on "The Assessment of the State of the Digital Economy in Southeast Asia" involved the following activities and actions, allowing it to be carried out, by adopting the following research procedure:

1) firstly, it was necessary to outline the research area and the title of the paper and to conduct a preliminary analysis of the literature on the subject,
2) then the need to formulate basic research assumptions was identified, including:

- identification of the research gap,
- formulation of the research problem,
- determination of the objective of the scientific work,
- determination of the subject, object, temporal and spatial scope of the planned empirical research,
- formulation of research hypotheses,

3) The next step of the research procedure was a proper analysis of the literature on the subject, providing the basis, the foundation, so to speak, for conducting the empirical research. This part of the paper presents certain conclusions and inferences from the literature review, emphasizing the importance of factors described as driving forces in the process of digitalization in the ASEAN countries, while drawing attention to certain differences in this respect between the countries in the aforementioned region.
4) The selection of the research method and the selection of adequate data necessary to be used within the framework of the indicated research method, together with the presentation of research limitations.
5) Implementation of the empirical research.
6) Formulation and presentation of conclusions.
7) Indication of possible areas for future research.

The lack of research dedicated to the issue of digitalization level of Southeast Asian countries together with the identification of similarity of structures in this regard were identified as the research gap. To fill the research gap thus identified, the choice was made to use clustering within cluster analysis as part of the statistical methods, which makes it possible to divide groups of countries into so-called superior and inferior clusters.

The research problem was formulated in the form of the following question: *Are the digitalization levels of Southeast Asian countries similar or are there specific differences between them and, if so, are they significant?*

With the research gap thus identified and the research problem formulated, the authors of the paper defined the objective of this research paper, which is to analyze and assess the digitalization levels of Southeast Asian countries together with an indication of their similarities and differences, and to present the relevant conclusions and inferences arising therefrom.

The subject of the research relates directly to its objective defined above and that is to analyze and assess the digitalization levels of Southeast Asian countries.

The object of the research includes the following Southeast Asian countries: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar (Burma), Philippines, Singapore, Thailand, and Vietnam, which together form one region centered around the Association of Southeast Asian Nations (ASEAN).

The spatial scope of the research, on the other hand, takes into account the spatial-geographical location of the aforementioned ten countries which form one region and whose countries belong to the Association of Southeast Asian Nations (ASEAN). It is worth mentioning at this point that the objectives behind the creation and development of ASEAN include:

- economic aspects: to accelerate economic growth in the region,
- social and cultural aspects: social progress and cultural development in the region,
- legal and security aspects in the region: to promote regional peace and stability through abiding respect for justice and the rule of law in the relationship among countries in the region and adherence to the principles of the United Nations Charter.

The choice of the ASEAN countries was not random, but is related to their importance and the role they play in the global economy. It is a region with a population of 686 million as

of 2024 – i.e. more than 8% of the world's population, real GDP growth of 4.6%, i.e. 4.08 thousand billions of US dollars in current prices, which is just under 4% of the GDP share of the world economy in 2024. [https://www.imf.org/external/datamapper/profile/SEQ, https://aseanaustralia.pmc.gov.au/ sites/default/files/asean-cef.pdf, 18.06.2024].

The strength of these countries is their dynamic economic development which began at the turn of the 1990s, making them the so-called “Asian tigers” that not only pursue intra-regional cooperation, but meet the needs and opportunities in this respect through cooperation with countries in Europe, America, the rest of Asia, Australia and other regions of the world.

It is worth noting at this point that in 2020, the foreign ministers of the European Union and ASEAN countries decided to elevate cooperation between the EU and ASEAN to the level of a strategic partnership [https://pism.pl/publikacje/perspektywy-rozwoju-partnerstwa-strategicznego-ue-asean, 18.06.2024], which, also in the European context, speaks in favour of conducting scientific research in the horizon of mutual cooperation and development of scientific thought between scientists from these regions.

The temporal scope of the research covers the period between 2017 and 2022, which was adopted due to the availability of data in the topic of analysis and assessment of digitalization level of the analyzed economies of the ASEAN countries.

In the study, the following research hypotheses (RHs) were formulated:

RH1: The Southeast Asian (ASEAN) region is characterized by significant diversity not only in terms of the level of socio-economic development but also in terms of the digitalization level of individual countries in this region, which makes it possible to distinguish particular groups of them in the form of so-called clusters.

RH2: Among the ASEAN countries, groups of countries with high, medium and low levels of their digitalization are distinguished from the region as a whole.

RH3: Among the countries in the ASEAN region, a correlation can be observed that countries characterized by high levels of GDP, degree of industrialization and social development simultaneously belong to countries with high levels of digitalization, these are: Malaysia, Singapore and Brunei; while countries characterized by low levels of GDP, degree of industrialization of the economy and social development, such as Vietnam, Laos and Cambodia, belong to countries with low levels of digitalization.

3.2. Methods, sources of data and limitations of the research

With reference to the research method, a choice of taxonomic clustering of similarities was made to assess the structures of digitalization level of the ASEAN countries. In this respect, the choice concerned the clustering method which consisted of:

- division of the data into groups containing elements that are similar to each other, i.e. have common features, in other words overlapping,
- close to a given k-means distance,
- generated from a similar distribution, and
- minimising disorder, i.e. entropy.

Taking into account the chosen research method, which is in line with the adopted objective of this paper and other conceptual assumptions, a selection of data was made, which will be used for calculations using the aforementioned research method. For this purpose, data were collected from the International Telecommunication Union (ITU) database. ITU is the United Nations specialised agency for information and communication technologies (ICTs), which, in terms of the thematic aspect of the research, provides the substantive justification for this choice. It should be mentioned that the ITU database includes a total of 178 indicators.

For the purposes of this research paper, a division was made into three base research areas which were named:

1) Connectivity Area

2) Markets Area

3) Governance, Affordability, Sustainability and Trust Area (GAST Area).

Finally, following the selection of available data in the database according to the aforementioned selection rules for the ASEAN countries, 23 indicators were selected through expert selection, including:

- 8 for Connectivity Area,
- 8 for Markets Area, and
- 7 for the GAST Area

The next step was to develop a main synthetic indicator, called CMG indicator (named after the first letters of the area names). The CMG Indicator is the measure enabling the hierarchy of economies according to the three areas:

- Connectivity Area (C),
- Markets Area (M),
- Governance, Affordability, Sustainability and Trust Area ($GAST$).

