The Interaction Model of Digitalization and Financial Inclusion: A Bayesian Analysis of Its Role in Economic Growth

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Abstract. This study aims to analyze the impact of digitalization and financial inclusion on economic growth in the ASEAN-6 countries, with a particular highlight on the interaction between these two factors. This research topic is compelling, as most previous studies have examined the individual effect of either digitalization or financial inclusion on economic growth, lacking empirical evidence on their interactive impact. The author utilizes a Bayesian approach to estimate the research model, providing a clearer understanding of the extent and probability of each variable's effect. The findings reveal that economic growth in the ASEAN-6 countries is positively influenced not only by digitalization and financial inclusion individually but also by their significant interaction. Additionally, economic growth is notably affected by population growth and inflation. These findings offer a reliable foundation for the ASEAN-6 countries to identify appropriate policies that foster digitalization coupled with financial inclusion, thereby promoting economic growth.

1. INTRODUCTION

Digitalization is an emerging global trend and serves as a critical foundation that positively supports corporate operations and brings numerous benefits to consumers. In fact, it is considered the base for the development of information and communications technologies (ICT) [1]. Promoting digitalization is viewed as an indispensable driver in promoting each country's economy [2]. Indeed, digitalization can stimulate economic growth by fostering product creation

and innovation [1], facilitating and advancing business operations [3], [4], increasing productivity [5], [6], and promoting savings and investment [7]. Therefore, its role in economic growth has been highlighted in a majority of the existing studies, including those conducted in both developed and developing countries [8].

With these features, it is crucial in fostering economic growth, reducing income inequality, and alleviating poverty [9]–[11]. Indeed, financial inclusion can positively affect economic growth in the following ways: (i) Enhancing access to and use of financial services at affordable costs [12], [13]; (ii) Increasing transaction volume and improving the efficiency of financial resource allocation within the economy [11]–[13]; (iii) Improving the risk management efficiency of the financial system [13]–[15]; and (iv) Reducing information asymmetry [9], [13]. Hence, its impact on economic growth is an intriguing topic frequently explored in empirical studies, especially since Keynes [16] asserted that the financial sector plays an essential role in increasing income and reducing poverty.

In fact, economic growth is impacted not only by digitalization and financial inclusion individually, but also by their interaction. In other words, digitalization and financial inclusion can support each other in enhancing economic growth. This issue is evident in real-world scenarios and has even been suggested in the studies of Andrianaivo and Kpodar [17], Onaolapo [18], Maiti and Kayal [19], Myovella et al. [1], and Iddrisu and Chen [6]. However, there is a lack of empirical studies examining the interaction between digitalization and financial inclusion when analyzing their influence on economic growth. This gap has created certain challenges for countries in identifying suitable policies related to digitalization and financial inclusion to promote long-term economic growth. In other words, by addressing this gap, they would have a solid foundation for improving digitalization alongside financial inclusion, ultimately driving sustainable economic growth. With this aim, the study analyzes the impact of digitalization and financial inclusion on economic growth in the ASEAN-6 countries. Furthermore, it also examines these effects in their interaction, which distinguishes it from previous research. This study uses a dataset from the six leading countries in the ASEAN region (known as the ASEAN-6) to ensure consistency among the countries in the sample, thereby providing meaningful empirical evidence.

The paper proceeds by reviewing the relevant literature and formulating hypotheses. Subsequently, the methodology and data are detailed. The following section presents the

empirical analysis and findings. The paper concludes with a discussion of the results and provides implications.

2. LITERATURE REVIEW

2.1. The impact of digitalization on economic growth

In the neoclassical growth model, long-term economic growth is primarily explained by the accumulation of capital, labor, and technological progress, which are all considered exogenous factors [20]. Digitalization is seen as the foundation for the emergence of ICT, particularly the internet and mobile technologies, which create new products and processes, along with technological advancement [1]. Therefore, it is an essential foundation and driver in the process of achieving prosperity among countries [2].

