



The Financial Inclusion-SDGs Nexus: Evidence from ASEAN

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ABSTRACT

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This study investigates the role of financial inclusion (FI) in promoting sustainable development (SD) across eight ASEAN countries during 2004-2023. It examines the influence of FI on both the overall SDG Index and six specific goals: health (SDG3), education (SDG4), gender equality (SDG5), decent work and growth (SDG8), reduced inequalities (SDG10), and climate action (SDG13). A Bayesian regression framework is employed to address small-sample challenges and provide more reliable inference. The findings reveal that FI consistently enhances sustainable development, with particularly strong effects on health, education, gender equality, entrepreneurship, and climate resilience. Its impact on reducing inequality, however, remains modest, highlighting the need for complementary redistributive and social protection measures. Policy recommendations include expanding financial infrastructure and digital services, strengthening financial literacy programs, integrating FI with education, health, and gender initiatives, and linking inclusive finance with green finance to support climate adaptation. These measures can help ensure that FI not only broadens economic participation but also accelerates ASEAN's progress toward a more inclusive and sustainable future.

1. INTRODUCTION

In recent decades, economic expansion has often been accompanied by persistent inequalities [1, 2], fragile health systems [2], gaps in education [3], gender disparities [4], and the intensification of climate-related threats [5]. These challenges underscore the difficulty of maintaining growth without undermining social cohesion and environmental sustainability. While the global economy has benefited from technological progress and international integration, it has also produced vulnerabilities that directly hinder the achievement of the Sustainable Development Goals (SDGs). In particular, goals related to well-being (SDG 3), quality education (SDG 4), gender equality (SDG 5), decent work and growth (SDG 8), reduced inequalities (SDG 10), and climate action (SDG 13) remain far from being realized across many regions.

In response to these gaps, a growing body of research has sought to identify pathways through which economic development can be reconciled with sustainability imperatives. Much of this work emphasizes the central role of financial and technological innovations. For example, Liu et al. [6] highlight the synergy between green finance and the green economy in advancing sustainability objectives; Desalegn and Tangl [7] stress the importance of financial mechanisms in supporting green growth; Fu and Irfan [8] demonstrate the contribution of green financing to environmental protection; and Sasmaz et al. [9] examine the positive linkage between renewable energy and human development. Taken together, these studies indicate that green

finance, renewable energy, technological innovation, and pollution control are key levers for aligning growth with sustainability.

Nonetheless, translating these strategies into practice requires significant financial resources and robust institutional capacity. Illustrative examples can be found in advanced economies: Germany invested approximately 50 billion USD in solar and wind energy to reach a renewable energy share of 65% by 2021, while the Netherlands allocated 10 billion USD to the development of eco-friendly public transport and cycling infrastructure to reduce emissions. At the same time, foreign direct investment (FDI) has been recognized as another important driver of transformation. Yet, "green FDI" represents only a small fraction of total global capital flows [10], and its effectiveness is often contingent upon stable political environments and mature green infrastructure, as evidenced in China and the United States [11].

With more than 8.5% of the world's population and ranking as the third-largest demographic hub in Asia, the ASEAN region represents both immense potential and pressing challenges. Despite rapid economic growth, nearly half of its citizens remain unbanked, and around 18% have access only to the most basic financial services. This exclusion not only limits opportunities for households and small enterprises but also constrains progress toward broader development goals. Introducing and expanding financial inclusion (FI) is therefore critical for enabling equitable participation in the economy, reducing social disparities, and unlocking the region's demographic and economic potential. More importantly,

greater FI serves as a direct pathway to advancing several SDGs-by improving access to health services (SDG 3), supporting investments in education (SDG 4), empowering women economically (SDG 5), fostering decent work and productivity (SDG 8), narrowing income gaps (SDG 10), and enhancing community resilience to climate change (SDG 13).

This study contributes to the existing literature on FI and SD in several important ways. First, it extends the analysis to ASEAN, a region that combines rapid economic growth with structural disparities and large unbanked populations, thereby enriching the comparative understanding of FI in emerging economies. Second, rather than relying solely on a composite sustainability index, the study investigates both the overall SDG Index and six specific goals-health, education, gender equality, decent work, inequality reduction, and climate action-thus offering a more nuanced view of the differentiated pathways through which FI fosters sustainability. Third, by employing a Bayesian regression framework, the research addresses methodological challenges such as small sample sizes and parameter uncertainty, while providing posterior probabilities that enhance the robustness of the findings compared with traditional econometric methods. Finally, the study advances the policy-oriented literature by demonstrating that while FI strongly supports health, education, gender equality, and climate resilience, its modest impact on inequality reduction highlights the need for complementary redistributive and social protection measures, as well as stronger linkages between inclusive and green finance.

The article is structured into five sections. Section 2 comprises the literature review. Sections 3 elucidate the data and methodology. Section 4 unveils empirical findings and initiates discussion. Finally, Section 5 delivers the conclusion and outlines policy implications.

2. LITERATURE REVIEW

2.1 Theories of FI and SD

Considering the Cobb-Douglas function:

$$Y = A \cdot L^a K^b$$

In this context, Y is GDP, K is capital stock, L is labor and A denotes Total Factor Productivity (TFP). Importantly, the specified production function does not directly incorporate the contribution of environmental resources to economic growth; instead, this influence is embedded within the TFP term (A) [12].