The general form of the indicator is as follows:

$$CMG_i = w_1 C_i + w_2 M_i + w_3 GAST_i \qquad (1)$$

where the components C_i, M_i and $GAST_i$ denote the values of sub-indicators for the i- country, respectively.

Linear ordering according to the standardised sums method was used to determine the sub-indicators C_i, M_i and $GAST_i$. The procedure for estimating sub-indicators is as follows:

1. Selection of diagnostic variables (x_{ij}).
2. Determining preferences regarding variables, i.e. which of the diagnostic variables is:
   - stimulant,
   - destimulant,

- nominee.

3. Bringing all the variables into the stimulant form.
4. Determining the weights (w_j) for diagnostic variables.
5. Standardization of variables (z_{ij}).
6. Determining the maximum and minimum values of standardized variables:

$$z_{0j}^{+} = \max_i z_{ij} \quad (2)$$

$$z_{0j}^{-} = \min_i z_{ij} \quad (3)$$

7. Determining the value q_i for the standardized sum method:

$$q_i = \sum_{j=1}^{m} w_j z_{ij} \quad (4)$$

8. The above should be done separately for each group of variables constituting individual sub-indexes.
9. Determination of sub-indicators based on the formula:

$$C_i = \frac{q_i - q_0^-}{q_0^+ - q_0^-} \quad (5)$$

$$M_i = \frac{q_i - q_0^-}{q_0^+ - q_0^-} \quad (6)$$

$$GAST_i = \frac{q_i - q_0^-}{q_0^+ - q_0^-} \quad (7)$$

where $q_0^+ = \sum_{j=1}^{m} w_j z_{0j}^+$ and $q_0^- = \sum_{j=1}^{m} w_j z_{0j}^-$.

10. Determination of the indicator:

$$CMG_i = w_1 C_i + w_2 M_i + w_3 GAST_i \quad (8)$$

where w_i is the weight assigned to the i-th sub-indicator ($\sum w_i = 1$), where: $w_{1,}\, w_{2,}\, w_3 = \frac{1}{3}$.

11. Creating a ranking of facilities

Both the C_i, M_i and $GAST_i$ sub-indicators, as well as the general CMG_i indicator, have values from 0 to 1. The value 0 means the lowest position in the ranking, while the value 1 means the highest position in the ranking.

The following diagnostic variables were used in the study:

A. **Connectivity Area** (8 indicators):

1. Households with a computer (% of households that have a computer. A computer refers to a desktop computer, a laptop (portable) computer or a tablet (or similar handheld computer). Weighted: 0,05
2. Households with Internet access at home (% of households with Internet access at home. Access can be via a fixed or mobile network. If one member of the household has a mobile phone with connection to the Internet and makes it available for all members, then it should be considered that the household has access to the Internet). Weighted: 0,2
3. Fixed-telephone subscriptions (Refers to the sum of all active analogue fixed-telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents, fixed public payphones and satellite-based subscriptions provided to fixed locations that allow for a voice communication). Weighted: 0,05
4. Mobile-cellular subscriptions (Refers to the number of subscriptions to a public mobile-telephone service that provide access to the public switched telephone network (PSTN) using cellular technology. It includes the number of postpaid subscriptions and the number of active prepaid accounts). Weighted: 0,1
5. Population coverage, by mobile network technology. Weighted: 0,1
6. Fixed-broadband subscriptions (Refers to fixed subscriptions to high-speed access to the public Internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s divided by population and multiplied by 100; per 100 people. Weighted: 0,1

7. Active mobile-broadband subscriptions (Refers to the sum of active handset-based and computer-based (USB/dongles) mobile-broadband subscriptions that allow access to the Internet). Weighted: 0,1
8. Individuals using the Internet (Refers to the proportion of individuals who used the Internet from any location in the last three months. Access can be via a fixed or mobile network); (in %). Weighted: 0,3

B. **Markets Area** (8 indicators):

1. Wireless Local Loop (status: Full competition (year when competition was introduced); Monopoly; Partial competition (year when competition was introduced). Weighted: 0,12
2. Local fixed line services (status: Full competition (year when competition was introduced); Monopoly; Partial competition (year when competition was introduced). Weighted: 0,12
3. Mobile Broadband (status: Full competition (year when competition was introduced); Monopoly; Partial competition (year when competition was introduced). Weighted: 0,14
4. Annual investment in telecommunication services (Annual investment in telecommunication services refers to the investment during the financial year made by entities providing telecommunication networks and/or services (including fixed, mobile and Internet services, as well as the transmission of TV signals) for acquiring or upgrading fixed assets (usually referred to as CAPEX), less disinvestment owing to disposals of fixed assets). Weighted: 0,14
5. National broadband plan exists (status: Yes, No). Weighted: 0,14
6. Revenue from mobile networks (Revenue from mobile networks refers to retail revenue earned from the provision of mobile-cellular communication services, including all

voice, SMS and data (narrowband and broadband) services offered by mobile operators offering services within the country during the financial year under review), value in USD. Weighted: 0,12

7. Revenue from all telecommunication services (Revenue from all telecommunication services refers to revenue earned from retail fixed telephone, mobile-cellular, Internet and data services offered by telecommunication operators (both network and virtual, including resellers) offering services within the country during the financial year under review. It includes retail revenues earned from the transmission of TV signals, but excludes revenues from TV content creation), value in USD. Weighted: 0,12
8. Full-time equivalent telecommunication employees (Full-time equivalent telecommunication employees refers to the total number of persons, in full-time equivalent (FTE) units, employed by telecommunication operators in the country for the provision of telecommunication services, including fixed-telephone, mobile-cellular, Internet and data services). Weighted: 0,1

C. **Governance, Affordability, Sustainability and Trust (GAST) Area** (7 indicators):

1. Consumer protection authority (status: Yes, No). Weighted: 0,15
2. ICT Policy (status: Yes, No). Weighted: 0,15
3. Regulatory framework for e-Applications (status: Yes, No). Weighted: 0,15
4. Individuals with ICT skills, Finding, downloading, installing and configuring software. (Refers to the proportion of individuals with ICT skills, defined as having undertaken certain activities in the last three months, independent of the device(s) used. Individuals can have carried out multiple activities and therefore be considered to possess several ICT skills). Weighted: 0,1
5. Individuals with ICT skills, Writing a computer program using a programming language. (Refers to the proportion of individuals with ICT skills, defined as having

undertaken certain activities in the last three months, independent of the device(s) used. Individuals can have carried out multiple activities and therefore be considered to possess several ICT skills). Weighted: 0,15

6. ICT consumer protection legislation (status: Yes, No). Weighted: 0,15
7. Cybersecurity legislation/regulation exist (status: Yes, No). Weighted: 0,15

Only quantitative variables were used to determine sub-indicators. Binary variables (Yes/No) were recoded into dummy variables. Any missing data were supplemented using data imputation method: linear interpolation and the k-NN (k-Nearest Neighbours).