In fact, digitalization can facilitate business operations [3], and even stimulate the expansion of business activities abroad [4], thereby promoting economic growth [21]. Moreover, digitalization, particularly through ICT, provides numerous benefits to individuals, especially by helping them easily access financial services, increase savings, and boost investment [7]. Thus, its importance in economic growth has been examined in a substantial body of the existing literature. Dewan and Kraemer [22], for instance, stated that investment in technology brings several economic benefits that are more noticeable in developed countries than in developing ones, especially in African nations. Meanwhile, Thompson and Garbacz [23] demonstrated that the rapid development of technology infrastructure plays a crucial role for all countries, particularly for low-income economies. More precisely, Arendt [8] argued that low-income countries can catch up with high-income ones by encouraging digitalization, particularly by boosting ICT use. It can be observed that, in developing countries, digitalization is considered a major driver of economic growth by improving the efficiency of capital and labor, lowering transaction costs, and facilitating access to global markets [24]. In another study, Habibi and Zabardast [5] asserted that ICT significantly contributes to the development of OECD countries and the Middle East by improving productivity. The studies by Habibi and Zabardast [5] and Iddrisu and Chen [6] also confirmed that digitalization facilitates economic growth by increasing productivity and innovation across different sectors. Furthermore, by increasing demand for digital products, technological investments in high-tech industries can promote innovation and economic growth [25].

Nevertheless, the impact of digitalization on economic growth may depend on the level of each country's development [26]. It should be acknowledged that the effect of digitalization on economic growth could be inconsistent, varying across economic sector structures and levels of technological progress. However, the prevailing trend in empirical studies confirms its positive impact on economic growth. Despite this, digitalization also poses certain challenges for the economy, particularly the disparity in access to advanced technologies between developed and developing countries, which could result in different levels of economic growth across regions [27]. Brodny and Tutak [28] stated that the initial phase of digital technological innovation can lead to short-term economic disruptions. Specifically, economic performance may be hindered in the short term as companies and the economy require time to adjust to the new digital infrastructure. These findings also emphasize the necessity of effectively managing digitalization to enhance economic performance. Some empirical studies also highlight the inconsistency in its impact on economic growth, as the extent of this impact can significantly depend on country-specific factors. Sabbagh et al. [29] and Vyshnevskyi et al. [27], for instance, suggested that the degree of technological innovation and the composition of economic sectors may influence the contribution of digitalization to economic growth. In addition, Myovella et al. [1] and Boikova et al. [30] demonstrated that digitalization positively contributes to economic growth in Sub-Saharan Africa and OECD countries; however, the scale and nature of these effects might differ greatly between regions.

Although there are contradictory views on the impact of digitalization on economic growth, the positive effects remain predominant. Based on this foundation, the first research hypothesis is proposed as follows:

Hypothesis H₁: Digitalization has a positive impact on economic growth in the ASEAN-6 countries.

2.2. The impact of financial inclusion on economic growth

From a theoretical perspective, endogenous growth theory emphasizes that the accessibility of the financial sector, particularly the expansion of banking services, can stimulate the allocation of financial resources within an economy. This, in turn, increases the investment efficiency of available capital, especially by encouraging economic innovation [31]. In agreement with this view, Schumpeter [32], Gurley and Shaw [33], McKinnon [34], and Shaw [35] also affirmed that improvements in banking services exert a positive benefit on economic growth, as evidenced by

increased efficiency in mobilizing savings, enhancing resource allocation, and stimulating technological innovation.

The impact of financial inclusion on economic growth has been widely discussed since Keynes [16] reported that the financial sector can result in income increase and poverty reduction. In fact, financial inclusion makes financial services accessible to individuals, thereby meeting their basic needs. In other words, its goal is to provide official financial services to all sectors of the economy, which is particularly significant for vulnerable groups who have difficulty accessing these services. This enables them to easily access the services at reasonable costs, thus boosting economic growth [36].

The role of financial inclusion in economic growth can be demonstrated through four main channels as follows: (i) It encourages affordable access to and utilization of financial services, which is crucial for low-income individuals and those who face barriers to financial service accessibility [12], [13]; (ii) It contributes to increasing transaction volumes, especially by improving the economy's ability to allocate financial resources efficiently [11]–[13]; (iii) It helps improve the risk management efficiency of the financial system, as evidenced by reducing high-risk investments and diversifying portfolio [13]–[15]; (iv) It provides information on investment potential and capital availability, thereby minimizing information asymmetry [9], [13].