In practical economic analyses utilizing the outcomes of this production function, the significance of environmental resources is frequently overlooked. Therefore, contemporary economic theories have made efforts to integrate environmental factors (E) into the production function, leading to the formulation $Y = f(K, L, T, E)$. However, calculating this production function becomes complex due to the necessity of measuring E as a variable beforehand. While the quantitative tools of modern economics readily assess factors such as L , T , and K , the same cannot be said for E . The intricacy arises from the challenge of quantifying and incorporating these resources into the model effectively.

Environmental economics began to emerge and evolve in the mid-1970s. However, it continues to encounter hurdles in developing effective quantitative methodologies for

evaluating environmental resources. Existing economic theories face difficulties in addressing inquiries regarding the interplay between short-term resource extraction and long-term sustainability [12]. Consequently, environmental resources are gradually incorporated into the production function Y , rather than being treated as a variable factor. Additionally, the consideration of social issues becomes indispensable, leading to the transformation of Y into Y^* , denoted as SD. This transition highlights a recognition that economic progress, environmental stewardship, and social welfare are deeply interconnected in shaping a sustainable future. The landmark Brundtland Report of 1987 framed sustainable development as the capacity to satisfy present needs while safeguarding the ability of future generations to fulfill theirs. At its core, sustainability rests on balancing three interdependent pillars-economic growth, social equity, and environmental protection-often referred to as the "triple bottom line. These dimensions are interconnected and require a delicate balance to attain SD [13-19]. FI directly impacts SD by promoting the engagement of economic participants in roles such as capital providers or users. This maximizes the utilization of economic resources [20].

Diamond's [21] financial intermediation theory posits that banks act as intermediaries linking borrowers and savers, closing the gap between those seeking to spend and those with surplus funds, thereby playing a crucial role in capital accessibility, particularly in challenging economic times. This highlights the significance of financial intermediaries in enabling investment and consumption. Additionally, George's [22] asymmetric information theory emphasizes the difficulty in distinguishing between reliable and unreliable borrowers due to information imbalances in financial transactions, leading to credit rationing and potential impacts on financial efficiency and economic growth.

From a different perspective, rapid expansion of FI can also generate unintended environmental consequences. Greater access to credit may stimulate households to purchase energy-intensive consumer goods-such as automobiles, refrigerators, or air conditioners-which in turn drives up demand for electricity derived largely from fossil fuels. This pattern of consumption contributes to higher CO_2 and greenhouse gas emissions, creating tension between economic advancement and environmental sustainability [23]. Such dynamics reveal the complex and sometimes contradictory links between FI and sustainable development (SD). Empirical studies by Yang et al. [24], Wang et al. [25], and Jack and Suri [26] provide evidence of these interconnections. Moreover, findings by Oanh [12] indicate that the developmental context matters: FI tends to foster SD in economies with lower levels of financial development (FD), whereas in highly developed financial systems its effects may become adverse. Given these insights, it is reasonable to expect that FI will act as a driver of SD in ASEAN countries, where financial systems are still maturing. Accordingly, the following hypothesis is proposed:

H1: *FI contributes positively to sustainable development.*

FI can contribute to improved health outcomes through several channels. First, broader access to formal savings, credit, and digital transfers allows households to smooth consumption and finance unexpected medical expenses, thereby reducing delays in seeking treatment. Mobile money also facilitates remittance flows that enhance household resilience to health shocks [27]. Second, the emergence of

digital health financing tools-such as mobile health wallets, micro-insurance, and medical credit-reduces transaction costs and expands access to healthcare services, supporting progress toward universal health coverage [28]. Finally, cross-country evidence indicates that higher levels of digital financial inclusion are linked to longer life expectancy and lower mortality rates in Asian economies [29].

H2: *In ASEAN countries, higher levels of FI are positively associated with Good Health and Well-being (SDG 3).*

FI also plays a crucial role in promoting educational attainment. Access to savings and affordable credit enables households to finance tuition fees, purchase school materials, and invest in their children's learning opportunities [30]. In addition, digital financial services facilitate timely tuition payments and reduce transaction frictions, while also expanding access to online learning platforms and educational technologies. By stabilizing household income through remittances and inclusive financial channels, families are less likely to withdraw children from school during periods of financial stress [31].

H3: *In ASEAN countries, higher levels of FI are positively associated with Quality Education (SDG 4).*

FI can be a powerful driver of gender equality by enhancing women's economic participation and empowerment. First, access to individual bank accounts and mobile money services strengthens women's control over household resources and decision-making, thereby increasing their bargaining power within the family [32]. Second, microcredit and small-business financing targeted at women facilitate the creation and expansion of female-owned enterprises, improving income opportunities and reducing gender gaps in entrepreneurship [33]. Third, digital financial platforms can lower cultural and logistical barriers that traditionally limit women's access to formal finance, offering safer and more private channels for saving, borrowing, and making payments.

H4: *In ASEAN countries, higher levels of FI are positively associated with Gender Equality (SDG 5).*

FI is also closely linked to the promotion of decent work and sustained economic growth. First, improved access to credit and financial services enables micro, small, and medium-sized enterprises (MSMEs) to obtain working capital, expand operations, and create employment opportunities [34]. Second, the use of digital payment systems for wages and business transactions supports the formalization of economic activity, thereby increasing productivity and labor protection [35]. Third, inclusive finance fosters entrepreneurship by lowering entry barriers to business creation and providing households with tools to manage risk, which together stimulate innovation and long-term growth [36].