The next step of the methodology procedure was adopting the clustering method. To classify countries in terms of the similarity of the value and structure of the new, created "CMG indicator", a cluster analysis was used as one of the basic methods of so-called unsupervised grouping (Borowiecki et al. 2021).

Cluster analysis is a set of methods of multidimensional statistical analysis, used to extract homogeneous subsets of objects of the study population, which helps to find groups of so-called clusters of objects based on variables that characterize the analyzed objects and this method uses measures of discrepancy or distance between objects when forming clusters (Borowiecki et al. 2021). By applying the Ward method, clusters of ASEAN-10 countries were formed using CMG data for both 2017 and 2022 – with forming clusters in each year and showing it by dendrograms, presented in the form of figures. The choice of countries to represent each cluster was driven by the components of the CMG values and its internal structures consisting of the following indexes: Connectivity, Market and GAST. It is worth explaining that the most direct way to calculate the distance between objects in a multidimensional space is to calculate the Euclidean distance, however, often in this analysis a different metric can be taken as a measure of distance. The chosen method is considered to be the most effective, although it aims to create clusters of small size (Stanisz 2007). The selection

of the number of clusters is based on the difference between the maximum similarity within the groups and the minimum (Kaufman and Rousseeuw 1990). On this basis, an optimal number of concentrations of three was established.

The limitations of this research are connected above all with the limitations of the methods which were used in this research - they are described in detail in the literature on the subject of statistical methods (Pociecha et al. 1988; Evans 2008; Ott and Longnecker 2021) and also with the limitations of the data in the ITU database – the lack of completeness.

This research on the topic of digitalization levels of the ASEAN countries, with its analysis and assessment, inference and presentation of conclusions based on data from the ITU database, selected through expert selection, together with the development of a synthetic main indicator and synthetic partial indicators, is clearly of a pioneering nature, which is also confirmed by the earlier review of the literature on this topic area.

4. Results and discussion

The ITU indicators, which are collected in the ITU database correspond to the development of the digital economy and society, impacting the standard of living and economic competitiveness in the ASEAN. The authors of this publication chose ITU database indicators for the following reasons:

- this database contains not only quantitative but also qualitative measures which is very important in the context of the methodology approach and allows for a reduction of measurement error and a higher quality of the research,
- this database does not only contain some indicators but also their grouping in critical areas from the point of view of digitalization issues;

- this database enables time comparison of the indicators for a given economy, and countries' areas as well as comparison of countries in the world between them in the years and periods.

Based on data from the ITU database, an appropriate measurement was made in terms of the newly created proprietary "CMG" indicator and its partial sub-indicators: Connectivity, Market and GAST.

The authors adopted two main research years: 2017 and 2022 which show a difference of 6 years of the above-mentioned indicators, which, taking into account the time range and the development of digitalization in the world, illustrates a specific degree of these changes.

In Fig. 1 the ASEAN countries' values of CMG indicator and its sub-indicators are presented.

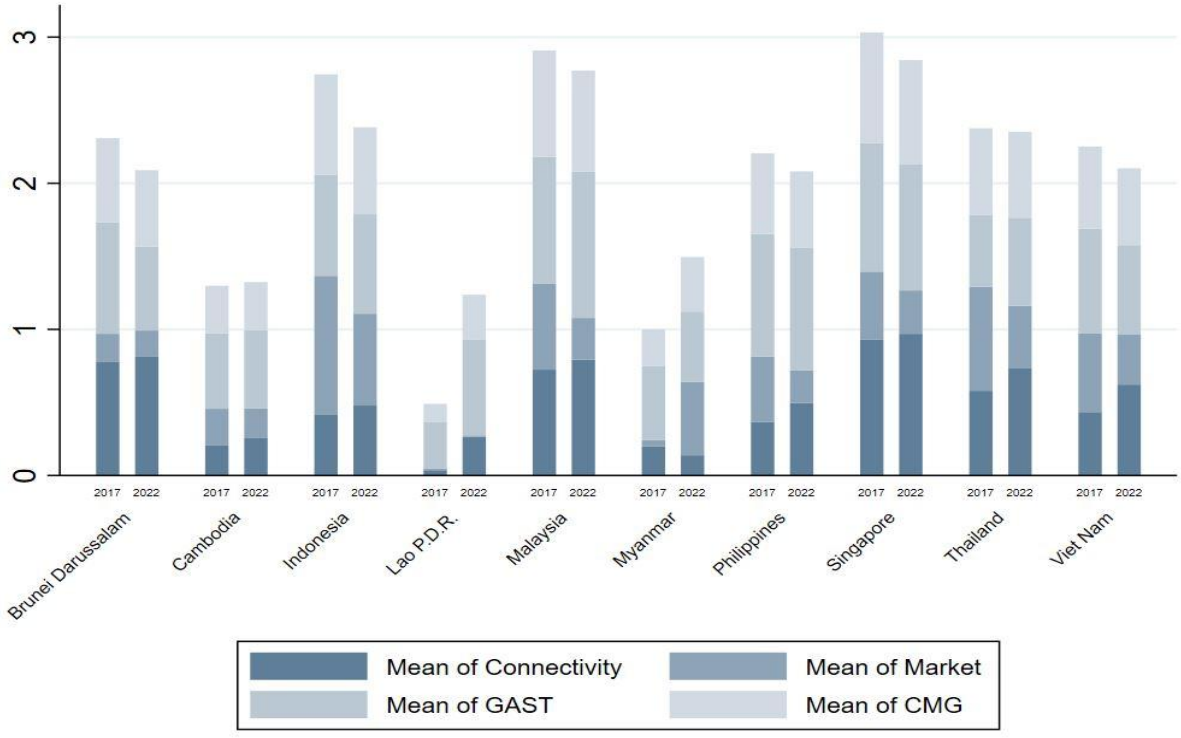


Fig. 1 ASEAN countries' values of the CMG indicator and its sub-components
Source: Authors own analysis

The data presented in Figure 1 indicate the existence of certain similarities, but also differences between the countries of the ASEAN group. Comparing the results for individual ASEAN countries over time (in 2017 and in 2022), for some of them there is an improvement

in the value of the main CMG indicator and its sub-indicators and for others a decrease in their value. This illustrates that despite belonging to one geographical, socio-cultural and civilization region such as ASEAN countries, their development including its level, directions and dynamics of changes in their digital transformation, are not the same. In order to better and deeper analyze this area, the clustering method for ASEAN countries is prepared. In Fig. 2 the hierarchical clustering analysis is presented.