The positive impact of financial inclusion on economic growth has also been proved in numerous empirical studies. For example, Sarma and Pais [37] discovered that financial inclusion reduces the dominance of informal financial institutions and makes it easier to access formal financial services, which improves the efficiency of financial resource allocation and reduces capital costs. Dabla-Norris et al. [38] and Onaolapo [18] highlighted that financial inclusion promotes comprehensive economic growth by fostering savings mobilization and increasing investment in the manufacturing sector. Kim et al. [39] revealed a positive impact of financial inclusion on developments in Organization of Islamic Cooperation (OIC) countries. Cheng et al. [40] suggested that an efficient and accessible financial sector can help minimize risks, enhance corporate governance, and thereby stimulate economic growth. Abdul Karim et al. [41] confirmed that an accessible financial system positively influences economic growth in the Asia region, with this effect being more pronounced in developing countries than in advanced economies. Abdelghaffar et al. [42] contended that financial inclusion contributes to longer and healthier lives, improves the quality of education, and enhances living standards. However, this impact is

stronger in low-income countries compared to high-income countries. More recently, Hussain et al. [31] reported a positive impact of financial inclusion on economic growth in 21 Asian countries, with the effect being more evident in developing countries than in developed ones.

It can be observed that most empirical studies have revealed a positive impact of financial inclusion on economic growth. Following this, the author proposes the next hypothesis as follows:

Hypothesis H_2: Financial inclusion has a positive impact on economic growth in the ASEAN-6 countries.

2.3. The impact of the interaction between digitalization and financial inclusion on economic growth

Nowadays, financial institutions are striving to identify innovative solutions to improve their service quality, which in turn helps a greater percentage of the population to access formal financial services. Among these solutions is the effort to promote digitalization, which contributes to the formation and development of electronic banking services, ultimately promoting financial inclusion. Moreover, digitalization helps reduce information disparity, enabling customers to easily access suitable financial services at reasonable prices [9], [13]. It also makes financial institutions accessible to customers, thereby enhancing their ability to mobilize and allocate capital effectively. This suggests that digitalization can promote financial inclusion, thereby improving the efficiency of capital allocation and stimulating investment, which is a crucial foundation for driving economic growth. Obviously, promoting digitalization can reduce transaction costs for both customers and financial institutions, thereby improving the service quality of financial institutions and convenience for customers. Furthermore, digitalization facilitates the emergence of electronic banking, or branchless banking, by increasing the flexibility of financial services [36].

In their empirical study, Andrianaivo and Kpodar [17] affirmed that digitalization, specifically ICT, exerts a positive impact on growth in African countries. More specifically, the role of mobile phones is more pronounced in countries with higher levels of financial inclusion. Furthermore, the study concluded that financial inclusion is accelerated by a higher rate of mobile phone usage. Onaolapo [18] concluded that financial inclusion requires financial institutions to provide services outside of their branches, which proves to be more effective when ICT is improved. Maiti and Kayal [19] argued that digitalization can improve financial performance and

accessibility, thereby enhancing economic efficiency in India. In Africa, Myovella et al. [1] confirmed that promoting technological advancements can address issues arising from poor institutional quality and the high costs associated with using banking services in most developing countries. Similarly, in this region, Iddrisu and Chen [6] emphasized that digitalization strengthens the financial sector and stimulates economic growth in Africa.

It can be seen that economic growth is not only influenced by digitalization and financial inclusion individually but also by the interaction between these two factors. In other words, digitalization and financial inclusion can mutually support each other in striving for the economy. This issue is evident in practice, yet there is a lack of empirical studies examining the role of this interaction on economic growth, which represents a significant gap that needs to be explored. To fill this gap, the author tests the final research hypothesis as follows:

Hypothesis H₃: The interaction between digitalization and financial inclusion has a positive impact on economic growth in the ASEAN-6 countries.

3. METHODOLOGY

The current literature indicates that economic growth is significantly affected by digitalization [5], [6], [8], [22]–[25] and financial inclusion [18], [31], [38]–[41]. Moreover, economic growth may also be influenced by the interaction between digitalization and financial inclusion, which was highlighted in the studies by Andrianaivo and Kpodar [17], Onaolapo[18], Maiti and Kayal [19], Myovella et al. [1], and Iddrisu and Chen [6]. Based on this foundation, the author develops the research model with the following equation:

$$Y_{it} = \beta_0 + \beta_1\, Dig_{it} + \beta_2\, Fi_{it} + \beta_3\, Dig_{it} \times Fi_{it} + \beta_4\, Pg_{it} + \beta_5\, Inf_{it} + \varepsilon_{it} \qquad (1)$$

In particular, economic growth (Y) is measured by the logarithm of GDP per capita, following what has been done by most of the previous researchers, such as Pradhan et al. [43], Asongu and Odhiambo [7], Myovella et al. [1], Chatterjee [36], and Hussain et al. [31].