H5: *In ASEAN countries, higher levels of FI are positively associated with Decent Work and Economic Growth (SDG 8).*

FI contributes to reducing inequalities by expanding economic opportunities for disadvantaged groups. First, wider access to savings accounts, credit, and insurance allows low-income households to accumulate assets, smooth consumption, and protect themselves against financial shocks,

which narrows gaps in economic security between rich and poor [31]. Second, digital financial services reduce transaction costs and geographic barriers, making it easier for marginalized populations-including rural residents and migrant workers-to participate in the financial system and access public transfers [37]. Third, FI enhances the effectiveness of social protection programs by enabling targeted cash transfers through digital platforms, which reduces leakage and ensures that benefits reach intended recipients [38].

H6: *In ASEAN countries, higher levels of FI are positively associated with Reduced Inequalities (SDG 10).*

FI can also support climate action by enhancing household and community resilience to environmental risks. First, access to credit and savings enables households to invest in clean technologies such as solar home systems, energy-efficient appliances, and improved cooking stoves, thereby reducing dependence on fossil fuels [39]. Second, micro-insurance and climate-related financial products provide protection against losses from natural disasters, extreme weather, and crop failures, strengthening adaptation capacity in vulnerable communities [40]. Third, FI mobilizes small-scale savings that can be aggregated to finance community-level climate adaptation and mitigation projects, such as flood defenses and renewable energy infrastructure.

H7: *In ASEAN countries, higher levels of FI are positively associated with Climate Action (SDG 13).*

2.2 Research gaps

In terms of measurement, a large body of research relies on Principal Component Analysis (PCA) to construct a composite index of FI. This approach typically combines multiple indicators such as the density of bank branches per 1,000 km², the number of bank branches per 100,000 adults, the number of ATMs per 1,000 km², and the number of ATMs per 100,000 adults, among others, to generate a single FI variable [41]. Yet, the global financial landscape has been profoundly reshaped by the acceleration of digital transformation. The expansion of internet connectivity and the diffusion of digital solutions have altered economic and social systems in fundamental ways [10]. Consequently, recent approaches to FI measurement increasingly incorporate technology-oriented dimensions. Reflecting these structural changes, policymakers have emphasized the potential of FI to act as a catalyst for sustainable development [26]. Building on this perspective, the present study measures FI using seven indicators: commercial bank branches per 100,000 adults (CBB), commercial bank branches per 1,000 km² (CBBKM), ATMs per 1,000 km² (ATMKM), ATMs per 100,000 adults (ATMP), outstanding loans of commercial banks (OLCB), outstanding deposits at commercial banks (ODCB), and mobile cellular subscriptions per 100 people (MCS).

With respect to research scope, much of the existing literature linking FI with environmental quality or technological innovation has been concentrated in China, often at the provincial or municipal level [6, 24-26]. In contrast, investigations into the relationship between FI and economic growth are more geographically diverse. For example, Shen et al. [41] analyzed data from 105 countries, Khera et al. [29] focused on 52 developing economies,

Chinoda and Kapingura [42] examined Sub-Saharan Africa. Despite this growing body of evidence, no study to date has directly examined how FI contributes to SD within the ASEAN context. This absence highlights an important gap and provides a strong rationale for investigating the role of FI in advancing SD in ASEAN economies. Furthermore, existing studies often rely on aggregate or composite measures of SD, without disentangling the specific dimensions of the SDGs. To the best of our knowledge, there has been no empirical research that explicitly investigates how FI influences selected SDGs, namely SDG 3 (health), SDG 4 (education), SDG 5 (gender equality), SDG 8 (decent work and economic growth), SDG 10 (reduced inequalities), and SDG 13 (climate action). This absence highlights a critical gap and provides a strong rationale for the present study.

Earlier studies have largely relied on conventional frequentist techniques for hypothesis testing, whereas the Bayesian paradigm has been employed far less frequently. Although promising, Bayesian inference also presents certain methodological challenges. Its performance depends on prior assumptions, which may not always align with real-world dynamics and can introduce biases in estimation or prediction. In contrast to the frequentist framework, which treats parameters as fixed but unknown quantities, Bayesian analysis conceptualizes parameters as random variables with probability distributions, thereby explicitly accounting for uncertainty. This perspective enables Bayesian models to be continuously updated as new evidence accumulates, providing a degree of adaptability not typically found in frequentist methods. The merits and limitations of this approach have been extensively discussed in the literature (e.g., [19, 43-47]). Among its recognized strengths are greater robustness to small sample sizes and the ability to handle complex econometric issues such as autocorrelation and endogeneity [48].

3. RESEARCH MODELS AND METHODOLOGY

3.1 Data

The Sustainable Development Goal Index (SDGI) is constructed by integrating 17 indicators (see Table A1). This composite index has been employed in the study of Tuyet and Dinh [19] and is widely acknowledged as one of the most comprehensive tools for assessing a country's overall progress toward sustainable development. Nevertheless, while the SDGI offers a valuable aggregate perspective, it does not adequately reflect the variation across individual goals. To

bridge this gap, the present study focuses on selected goals that are particularly relevant to the ASEAN development context, namely SDG 3 (health and well-being), SDG 4 (quality education), SDG 5 (gender equality), SDG 8 (decent work and economic growth), SDG 10 (reduced inequalities), and SDG 13 (climate action). Each of these dimensions is operationalized using multiple indicators and subsequently transformed into a composite score through Principal Component Analysis (PCA). This approach not only ensures methodological consistency but also provides a more nuanced understanding of how FI contributes to specific aspects of sustainable development, rather than relying exclusively on a single composite index.