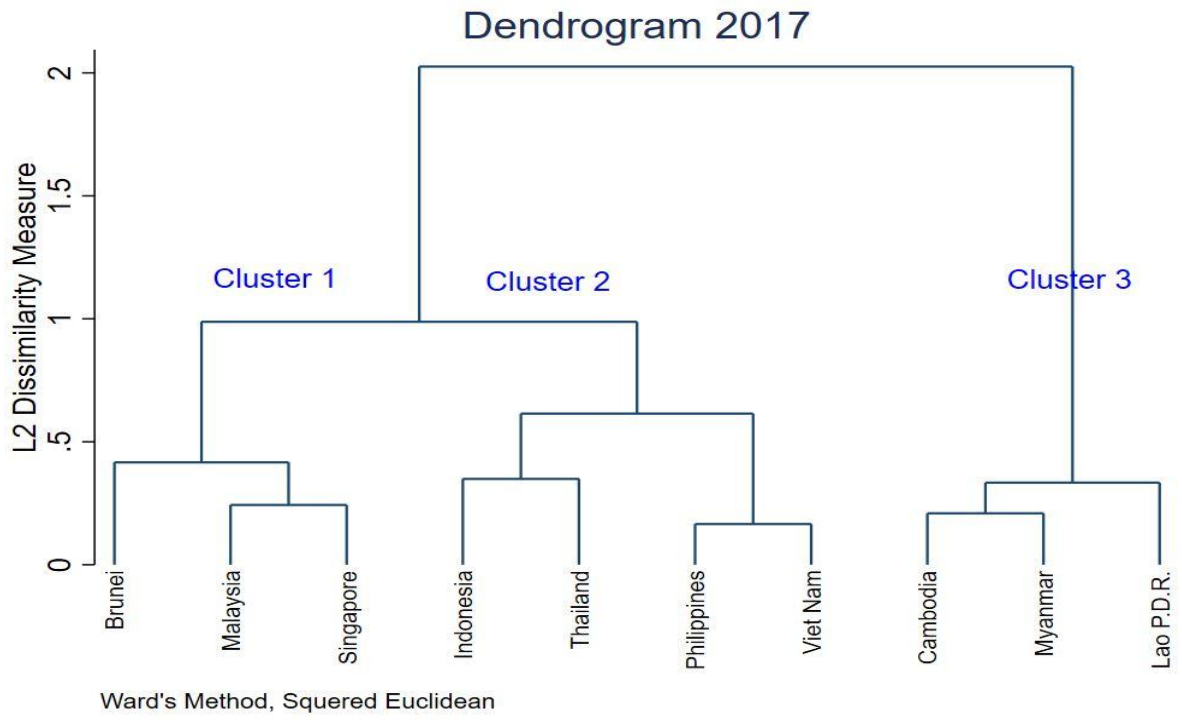


Fig. 2 Dendrogram for the ASEAN countries based on CMG indicator and its sub-indicators in 2017
Source: Authors own analysis

The hierarchical clustering analysis, shown in Figure 2, represents the degree of the CMG sub-indicators, measuring the global development of ICTs at the level of access, uses, and skills in various ASEAN countries in 2017.

Based on Ward's method with squared Euclidean distances, the clustering of countries was provided with a priori cluster structures based on CMG sub-indicators. The dendrogram clearly identified three clusters. Cluster 1, consisting of Brunei Darussalam, Malaysia, and Singapore, showing the relatively higher similarity probably because of advanced ICT

development and similar policies. Cluster 2, consisting of Indonesia, Philippines, Thailand, and Viet Nam with moderate similarity and at different levels of ICT development. Cluster 3, composed of Cambodia, Lao P.D.R., and Myanmar, formed lower independent group probably due to their relatively lower ICT development and different socio-economic factors. Consequently, the clustering shows the different extents of socio-economic development and competitiveness among ASEAN countries in the year 2017.

In Figure 3 the same analysis – clustering – for 2022 is prepared.

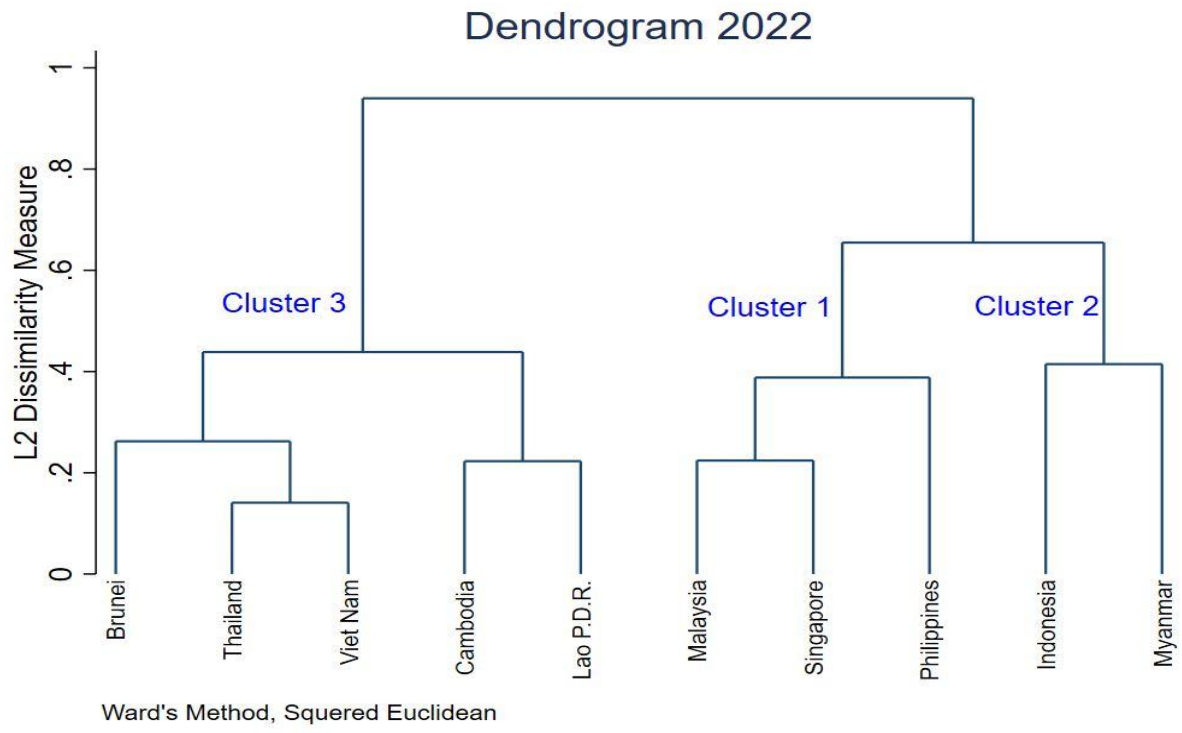


Fig. 3 Dendrogram for the ASEAN countries based on CMG indicator and its sub-indicators in 2022
Source: Authors own analysis