Digitalization (Dig) is determined using the principal component analysis (PCA) method, based on three component indicators: (Dig1) Fixed telephone subscriptions (% of population); (Dig2) Mobile cellular subscriptions (% of population); (Dig3) Individuals using the internet (% of population). This measurement is used in most prior studies, including those by Pradhan et al. [43], Myovella et al. [1], and Chatterjee [36]. The results of determining digitalization (Dig) through the PCA method are described in Table 1.

Table 1. Measuring digitalization (Dig)

Variable	Weighting
Dig_1	23.57%
Dig_2	32.16%
Dig_3	44.27%
Dig	**100%**

Financial inclusion (Fi) is a composite index, identified using the PCA method, based on four component indicators: (Fi_1) Automated teller machines (ATMs) (per 100,000 adults); (Fi_2) Borrowers from commercial banks (per 100,000 adults); (Fi_3) Commercial bank branches (per 100,000 adults); (Fi_4) Depositors with commercial banks (per 100,000 adults). The measurement is based on the studies of Chatterjee [36], Abdelghaffar et al. [42], and Hussain et al. [31]. The results of determining financial inclusion (Fi) are detailed in Table 2.

Table 2. Measuring financial inclusion (Fi)

| Variable	Comp1 (Weighting: 68.86%)	Comp2 (Weighting: 31.14%)
Fi_1	26.76%	10.39%
Fi_2	31.38%	10.26%
Fi_3	9.82%	62.21%
Fi_4	32.05%	17.14%
Fi	**100%**	

Additionally, the author includes some control variables which consist of population growth (Pg) and inflation (Inf). These control variables are selected based on previous studies by Asongu and Odhiambo [7], Myovella et al. [1], Chatterjee [36], and Hussain et al. [31].

For the estimation method, the author employs the Bayesian approach to estimate the research model. This is a relatively new approach that can clarify the extent of the impact of various variables on economic growth, particularly by highlighting the probability of these effects occurring [44], [45].

The sample used in this study includes the ASEAN-6 countries (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) over the period 2004 - 2021. Data for the variables are collected from the World Development Indicator (WDI) database of the World Bank.

4. EMPIRICAL RESULTS AND FINDINGS
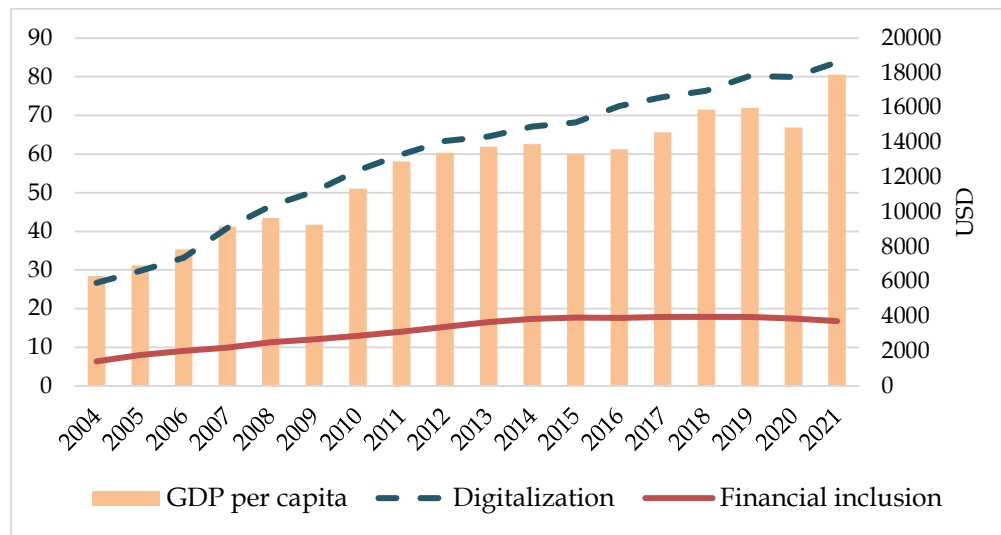
Figure 1. Digitalization, financial inclusion and GDP per capita in the ASEAN-6 countries