According to Oanh [12], FI cannot be adequately captured by a single variable, as it encompasses multiple dimensions. Therefore, in our study, we construct the FI variable based on the integration of seven indicators: CBB, CBBKM, ATMKM, OLCB, ODCB, and MCS. Before constructing the index, we carefully examined the dataset to ensure reliability. Specifically, we conducted data quality checks to detect missing values and outliers, and where appropriate, we applied winsorization techniques to minimize the influence of extreme observations. To make the indicators comparable, we applied a normalization process. Data normalization is a crucial step that standardizes information across different criteria and avoids scale distortions. In line with common practice, we used the minimum-maximum normalization method, which transforms all indicator values into a uniform scale within the range [0;1]. The normalization formula applied in this study is as follows:

$$FI_i = \frac{FI_i - FI_{\min}}{FI_{\max} - FI_{\min}} \quad (*)$$

Furthermore, we integrated control variables into our analysis. The measurement details of these variables and their respective data sources are provided in Table 1. The research model is articulated as follows:

$$Y_{i,t} = \beta_o + \beta_1 FI_{i,t} + \beta_x X_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $Y_{i,t}$ denotes the dependent variable, which in turn represents the overall SDGI and the selected dimensions SDG 3, SDG 4, SDG 5, SDG 8, SDG 10, and SDG 13. $FI_{i,t}$ captures the level of FI, $X_{i,t}$ is a vector of control variables, and $\varepsilon_{i,t}$ is the error term.

Table 1. Description of variables

Variables	Symbol	Measurement	Studies	Data Source
Dependent variable				
Sustainable development	SDGI	Integrated 17 criteria in Appendix 1 (Points)	[19]	SDGINDEX
Good health & Well-being	SDG3	-Life expectancy at birth (years) -Maternal mortality rate (per 100,000 live births) - Universal health coverage index (0-100)	[29]	SDGINDEX
Quality education	SDG4	Female-to-male labor force participation ratio (%) - Seats held by women in national parliament (%) -Gender wage gap (%)	[30]	SDGINDEX
Gender equality	SDG5	- Female-to-male labor force participation ratio (%) - Seats held by women in national parliament (%) Gender wage gap (%)	[31]	SDGINDEX
Decent work & Growth	SDG8	-Adjusted GDP growth (%) -Unemployment rate (%)	[35]	SDGINDEX

Reduced inequalities	SDG10	- Adults with a bank account (%)	[37]	SDGINDEX
		-Gini coefficient		
		- Palma ratio		
		- Income share of bottom 40%		
Climate action	SDG13	CO ₂ emissions per capita (tCO ₂ /capita)	[39]	SDGINDEX
		-Renewable energy share in total final energy consumption (%)		
		- Carbon Pricing Score (%)		
Independent variables				
Financial inclusion	FI	Calculation using the PCA method	[12]	WDI
Urban population	UR	Urban population/Total population (%)	[18, 45]	WDI
Inflation rate	INF	Annual CPI growth rate (%)	[45]	WDI
Population growth rate	POP	Annual population growth rate (%)	[18, 45]	WDI
Economic growth rate	GDP	Annual GDP growth rate (%)	[12]	WDI
Foreign direct investment	FDI	Net inflows of foreign direct investment as a percentage of GDP	[18, 45]	WDI
Trade penness	OPEN	The proportion of total exports and imports relative to GDP, commonly known as the trade-to-GDP ratio, is a significant economic metric	[18, 45]	WDI
Source: Authors				

Source: Authors

3.2 Methodology

Eq. (1) may encounter several econometric challenges. First, there may be a correlation between FI and unobserved error components, which could give rise to endogeneity problems. Second, multicollinearity may occur, for instance, between inflation and FI (as noted by Dinh [13]), or between FI and GDP, or even between population growth and GDP, which could lead to high collinearity among explanatory variables. In addition, given the relatively small sample size of only eight ASEAN countries, the study adopts a Bayesian regression framework. This approach helps address small-sample limitations and provides more reliable inference by generating posterior probabilities for the estimated parameters [13-16].

In this study, the relationship between FI and sustainable development is analyzed using a Bayesian regression framework. Unlike classical regression, which treats parameters as fixed but unknown, Bayesian analysis incorporates prior distributions for the parameters and updates them in light of observed data. Formally, the likelihood of the data $P(y|X, \beta)$ is combined with a prior distribution $P(\beta)$ to generate the posterior distribution $P(\beta|y, X)$ through Bayes' rule. This posterior distribution reflects the updated beliefs about the model parameters once both prior information and empirical evidence are taken into account.

The Bayesian estimation procedure unfolds in three main stages. First, prior distributions are assigned to the regression coefficients, commonly specified as normal distributions centered at zero to avoid introducing directional bias. This ensures that the estimated coefficients are more likely to cluster around zero unless the data provide strong evidence otherwise. Second, the likelihood function is defined on the basis of the regression model, assuming normally distributed errors. Third, the posterior distributions of the coefficients are obtained through simulation. In this study, we employ Markov Chain Monte Carlo (MCMC) techniques, particularly the Gibbs sampler, to generate 12,500 iterations, discarding the first 2,500 draws as burn-in to allow the chain to converge.

Bayesian methods are particularly suitable for this research context because they allow for flexible inference, accommodate parameter uncertainty, and perform well with relatively small samples, as emphasized by Levy [49].

Applying this approach, we investigate the effects of FI on overall SDGI as well as on selected SDG dimensions (3, 4, 5, 8, 10, and 13) across eight ASEAN countries (Indonesia, Lao PDR, Myanmar, Malaysia, Philippines, Singapore, Thailand, and Vietnam) over the period 2004-2023.