The hierarchical clustering in Figure 3 for the year 2022, indicating the level of ICT development in ASEAN countries. Applying Ward's method using squared Euclidean distances for the countries under study, three distinct clusters are shown. Cluster 1 represents the countries Malaysia and Philippines, with high similarity probably due to their ICT development and similar policies. Cluster 2, consists of Indonesia and Myanmar with moderate similarity and a

balance of ITC characteristics. Cluster 3 is the most diverse and includes Brunei Darussalam, Cambodia, Lao P.D.R., Singapore, Thailand, and Viet Nam, which represent a broad spectrum of socioeconomic conditions, from probably the most developed economy in the sample such as Singapore to some of the least developed, such as Cambodia and Lao P.D.R. Therefore, this clustering enables us to make inferences concerning the relative ICT development and competitiveness levels among these countries in the year 2022.

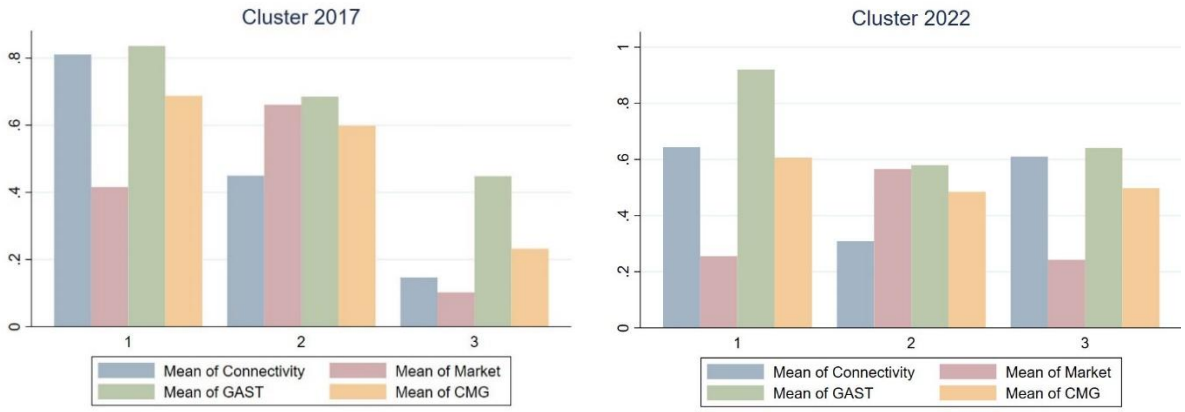


Fig. 4 Comparative Cluster Values of the CMG and its sub-components in ASEAN countries in 2017 and 2022
Source: Authors own analysis

Table 1 Value of the CMG indicator and its sub-components in a cross-section of isolated clusters for ASEAN countries in 2017 and 2022

	Cluster 1	Cluster 2	Cluster 3
In 2017	**Brunei Darussalam** **Singapore** **Malaysia**	**Indonesia** **Philippines** **Thailand** **Viet Nam**	**Cambodia** **Lao P.D.R.** **Myanmar**
CMG	0.6874	0.5986	0.2324
Connectivity	0.8106	0.4499	0.1467
Market	0.4158	0.6609	0.1022
GAST	0.8359	0.6849	0.4482
In 2022	**Malaysia** **Philippines**	**Indonesia** **Myanmar**	**Cambodia** **Lao P.D.R.** **Thailand** **Viet Nam** **Brunei Darussalam** **Singapore**
CMG	0.6065	0.4748	0.4978

Connectivity	0.6440	0.3084	0.6101
Market	0.2554	0.5659	0.2425
GAST	0.9200	0.5799	0.6406

Source: Authors own analysis

Additionally, as shown in Figure 4, the hierarchical clustering for 2017 and 2022 points to changes in the ICT development landscape of ASEAN countries. The clustering structure shows more variation in 2022, indicating the changes in the ICT metrics for ASEAN region. According to these shifts, there could be changes in economic policies or development programs and even external factors that might impacted the socio-economic conditions. While in 2017, there were more distinct clusters in the analysis; in 2022, countries at different levels of development blended as one block, which could be an indication of growing integration or changing policy impacts. This dynamic clustering underlines the need for further continuous monitoring and adaptive policies to foster balanced regional development. Additionally, the figures also indicate the convergence of clusters in 2022, while in 2017 the variation is highly heterogeneous.

The country-level analysis of the CMG indicator has outlined several changes between the two surveyed years. These changes are positive and show an increase in the CMG development. In the analyzed years, three of the teen ASEAN countries had below-average, while seven countries were above average in the ASEAN. Countries below the average, both in 2017 and 2022, were Cambodia, Lao PDR., and Myanmar. In 2017, the lowest country-level of CMG score was by Lao PDR., with 0.1225 points, while in 2022, it also was Lao PDR. with a slight increase to 0.3093 points. Countries with above-average CMG values in both years included Brunei Darussalam, Indonesia, Malaysia, Philippines, Thailand, Vietnam, and Singapore. As shown in Table 2, comparing the performance of individual countries against the ASEAN average in 2017, it was found that Lao PDR. had the lowest rate of 23.7%, while Singapore had the highest 147% rate. Similarly, in 2022, it was found that Lao PDR. had the lowest rate of 60.1%, while Singapore had the highest 137.9% rate.