The data sample is collected from the ASEAN-6 countries over the period 2004-2021. Figure 1 shows a significant increase in digitalization and GDP per capita in the ASEAN-6 countries during the period, whereas the growth in financial inclusion remains relatively modest.
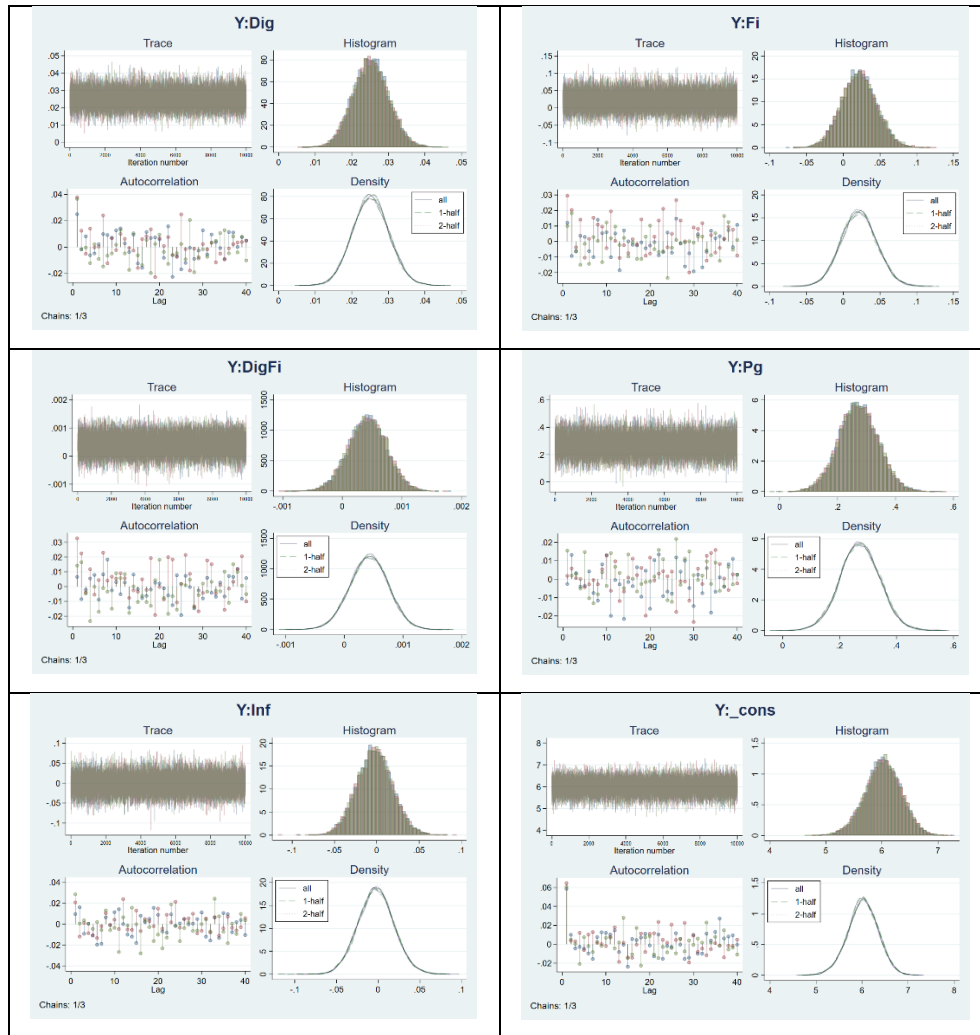
Figure 2. Convergence Diagnostics