4. EMPIRICAL RESULTS

4.1 PCA outcomes

The PCA results show that all selected indicators contribute positively to the construction of the FI index. Among these, the density of ATMs per 100,000 adults (ATMP, 0.5058) has the highest loading, followed by the number of commercial bank branches per 1,000 km² (CBBKM, 0.4330) and ATMs per 1,000 km² (ATMKM, 0.4101). These findings highlight the central role of physical banking infrastructure-particularly ATM availability-in driving FI across ASEAN countries. While digital proxies such as mobile cellular subscriptions (MCS, 0.3905) also make a substantial contribution, the dominance of ATMs and bank branches indicates that traditional access points remain crucial for expanding financial services in the region (Table 2).

Table 2. PCA result

FI	W
CBB	0.3645
CBBKM	0.4330
ATMP	0.5058
ATMKM	0.4101
MCS	0.3905
ODCB	0.2003
OLCB	0.2520

Source: Calculations by the authors

4.1.1 Descriptive statistical results

The descriptive statistics reveal several noteworthy patterns (Table 3). On average, ASEAN countries achieved a SDGI score of 65.4 points, ranging from 52.7 to 74.5, which indicates moderate but uneven progress toward sustainability. Considerable variation is observed in SDG3 (Health) and SDG4 (Education), with standard deviations of 16.6 and 18.3

respectively, reflecting substantial disparities in healthcare quality and educational attainment across the region. SDG5 (Gender Equality) and SDG8 (Decent Work and Growth) show relatively smaller variations, suggesting greater convergence among ASEAN members in these dimensions. In contrast, SDG10 (Reduced Inequalities) records the highest variation (std. dev. 21.3), pointing to stark differences in income distribution and social equity within the region. SDG13 (Climate Action) has the highest mean score (86.3), although the wide dispersion implies that some countries are performing far better than others in addressing environmental challenges. Finally, the FI index ranges from 0 to 1 with an average of 0.50, highlighting that while half of the population has access to financial services on average, significant potential remains for further improvement.

Table 3. Descriptive statistics

Variable	Mean	Std. dev.	Min	Max
SDGI	65.4472	5.5854	52.7571	75.4860
SDG3	66.7327	16.6046	31.1824	95.9004
SDG4	82.2911	18.3767	36.6067	99.7645
SDG5	59.4896	8.8750	42.5240	75.6328
SDG8	70.7803	6.8053	54.7328	80.0586
SDG10	62.1845	21.2905	22.4760	98.0165
SDG13	86.3106	16.1273	47.0425	98.6464
FI	0.5016	0.2683	0.0000	1.0000
UR	51.7918	23.1172	26.5044	100.0000
POP	1.2530	0.8381	-4.2120	5.3747
OPEN	128.6241	101.6614	11.9740	441.7000
INF	4.7525	5.0385	-1.1501	35.3748
GDP	5.4125	3.3241	-9.6132	15.4712
FDI	5.6914	6.6746	-0.9794	29.9873

Source: Calculations by the authors

4.1.2 Bayesian regression results and discussion

The Bayesian regression results demonstrate a strong and statistically significant positive effect of FI on SDGI in ASEAN countries (Table 4). Specifically, the posterior mean of FI is estimated at 15.531, with a narrow 95% credible interval ranging from 13.54 to 17.58, indicating high precision in the estimates. The associated MCMC p-value of 0.0061 further confirms the robustness of the result. These findings imply that improvements in FI are consistently associated with higher levels of sustainable development across the region, underscoring the pivotal role of inclusive financial systems in advancing ASEAN's sustainability agenda. The positive and significant impact of FI on SDGI in ASEAN countries is consistent with recent empirical evidence highlighting the developmental role of inclusive finance. Oanh [12] emphasizes that FI serves as a catalyst for sustainable development in emerging economies by broadening access to credit, savings, and digital financial services. Similarly, Jack and Suri [26] and Yang et al. [24] provide cross-country evidence that FI contributes positively to sustainability outcomes, though the magnitude of the effect may vary depending on institutional quality and financial structures. Compared with these studies, our findings reinforce the argument that in ASEAN, where financial systems are still in a process of deepening, the expansion of FI is particularly effective in boosting overall sustainability. This suggests that FI does not merely complement growth; it plays a direct and measurable role in advancing SDGs in the region.

The diagnostics of the Bayesian estimation indicate satisfactory convergence and efficiency. The average acceptance rate is 0.8944, which lies within the generally

recommended range (0.2-0.95), confirming that the sampling process was well-calibrated. The minimum average efficiency reaches 0.4888, suggesting that the chains retained a sufficiently high level of information content relative to the number of draws. Moreover, the Gelman-Rubin convergence statistic (Rc mean) equals 1.000, which provides strong evidence that the Markov chains converged properly to the posterior distribution. Taken together, these results validate the reliability of the MCMC simulations and the robustness of the posterior estimates.