Table 2 Summary of the CMG measure and its sub-indicators with the lowest-highest values compared to the ASEAN average in 2017 and 2022

Lowest-Highest Country Scores as a % of the ASEAN Average That Year		Included:		Difference [P.P.]	Degree of Recorded Differences	Assessing Changes in Implementing Convergence Processes
		Lowest Values [%]	Highest Values [%]			
Connectivity	2017	3.6	93.2	89.5	Degree 2	+
	2022	13.8	97.0	83.2		
Market	2017	1.3	94.8	93.5	Degree 3	+
	2022	1.0	62.9	61.8		
GAST	2017	31.9	87.9	56.0	Degree 1	+
	2022	48.0	100.0	52.0		
CMG	2017	12.3	75.8	63.6	-	+
	2022	30.9	71.1	40.1		

Note: Clarification: Degrees 1-4 represent the magnitude of differences between 2022 and 2017, with degree 1 being the smallest and degree 4 the largest. A "+" indicates positive changes enhancing convergence, while a "-" indicates negative changes reducing convergence.
Source: Authors own analysis

The fact that the gap between the lowest and highest rates as compared to the ASEAN average has been gradually decreasing from 63.6 pps in 2017 to 40.1 pps in 2022, gives a positive trend toward more convergence across ASEAN countries. This positive trend is further diluted by the countries' observation where the value of the ratio between the highest and the lowest rates dropped from 6.2 in 2017 to a far lower value of 2.2 in 2022.

Table 3 shows the trend in average CMG values and its sub-indicators from 2017 to 2022 in each clusters. The findings on CMG development in these clusters are conclude as following:

- For 2017, the CMG in Cluster 1 was 0.6874 points, which after five years, by 2022, reached 0.6065 points, a decrease of 11.7%. The values of CMG in Cluster 1 for 2017 and 2022 remained above than the ASEAN average.
- For 2017, the CMG in Cluster 2 was 0.5986 points, which after five years, by 2022, reached 0.4748 points, a decrease of 20.6%. The values of CMG in Cluster 2 for 2017 remained above, while for 2022 remained near the ASEAN average.

- For 2017, the CMG in Cluster 3 was 0.2324 points, which after five years, by 2022, reached 0.4978 points, an increase of 114%. The values of CMG in Cluster 3 for 2017 remained lower, while in 2022 remained almost the same as the ASEAN average.

Table 3 Dynamics of average CMG and its sub-indicators in 2017–2022 (2017 = 100%)

Cluster Number	Connectivity	Market	GAST	CMG
1	91.78	84.57	104.03	95.29
2	89.52	95.21	94.89	93.66
3	310.49	191.51	128.63	176.13
Average ASEAN	109.57	86.90	101.91	100.15

Source: Authors own analysis

The average CMG increased only in the 3rd cluster. For cluster 1, it almost decreased by 5%; on the other hand, cluster 2 decreased by 6.5%. While cluster 3 increased by 76%, putting Clusters 3 in positions of great momentum between the years 2017 and 2022.

Connectivity

The sub-components of the CMG indicator also present interesting findings. As such, Connectivity in 2022, show an increase of 19.2% compared to 2017, however its average is below the average value of the aforementioned CMG. Further, as presented in Figure 1, the countries with the highest growth rates were Lao P.D.R., Viet Nam, Philippines, Cambodia, Thailand. However, Myanmar experienced negative growth.

In 2017, six countries were below the ASEAN average. These countries included Cambodia, Indonesia, Lao P.D.R., Myanmar, Philippines, and Vietnam. Whereas in 2022 it was three countries such as Cambodia, Lao P.D.R., and Myanmar. The lowest scores on the connectivity indicator in the ASEAN Member States for 2017 appeared in Lao P.D.R. with 0.0361 points, Myanmar with 0.199, and Cambodia with 0.2052. While in 2022, it was Myanmar with 0.1381 points, Cambodia with 0.2596, and Lao P.D.R. with 0.2643. Significantly, for all of those countries which had the worst connectivity rates in 2017, their scores against the ASEAN average improved by 2022 except for Myanmar.

Conversely, in 2017, four countries were above the ASEAN average. These countries included Brunei Darussalam, Malaysia, Singapore, and Thailand. Whereas in 2022 it was 7 countries, such as Brunei Darussalam, Indonesia, Philippines, Vietnam, Malaysia, Singapore, and Thailand. The highest scores on the connectivity indicator in the ASEAN Member States for 2017 appeared in Singapore with 0.9315 points, Brunei Darussalam with 0.7759, and Malaysia with 0.7244. While in 2022, it was Singapore with 0.9696 points, Brunei Darussalam with 0.8122, and Malaysia with 0.7919. Significantly, for all those countries which had the highest connectivity rates in 2017, their scores against the ASEAN average improved by 2022.

Thus, as shown in Table 2, comparing the performance of individual countries against the ASEAN average in 2017, it was found that Lao P.D.R. had the lowest rate of 7.7%, while Singapore had the highest 181% rate. Similarly, in the 2022, it was found that Myanmar had the lowest rate of 26.5%, while Singapore had the highest 189% rate.

The fact that the gap between the lowest and highest rates as compared to the ASEAN average has been gradually decreasing from 89.5 pps in 2017 to 83.2 pps in 2022, gives a positive trend toward more convergence across ASEAN countries. This positive trend is further diluted by the countries observation where the value of the relationship between the highest and the lowest rates dropped from 23.6 in 2017 to a far lower value of 7.1 in 2022.

Table 3 shows the trend in average Connectivity sub-indicator from 2017 to 2022 in each cluster. In 2017 the average of Connectivity ratio for Clusters 1 was above the ASEAN average, while Cluster 2 and 3 were lower than the ASEAN average. Almost all countries in Cluster 1 and only Thailand in Cluster 2, and none of the countries in Cluster 3 had a connectivity ratio above the ASEAN average. In 2022, the average of Connectivity ratio in Clusters 1, Malaysia was above, and Philippines is almost same to the ASEAN average. while in Cluster 2, Indonesia is near the ASEAN average, while Myanmar is below. in Cluster 3, only Cambodia and Lao P.D.R. were below the ASEAN average.

All clusters had a mixed improvement/decline in the average indicator of connectivity during the period between 2017 and 2022, with Cluster 3 recording the highest increase of more than 315%, followed by decline in Cluster 2 with almost 31%, and Cluster 1 with 21% decline.

Market

The sub-components of the CMG indicator such as Market in 2022 show a decrease of 26.3% compared to 2017, however its average is below the average value of the aforementioned CMG. Further, as presented in Figure 1, the countries with the highest growth rates were Myanmar, while all other countries exhibit decline in the Market ratio and growth.