Figures 2 and 3 demonstrate that the variables meet the convergence conditions and are usable. Specifically, the Trace Plot exhibits stable convergence; the Autocorrelation Plot suggests negligible autocorrelation, primarily concentrated below the 0.02 level; and both the Histogram and Density plots approximate a standard distribution.
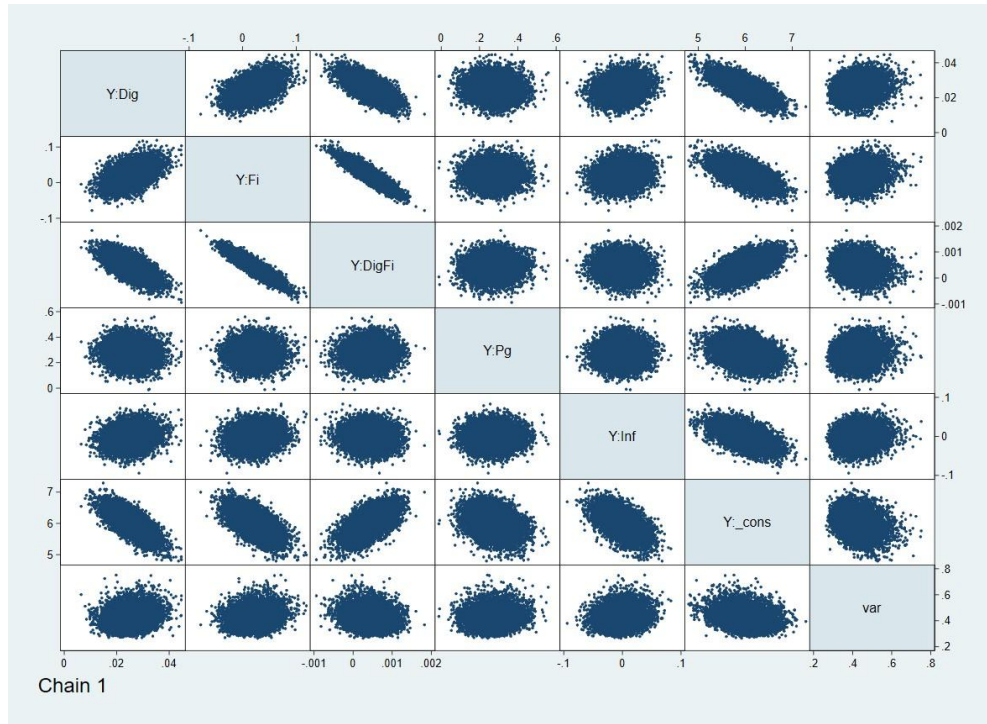
Figure 3. Bayesgraph matrix

The author then employs the Bayesian method to analyze the research model. With this approach, the estimation results are presented in terms of the magnitude of the impact and the probability of its occurrence. The estimation results are presented in Table 3.

Table 3. Estimation results using the Bayesian method

Y	Mean	Std. Dev.	MCSE	Median	Equal-tailed [95% Cred. Interval]	
Dig	0.0252	0.0050	0.3×10^{-4}	0.0252	0.0157	0.0351
Fi	0.0215	0.0243	1.4×10^{-4}	0.0214	-0.0252	0.0695
Dig×Fi	0.0004	0.0003	1.9×10^{-6}	0.0004	-0.0002	0.0011
Pg	0.2718	0.0692	4.0×10^{-4}	0.2711	0.1353	0.4086
Inf	-0.0024	0.0215	1.3×10^{-4}	-0.0025	-0.0441	0.0405
_cons	6.0180	0.3281	2.0×10^{-3}	6.0221	5.3473	6.6454
Avg acceptance rate	1					
Avg efficiency: min	0.8148					
Max Gelman-Rubin Rc	1					

Table 3 indicates that the estimation results using the Bayesian method are reliable and suitable for analysis. Specifically, the average acceptance rate, minimum effective sample size, and maximum Gelman-Rubin Rc are all satisfactory. In addition, the Monte Carlo Standard Error (MCSE) for all parameters is very low (less than 1%), demonstrating that all the explanatory variables exert a significant effect on economic growth in the ASEAN-6 countries.

Table 4. Results of Interval

Interval tests	Mean	Std. Dev.	MCSE
prob: {Y:Dig} > 0	1	0	0
prob: {Y:Fi} > 0	0.8121	0.3906	0.0023
prob: {Y:Dig×Fi} > 0	0.9003	0.2996	0.0018
prob: {Y:Pg} > 0	0.9999	0.0100	0.0001
prob: {Y:Inf} < 0	0.5474	0.4978	0.0029

Regarding digitalization (Dig), the estimation results indicate that this variable is positively correlated to economic growth in the ASEAN-6 countries (Table 3), with a very high probability of occurrence (Table 4). These results are consistent with what has been reported in most previous studies, such as Dewan and Kraemer [22], Thompson and Garbacz [23], Arendt [8], Dahlman et al. [24], Habibi and Zabardast [5], Aleksandrova et al. [25], and Iddrisu and Chen [6]. Furthermore, these findings support the appropriateness of the neoclassical growth theory regarding the role of technology in economic growth. Thus, digitalization can promote economic growth in the ASEAN-6 countries, which can be manifested through creating products and innovation, facilitating and advancing business production processes, increasing productivity, and promoting savings and investment.