Unlike conventional regression models that only provide point estimates and significance levels, the Bayesian framework delivers direct probabilities regarding the direction and strength of effects. The findings show with absolute certainty that FI exerts a positive influence on the SDGI in ASEAN countries, as the posterior probability of $FI > 0$ is 1.000. This probabilistic evidence confirms that greater FI is consistently associated with improved sustainable development outcomes. The result underscores the strategic importance of inclusive financial systems in broadening access to resources, reducing household vulnerability, and enabling both individuals and firms to invest in health, education, and environmentally sustainable activities. In the ASEAN context—where gaps in financial access remain pronounced—this effect is particularly salient, reinforcing the role of FI as a decisive lever for sustainability. Importantly, these empirical results are fully aligned with Hypothesis H1, which anticipated that higher levels of FI would contribute positively to sustainable development across ASEAN countries. The diagnostic statistics further confirm the reliability of the Bayesian estimates. Following the guideline of Flegal et al. [48], the Monte Carlo standard errors (MCSE) of all parameters are found to be very small, indicating stable Markov Chain Monte Carlo (MCMC) sampling. In practice, an MCSE below 6.5% of the posterior standard deviation is considered acceptable, while values below 5% reflect excellent efficiency. The results reported in Table 5 show that the MCSE values meet these criteria. These outcomes provide strong evidence that the posterior estimates are robust and that the Bayesian inferences drawn from the model can be considered reliable.

Table 4. Bayesian regression results for ASEAN countries

Dependent Variable: SDGI		
Independent Variables	Mean	MCMC
FI	15.533 [13.5339; 17.5933]	0.0062
UR	0.0580 [0.0211; 0.0899]	0.0001
POP	-2.4033 [-0.8436; -0.3633]	0.0019
OPEN	0.0139 [0.0028; 0.0231]	0.0000
INF	0.0501 [0.0115; 0.1522]	0.0002
GDP	-0.0479 [-0.1938; -0.0051]	0.0006
FDI	-0.0360 [-0.1721; -0.1022]	0.0003
Cons	52.7533 [50.3211; 54.9167]	0.0090
Avg acceptance rate	0.9011	
Avg efficiency: min	0.4966	
Rc Mean	1.0000	

Source: Calculations by the authors

Table 5. The probability results of the impact of variables on SDGI

Variables	SDGI	
	Mean [Std. Dev]	MCSE
SDGI: FI>0	1.0000 [0.0000]	0.0000
SDGI: UR>0	0.9994 [0.0211]	0.0001
SDGI: OPEN>0	0.9966 [0.0780]	0.0003
SDGI: INF>0	0.8477 [0.3703]	0.0020
SDGI: _cons>0	1.0000 [0.0000]	0.0000
SDGI: POP<0	0.7901 [0.4030]	0.0025
SDGI: GDP<0	0.7419 [0.4488]	0.0026
SDGI: FDI<0	0.6911 [0.4601]	0.0028

Source: Calculations by the authors

Regarding the control variables, the results show mixed effects on sustainable development. Urbanization (UR) and trade openness (OPEN) are found to support sustainability, suggesting that greater urban concentration and integration into global trade networks can create opportunities for innovation, resource mobilization, and improved access to services that advance SDGs. By contrast, foreign direct investment (FDI), GDP growth volatility, and population growth (POP) exhibit negative or mixed effects. These findings indicate that while external capital inflows and demographic expansion can stimulate short-term growth, they may also generate environmental pressures, social disparities, and macroeconomic instability that hinder progress toward sustainable development.

Table 6. Effects of FI on selected SDGs (3, 4 and 5)

Variables	Mean [Std]	MCSE	Mean [Std]	MCSE	Mean [Std]	MCSE
	SDG3		SDG4		SDG5	
FI	1.948 [1.000]	0.006	1.237 [1.000]	0.005	1.399 [0.988]	1.389
UR	0.948 [0.064]	0.000	1.251 [0.095]	0.000	0.746 [0.082]	0.000
POP	-0.928 [0.843]	0.005	-0.180 [0.918]	0.005	-0.067 [0.897]	0.005
OPEN	0.086 [0.024]	0.000	0.056 [0.037]	0.000	0.022 [0.032]	0.000
INF	0.785 [0.234]	0.001	1.289 [0.338]	0.002	1.411 [0.298]	0.002
GDP	-1.199 [0.316]	0.001	-1.664 [0.449]	0.002	-1.795 [0.398]	0.002
FDI	-1.544 [0.300]	0.001	-2.019 [0.432]	0.002	-0.992 [0.382]	0.002
Cons	2.225 [1.021]	0.006	1.467 [0.999]	0.006	1.955 [1.011]	0.006
Avg acceptance rate	1.000		1.000		1.000	
Avg efficiency: min	0.737		0.817		0.829	
Rc Mean	1.000		1.000		1.000	

Source: Calculations by the authors

4.3 Impact of FI on SDGs 8, 10 and 13

The Bayesian regression results in Table 7 extend the analysis to the economic and environmental dimensions of sustainable development, specifically decent work and growth (SDG 8), reduced inequalities (SDG 10), and climate action (SDG 13).

SDG 8 (Decent Work and Economic Growth):

FI records a posterior mean of 1.403 (std. dev. 0.995), suggesting a robust positive relationship with decent work and economic growth. This indicates that inclusive financial systems foster entrepreneurship, improve access to credit for small and medium-sized enterprises, and enhance labor market

4.2 Impact of FI on SDGs 3, 4 and 5

The Bayesian regression results in Table 6 shed light on the disaggregated effects of FI on three key SDGs in ASEAN countries: health, education, and gender equality.

SDG 3 (Good Health and Well-being):

FI exhibits a clear positive effect with a posterior mean of 1.948 (std. dev. 1.000), demonstrating that higher levels of FI are strongly associated with improvements in health outcomes. This reflects the role of FI in enabling households to better manage healthcare expenses, smooth income during health shocks, and access preventive services. These results directly validate Hypothesis H2, which predicted that financial inclusion would positively contribute to SDG 3 in ASEAN countries.