In 2017, four countries were below the ASEAN average. These countries included Brunei Darussalam, Cambodia, Lao P.D.R., and Myanmar. Whereas in 2022 it was seven countries such as Brunei Darussalam, Cambodia, Lao P.D.R., Malaysia, Philippines, Singapore, and Vietnam. The lowest scores on the Market indicator in the ASEAN Member States for 2017 appeared in Lao P.D.R. with 0.0126 points, Myanmar with 0.0426 points, and Brunei Darussalam with 0.194. While in 2022, it was Lao P.D.R. with 0.0104, Brunei Darussalam with 0.1798 points, and Cambodia with 0.1997. Significantly, for all those countries which had the worst Market rates in 2017, only Myanmar scores improved by 2022 against the ASEAN average.

Conversely, in 2017, six countries were above the ASEAN average. These countries included Indonesia, Malaysia, Philippines, Singapore, Thailand, and Viet Nam. Whereas in 2022 it was three countries such as Myanmar, Indonesia, and Thailand. The highest scores on the Market indicator in the ASEAN Member States for 2017 appeared in Indonesia with 0.9477 points, Thailand with 0.712, and Malaysia with 0.5901. While in 2022, it was Indonesia with 0.6285 points, Myanmar with 0.5033, and Thailand with 0.4281. Significantly, for all those countries which had the highest Market rates in 2017, their scores against the ASEAN average declined by 2022.

Thus, as shown in the Table 2, comparing the performance of individual countries against the ASEAN average in 2017, it was found that Lao P.D.R. had the lowest rate of 3.5%, while Indonesia had the highest 260% rate. Similarly, in the 2022, it was found that Lao P.D.R. had the lowest rate of 2.9%, while Myanmar had the highest 138% rate.

The fact that the gap between the lowest and highest rates as compared to the ASEAN average has been gradually decreasing from 93.5 pps in 2017 to 61.8 pps in 2022, gives a positive trend toward more convergence across ASEAN countries. This positive trend is further diluted by the countries observation where the value of the relationship between the highest and the lowest rates dropped from 74 in 2017 to a far lower value of 47 in 2022.

Table 3 shows the trend in average Market sub-indicator from 2017 to 2022 in each cluster. In 2017 the average Market ratio for Clusters 1 and 2 was above the ASEAN average, while Cluster 3 was lower than the ASEAN average. Singapore and Malaysia in Cluster 1, all country in Cluster 2, and none of the countries in Cluster 3 had a Market ratio above the ASEAN average. In 2022 the average Market ratio for only Clusters 2 was above the ASEAN average. Additionally, none of the countries in Cluster 1, Indonesia and Myanmar in Cluster 2, and Thailand in cluster 3, had a Market ratio above the ASEAN average.

All clusters had a mixed improvement/decline in the average indicator of Market during the period between 2017 and 2022, with Cluster 3 recording the highest increase of more than 137%, followed by decline in Cluster 2 with almost 14%, and Cluster 1 with 39% decline.

Governance, Affordability, Sustainability and Trust (GAST)

The sub-components of the CMG indicator, such as GAST indicator in 2022 show an increase of 3.9% compared to 2017, however its average is above the average value of the aforementioned CMG. Further, as presented in Figure 1, the countries with the positive growth rates were Lao P.D.R., Thailand, Malaysia, and Cambodia respectively, while other countries experienced negative growth.

In 2017, four countries were below the ASEAN average. These countries included Cambodia, Lao P.D.R., Myanmar, and Thailand. Whereas in 2022 it was six countries such as Brunei Darussalam, Cambodia, Lao P.D.R., Myanmar, Thailand, and Vietnam. The lowest scores on the GAST indicator in the ASEAN Member States for 2017 appeared in Lao P.D.R. with 0.3189 points, Thailand with 0.4908, and Myanmar with 0.5084. While in 2022, it was Myanmar with 0.4797, Cambodia with 0.5333, and Brunei Darussalam with 0.5751. Significantly, for all those countries which had the worst GAST rates in 2017, their scores against the ASEAN average improved, but not above ASEAN average by 2022.

Conversely, in 2017, six countries were above the ASEAN average. These countries included Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, and Vietnam. Whereas in 2022 it was 3 countries such as Philippines, Singapore, and Indonesia. The highest scores on the GAST indicator in the ASEAN Member States for 2017 appeared in Singapore with 0.8793 points, Brunei Darussalam with 0.7759, and Malaysia with 0.7244. While in 2022, it was Singapore with 0.9696 points, Malaysia with 0.8669, and Philippines with 0.8393. Significantly, for all those countries which had the highest GAST rates in 2017, their scores against the ASEAN average declined by 2022, except for Malaysia.

Thus, as shown in the Table 2, comparing the performance of individual countries against the ASEAN average in 2017, it was found that Lao P.D.R. had the lowest rate of 47.47%, while Singapore had the highest 130% rate. Similarly, in the 2022, it was found that Myanmar had the lowest rate of 71%, while Malaysia had the highest 148.8% rate.

The fact that the gap between the lowest and highest rates as compared to the ASEAN average has been gradually decreasing from 56 pps in 2017 to 52 pps in 2022, gives a positive trend toward more convergence across ASEAN countries. This positive trend is further diluted by the countries observation where the value of the relationship between the highest and the lowest rates dropped from 2.8 in 2017 to a far lower value of 2.1 in 2022.

Table 3 shows the trend in average GAST sub-indicator from 2017 to 2022 in each cluster. In 2017 the average GAST ratio for Clusters 1 and 2 were above the ASEAN average, while Cluster 3 was lower than the ASEAN average. Almost all countries in Cluster 1 and except Thailand in Cluster 2, and none of the countries in Cluster 3, had a GAST ratio above the ASEAN average. In 2022 the average GAST ratio for only Clusters 1 was above the ASEAN average. Additionally, Indonesia and Philippine in Cluster 1, Indonesia in Cluster 2, and Singapore in cluster 3, had a GAST ratio above the ASEAN average.

All clusters had a mixed improvement/decline in the average indicator of GEST during the period between 2017 and 2022, with Cluster 3 recording the highest increase of more than 43%, followed by Cluster 1 with almost 10% increase, and Cluster 2 with 15% decline.

5. Conclusions

As part of this publication, scientific research was conducted to fill the identified research gap and resolve the research problem. Undoubtedly contributes to the field by addressing a notable gap to the development of research on the level of digitalization of economies in ASEAN countries, thus constituting policy-relevant insights in the field of economic and management sciences.

The research procedure began with a literature review on the subject of digital transformation in ASEAN countries, followed by the presentation of the research methodology and the results of empirical research.