For financial inclusion (Fi), this variable positively influences economic growth in the ASEAN-6 countries (Table 3), with an 81.21 percent probability of this effect (Table 4). This supports endogenous growth theory and aligns with previous findings by Sarma and Pais [37], Dabla-Norris et al. [38], Onaolapo [18], Kim et al. [39], Cheng et al. [40], Abdul Karim et al. [41], Abdelghaffar et al. [42], and Hussain et al. [31]. Therefore, financial inclusion contributes greatly to fostering economic growth in these countries. This effect is reflected through the promotion of access to and use of affordable financial services, an increase in transaction volume, enhanced

efficiency in allocating financial resources within the economy, improved risk management effectiveness within the financial system, and, notably, a reduction in information asymmetry.

Regarding the interaction between digitalization and financial inclusion, the results indicate that the interaction variable Dig×Fi positively affects economic growth in the ASEAN-6 countries. The study also finds a 90.03 percent probability of this effect, representing this finding's novelty. Consequently, digitalization and financial inclusion can support each other in promoting economic growth in these countries. For example, digitalization enhances financial inclusion by creating a technological foundation that enables financial institutions to improve their capacity in providing financial services, while also making these services accessible to customers. Conversely, financial inclusion serves as a driver for digitalization and further contributes to enhancing the availability of financial resources for developing digitalization. Therefore, to foster economic growth, the ASEAN-6 countries need to implement coordinated measures related to both digitalization and financial inclusion. While previous studies [1], [6], [17]–[19] have explored the impact of the interaction between digitalization and financial inclusion on economic growth, this study significantly contributes by clarifying the impact of their interaction and estimating its probability.

Regarding the control variables, economic growth is positively influenced by population growth (Pg) but negatively affected by inflation (Inf). Specifically, the probability of population growth affecting economic growth is 99.99 percent, whereas the impact of inflation on economic growth is relatively low (54.74 percent). Therefore, in addition to promoting digitalization and financial inclusion, the ASEAN-6 countries should pay greater attention to domestic characteristics to facilitate economic growth.

5. CONCLUSION AND POLICY IMPLICATIONS

In this study, the author focuses on examining the role of digitalization and financial inclusion in economic growth in the ASEAN-6 countries. Furthermore, the author considers the impact of the interaction between digitalization and financial inclusion on economic growth in these countries, which represents a distinctive aspect of this study compared to previous research. A Bayesian analysis provides compelling evidence highlighting that digitalization and financial inclusion play an essential role in enhancing economic growth, with a very high probability of these effects occurring. Additionally, economic growth is positively impacted by the interaction

between digitalization and financial inclusion, with a 90.03 percent probability of this effect. Therefore, economic growth is influenced not only by digitalization and financial inclusion individually but also by the interaction between these two variables, marking a novel finding of this study compared to previous research. Furthermore, economic growth in the ASEAN-6 countries is also considerably affected by the control variables in the model, including population growth and inflation.

The findings demonstrate that economic growth in the ASEAN-6 countries is positively affected by digitalization, financial inclusion, and their interaction. Hence, these countries must prioritize policies that promote both digitalization and financial inclusion to foster sustainable economic growth. In terms of digitalization, these countries should focus on developing technology infrastructure across all sectors, with an emphasis on technological innovation and cybersecurity within the financial sector. For financial inclusion, these countries need to encourage digital banking services, focusing on increasing access to formal financial services at affordable costs, especially for low-income individuals or those in remote areas. Besides, they should prioritize macroeconomic stability and invest in human capital development to keep pace with global technological advancements.

This study has made a substantial contribution to the literature by elucidating the impact of digitalization and financial inclusion on economic growth in the ASEAN-6 countries, particularly by examining the interaction between these factors. However, there still exist certain limitations in this study. For instance, digitalization is a relatively broad concept with various measurement approaches, but this study focuses on defining digitalization only through ICT, which is a commonly used method in empirical research. On the other hand, while each ASEAN-6 country may exhibit unique characteristics, due to data limitations, this study could not analyze the research model for each individual country. Furthermore, the study identifies the control variables which have been commonly used in previous studies. However, other factors may influence economic growth that have not been considered in this study. Therefore, future research could explore interesting avenues by addressing these gaps.

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