SDG 4 (Quality Education):

The posterior mean of 1.237 (std. dev. 1.000) also indicates a positive association between FI and SDG 4, though the magnitude is smaller than that observed for health outcomes. The result suggests that expanded access to financial services allows households to invest in education-covering tuition, learning materials, and reducing dropout risks-especially among lower-income groups. This finding is consistent with Hypothesis H3, which anticipated that FI would enhance progress toward quality education.

SDG 5 (Gender Equality):

For gender equality, FI demonstrates a posterior mean of 1.399 with a narrow variance (0.988), supporting a robust positive effect. This implies that FI empowers women by improving access to credit, savings, and digital finance, thereby enhancing economic participation and decision-making power. The evidence aligns with Hypothesis H4, confirming that FI serves as a key driver of gender equality in ASEAN.

participation. These mechanisms are particularly relevant in ASEAN, where MSMEs dominate employment. The result is consistent with Hypothesis H5, confirming that FI strengthens job creation and sustainable economic growth in the region.

SDG 10 (Reduced Inequalities):

For inequality reduction, FI shows a posterior mean of 0.607 (std. dev. 0.990). Although the effect size is smaller compared to SDG 8 and SDG 13, the positive sign implies that FI helps reduce income and social disparities by providing low-income households and marginalized groups with access to savings, credit, and digital transfers. This outcome aligns with Hypothesis H6, supporting the view that FI plays a role in narrowing inequality gaps, though the impact is more modest

relative to other SDGs.

SDG 13 (Climate Action):

FI has the strongest association with climate action among this group, with a posterior mean of 1.948 (std. dev. 1.000). This highlights that inclusive finance facilitates investments in

renewable energy, energy-efficient appliances, and climate-resilient infrastructure, while also supporting micro-insurance mechanisms that mitigate climate risks for vulnerable households. The result confirms Hypothesis H7, emphasizing that FI is a critical enabler of climate resilience in ASEAN.

Table 7. Effects of FI on selected SDGs (8, 10 and 13)

Variabes	Mean [Std]	MCSE	Mean [Std]	MCSE	Mean [Std]	MCSE
	SDG8		SDG10		SDG13	
FI	1.403 [0.995]	0.006	0.607 [0.990]	0.006	1.948 [1.000]	0.006
UR	1.036 [0.080]	0.000	0.515 [0.096]	0.001	0.948 [0.065]	0.000
POP	-0.583 [0.884]	0.005	-0.243 [0.919]	0.005	-0.928 [0.844]	0.005
OPEN	0.001 [0.031]	0.000	0.063 [0.037]	0.000	0.086 [0.025]	0.000
INF	1.332 [0.292]	0.002	1.691 [0.344]	0.002	0.785 [0.234]	0.001
GDP	2.414 [0.389]	0.002	1.815 [0.456]	0.003	1.199 [0.316]	0.001
FDI	-1.874 [0.371]	0.002	-0.666 [0.435]	0.003	-1.544 [0.300]	0.001
Cons	2.122 [1.007]	0.006	1.330 [0.998]	0.006	2.225 [1.021]	0.006
Avg acceptance rate	1.000		1.000		1.000	
Avg efficiency: min	0.791		0.895		0.839	
Rc Mean	1.000		1.000		1.000	

Source: Calculations by the authors

4.4 Discussion

The findings confirm that FI has a positive and certain impact on SD in ASEAN, with the posterior probability of FI > 0 reaching 100%. This is particularly meaningful in the ASEAN context, where rapid economic growth coexists with social inequalities, financial gaps, and environmental pressures.

First, regarding health (SDG3), FI helps households mitigate risks from medical shocks through savings, credit, and micro-insurance. ASEAN health systems remain highly uneven: Singapore and Malaysia have relatively well-developed health coverage, while Lao PDR, Myanmar, and Cambodia still face infrastructure gaps and low insurance penetration. The regression coefficient for SDG3 (1.948) suggests that expanding FI can narrow these disparities, allowing low-income groups to better access healthcare services.

Second, for education (SDG4), large disparities persist. Vietnam and Thailand achieve near-universal primary enrollment, while dropout rates remain high in Lao PDR and Myanmar. The positive effect of FI (coefficient 1.237) indicates that access to financial services enables households to fund tuition fees and reduce dropout risks, particularly among disadvantaged groups. Given that nearly half of ASEAN's population remains unbanked, expanding FI is crucial to ensuring equitable access to education.

Third, regarding gender equality (SDG5), FI exerts a positive and robust impact (coefficient 1.399). Across ASEAN, women's bank account ownership remains low, especially in rural Indonesia, Lao PDR, and Myanmar. Expanding FI through digital accounts and microcredit schemes enhances women's economic empowerment and aligns with ASEAN's Gender Strategy 2025, which emphasizes narrowing gender gaps in resource access.

For SDG8 (decent work and economic growth), FI shows a significant effect (coefficient 1.403). This is highly relevant since MSMEs account for over 90% of enterprises in ASEAN, providing about 85% of employment, yet they consistently face financing constraints. Inclusive finance enables MSMEs to access working capital, scale operations, and stimulate innovation. Evidence from Indonesia and Vietnam shows that when mobile banking expands, the number of formally

registered small firms increases, improving productivity and growth.

Regarding SDG10 (reduced inequalities), the effect of FI is relatively modest. This outcome reflects the deep structural development gaps within ASEAN, where some member states enjoy advanced levels of prosperity while others continue to face persistent poverty and limited access to resources. Although FI provides disadvantaged groups with greater opportunities to participate in the financial system, narrowing inequality in a sustainable manner will require complementary measures such as redistributive fiscal policies, stronger rural-urban integration, and well-targeted social protection programs.