Based on the literature review, the key actions that require both bottom-down and top-down initiatives were identified. A thematic review of recent literature further consolidates understanding in five dominant areas:

(1) **Theoretical frameworks of digital transformation:** The literature illustrates a strong conceptual foundation built around the evolution from digitization to digitalization and finally to digital transformation. This sequence reflects increasing degrees of

technological integration, from basic data conversion to strategic shifts in organizational structures and business models. Scholars such as Kraus et al. (2022) and Verhoef et al. (2021) underscore the importance of understanding digital transformation as an enterprise-wide reorientation driven by technology.

(2) **ICT infrastructure in ASEAN:** Multiple studies recognize digital infrastructure as a foundational driver for digital economy readiness in ASEAN countries. Broadband penetration, internet speed, and connectivity quality are frequently cited as critical determinants of digital competitiveness. Research has emphasized the enabling role of infrastructure in facilitating e-commerce, financial inclusion, and innovation ecosystems across the region.

(3) **Digital divide and disparities:** The digital divide is consistently portrayed as a multi-layered challenge, spanning access to digital technologies, their use, and the capacity to derive meaningful benefits. This divide is observed not only between ASEAN countries but also within them – across urban and rural divides and socio-economic groups. Recent studies, including those by Wati et al. (2024), delve into sub-national disparities in digital literacy and ICT access.

(4) **Measurement methodologies:** There is a growing body of work that explores innovative ways to quantify digital progress. Recent literature emphasizes the value of composite indicators, taxonomic approaches, and clustering algorithms for comparing national digital transformation trajectories. These methods offer more granular and structured ways of interpreting multidimensional digital development, addressing some of the limitations of traditional indices.

(5) **Governance and policy frameworks:** Studies increasingly stress the pivotal role of regulatory and institutional structures in shaping the digital future of ASEAN countries. Research discusses the fragmented nature of digital governance in the region and calls

for harmonized digital regulations, investment in digital public goods, and coordinated capacity-building initiatives. The role of supranational frameworks like the ASEAN Digital Integration Framework is highlighted as essential for regional coherence.

The findings of this study carry several implications.

From a **theoretical perspective**, this research advances the conceptual understanding of digital transformation by developing a novel measurement framework – the CMG indicator and its subcomponents (Connectivity, Market, and GAST) – grounded in ITU data. This composite index provides a replicable model for assessing digital maturity in regional contexts, offering both academic and methodological contributions.

In terms of **policy relevance**, the study's clustering analysis reveals asymmetric digital readiness across ASEAN, suggesting a need for differentiated policy responses. For nations with below-average CMG scores, targeted investments in infrastructure, digital literacy, and governance reforms are essential. These insights support regional integration efforts under initiatives such as the ASEAN Digital Integration Framework.

On the **practical front**, the methodology offers policymakers and development agencies a benchmarking tool for tracking national progress in digital transformation. The use of both quantitative and qualitative methods enhances research reliability and demonstrates the value of triangulated approaches in comparative digital economy analysis.

Ultimately, the study supports the formulation of nuanced, evidence-based digital strategies that reflect the socio-economic and technological realities of individual ASEAN countries while promoting regional cohesion in the digital era.

The achievement of this article is not only the identification of a research gap, but above all, this research gap has been filled and the research problem presented in the form of a question "*Are the digitalization levels of Southeast Asian countries similar or are there specific*

differences between them and, if so, are they significant?" has been solved, also by verifying the hypotheses.

The research made it possible to verify the research hypotheses.

Hypothesis 1 was positively verified, where the research shows significant differences in the Southeast Asian region (ASEAN) not only in terms of the level of socio-economic development but also in the level of digitalization of individual countries in this region, which allowed for the separation of individual groups in the form of so-called clusters. In 2017, three clusters were identified among ASEAN countries and the grouping showed that each cluster included countries with a very similar level of socio-economic development and competitiveness. However, the grouping carried out in 2022 indicates the separation of 3 clusters within which greater differentiation can be indicated, which indicates changes in ICT indicators for the ASEAN region.

Based on the research conducted, hypothesis 2 was also positively verified and it can be indicated that among ASEAN countries there are groups of countries with high, medium and low levels of digitalization compared to the entire region. This was shown by the analysis of the values achieved by the CMG indicator in the analyzed years 2017 and 2022, three of the ASEAN countries achieved a result below the average, while seven countries in ASEAN achieved a result above the average. Below average countries in both 2017 and 2022 were Cambodia, Lao P.D.R. and Myanmar. Countries with above-average CMG values in both years included Brunei Darussalam, Indonesia, Malaysia, Philippines, Thailand, Viet Nam, and Singapore. Analysis of the CMG indicator at the national level highlighted several changes between the two years covered by the study. These changes are positive and indicate an increase in the development of CMG.

Hypothesis 3, however, was partially positively verified, because research in relation to Vietnam showed that when comparing GDP per capita in ASEAN in 2017-2022, it can be

indicated that Vietnam was among the countries with the lowest GDP per capita value. However, the results of the cluster analysis indicate that Vietnam belongs to cluster 2, together with countries such as Indonesia, Philippines, Thailand, with moderate similarity and at different levels of ICT development. In 2022, Vietnam is also in Cluster 3, which is the most diverse. Vietnam was also among countries with above-average CMG values in both years included, Brunei Darussalam, Indonesia, Malaysia, Philippines, Thailand, and Singapore. So Vietnam, despite having one of the lowest GDP per capita, is not one of the countries with the lowest level of economy digitalization.

Results of the research and analysis of the dynamics of Average CMGs' Individual Sub-rates in 2017–2022 show that the average CMG increased only in the 3rd cluster by 76%, putting Clusters 3 in positions of great momentum between the years 2017 and 2022. The sub-components of the CMG indicator also present interesting findings. As such, Connectivity and GAST in 2022, show an increases compared to 2017. The sub-components of the CMG indicator, as such Market in 2022 show a decrease compared to 2017, however its average is below the average value of the aforementioned CMG. The country level analysis of the CMG indicator has outlined several changes between the two surveyed years. These changes are positive and show an increase in the CMG development.

This research on the level of digitalization of ASEAN countries is clearly pioneering taking into account the methodological approach for data and indicators from the ITU's Database. They fill the identified research gap, which is confirmed by the literature review in this thematic area carried out in the first step. The novelty of the research is visible primarily in the analysis and assessment carried out, along with drawing conclusions and presenting them, based on data and indicators from the ITU database, selected through expert selection along with the development of a synthetic main indicator and partial synthetic indicators developed by the article's authors.

Declarations

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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