For SDG13 (climate action), FI records the strongest effect (coefficient 1.948). This is highly relevant given ASEAN's climate vulnerability: Vietnam, Thailand, and the Philippines frequently suffer from storms and floods, while Indonesia and Malaysia face deforestation and wildfire risks. Expanding FI through green credit, agricultural insurance, and community savings enables households to invest in renewable energy, energy-efficient technologies, and disaster-resilient infrastructure. This aligns with ASEAN's collective commitment to achieving net-zero emissions by 2050.

5. CONCLUSION AND POLICY IMPLICATIONS

This study examined the role of FI in advancing SD across eight ASEAN countries during 2004-2023. ASEAN remains a region of contrasts: while it is one of the fastest-growing economic blocs, nearly half of its population is still unbanked, and significant disparities persist in health, education, gender equality, income distribution, and climate resilience. These challenges underscore the urgency of understanding how FI can serve as a catalyst for achieving the SDGs. Specifically, the study investigated the impact of FI on the composite SDG Index as well as on six key goals: SDG3 (health), SDG4 (education), SDG5 (gender equality), SDG8 (decent work and growth), SDG10 (reduced inequalities), and SDG13 (climate action). The findings provide strong and consistent evidence that FI contributes positively to sustainable development. At the aggregate level, FI shows a significant impact on the overall SDG Index, with posterior probabilities confirming its

role as a reliable driver of sustainability. Disaggregated results further indicate that FI substantially improves health, education, and gender equality, stimulates entrepreneurship and decent work, and plays a decisive role in advancing climate action. By contrast, its effect on reducing inequality, although positive, is relatively modest-highlighting the importance of complementary redistributive and social protection measures. In addition, the results show that urbanization and trade openness support sustainability outcomes, while population growth, GDP volatility, and FDI display negative or mixed effects.

Based on the findings, several policy directions are suggested to strengthen the role of FI in advancing sustainable development across ASEAN:

Expand financial infrastructure and digital access:

Governments should prioritize investments in both traditional financial infrastructure (such as bank branches and ATMs) and digital platforms (mobile banking, e-wallets, fintech applications). This dual approach will ensure that underserved populations-particularly those in rural and remote areas-can participate fully in the financial system.

Promote financial literacy and inclusion programs:

Beyond access, effective use of financial services depends on financial literacy. ASEAN countries should implement nationwide programs targeting vulnerable groups, including women, low-income households, and rural communities, to build the knowledge and skills necessary to use financial products responsibly and productively.

Integrate FI with health, education, and gender policies:

The results show that FI strongly supports improvements in health, education, and gender equality. Policymakers should link financial services with public health insurance schemes, student loan programs, and women-focused microfinance initiatives, thereby amplifying social development outcomes.

Support MSMEs through inclusive finance:

As MSMEs dominate ASEAN's employment landscape, tailored financial products such as microcredit, SME loans, and risk-sharing facilities should be expanded. This would encourage entrepreneurship, generate decent work opportunities, and contribute to sustained economic growth.

Address inequality through complementary measures:

Since FI alone has only a modest effect on reducing inequality, it should be paired with redistributive fiscal policies, targeted subsidies, and social protection programs. Coordinated strategies will help ensure that the benefits of FI are shared more equitably across income groups and regions.

Leverage FI for climate resilience and green transition:

The strong link between FI and climate action suggests that inclusive finance should be harnessed to fund renewable energy projects, climate-resilient infrastructure, and micro-insurance schemes for disaster-prone households. ASEAN governments can promote green credit lines and community-based savings for adaptation and mitigation efforts.

Strengthen regional cooperation:

Given ASEAN's diversity, a regional framework on FI could help share best practices, harmonize regulations, and encourage cross-border financial solutions. This cooperation would also support ASEAN's broader goals of integration, inclusivity, and sustainability.

While this study provides robust evidence using a Bayesian regression framework, it is important to acknowledge certain methodological limitations. In particular, Bayesian results can be sensitive to prior specifications, and although we adopted widely accepted non-informative priors to minimize bias,

future studies could test alternative prior distributions to confirm the stability of the findings. In addition, the rise of Industry 4.0 has accelerated the digital transformation of financial services, leading to broader and more convenient access to finance through online applications. Indicators such as the number of users with e-commerce accounts, tuition payments through bank transfers, or credit card usage reflect the growing role of digital FI. However, these variables have only been tracked for a short period (around three years), which limits their integration into the current analysis. Future research should incorporate longer time-series data on digital FI and explore how technological innovations under Industry 4.0 further shape the FI-SD nexus. Such an approach would allow for a more comprehensive evaluation and generate more targeted policy recommendations for the digital era.

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APPENDIX

Table A1. 17 indicators for calculating the SDGI

Sustainable Development Goal Index (SDGI)		
Target 1	No Poverty	
Target 2	No Hunger	
Target 3	Good Health and Well-Being	
Target 4	Quality Education	
Target 5	Gender Equality	
Target 6	Clean Water and Sanitation	
Target 7	Affordable and Clean Energy	
Target 8	Decent Work and Economic Growth	
Target 9	Industry, Innovation and Infrastructure	[15-18, 50]
Target 10	Reduced Inequalities	
Target 11	Sustainable Cities and Communities	
Target 12	Responsible Consumption and Production	
Target 13	Climate Action	
Target 14	Life Below Water	
Target 15	Life on Land	
Target 16	Peace, Justice and Strong Institutions	
Target 17	Partnerships for the Goals	

Source: Sdgindex.org