

Financial Inclusion as a Pathway to Sustainable Development: Regional Evidence from ASEAN and the Case of Vietnam

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Abstract

This study investigates the impact of Financial Inclusion (FI) on Sustainable Development (SD) in ASEAN countries over the period 2004–2022, aiming to provide robust regional and country-level empirical evidence using a Bayesian econometric framework. The core idea of the study is that inclusive financial systems serve as a critical transmission channel through which economic, social, and environmental dimensions of sustainable development can be jointly enhanced. The primary objective is to quantify the effect of FI on SD at the ASEAN level and to examine whether this relationship remains consistent when regional evidence is incorporated as prior information for country-level estimation. Using Bayesian regression, the results reveal a strong and positive effect of FI on SD, with an estimated posterior mean coefficient of 15.531 for ASEAN countries and 15.5448 for Vietnam. The posterior probability associated with these coefficients is approximately 1.000 ($\approx 100\%$), indicating an extremely high level of statistical confidence in the positive FI–SD relationship. Markov Chain Monte Carlo (MCMC) diagnostics confirm convergence and parameter stability across iterations, supporting the reliability of the Bayesian estimates. Robustness checks using Pooled Ordinary Least Squares (POLS) and Feasible Generalized Least Squares (FGLS) yield consistent coefficient signs and magnitudes, further validating the main findings. The results demonstrate that economies with higher levels of financial inclusion tend to achieve significantly better sustainable development performance. The key contribution and novelty of this study lie in its Bayesian regional-to-country estimation strategy, which integrates ASEAN-level evidence as informative priors to strengthen country-specific inference, thereby offering new methodological and policy-relevant insights into the finance–sustainability nexus.

Keywords: Financial Inclusion; Sustainable Development; Bayesian Regression; Markov Chain Monte Carlo; Financial Development.

1. Introduction

During the late 20th and early 21st centuries, significant upheavals rocked the realms of economics, politics, and societal dynamics. All serving as crucial turning points within this timeframe. These crises and conflicts have had adverse effects, pushing the global economy into prolonged periods of recession. Concurrently, the world faces non-traditional security issues of global significance, including environmental pollution and food security [1]. These challenges are rooted in what is often termed the “brown economy,” an economic model reliant on fossil fuels, over-exploitation of natural resources, and pollution-intensive growth. The detrimental impacts of the brown economy underscore the urgency of transitioning to Sustainable Development (SD), which seeks to harmonize economic, social, and environmental goals. As economic growth approaches a point where its negative impacts outweigh its benefits in terms of real wealth creation, there is a growing global interest in exploring alternative pathways towards an economy that prioritizes SD, simultaneously achieving three objectives: sustainable economy, sustainable society, and sustainable environment [2], [3]. The key to future prosperity lies in the gradual transition to SD.

Considering the global population is estimated to reach 9.8 billion by 2050, the policies implemented today will significantly impact the legacy passed on to future generations [4]. Up to the present, numerous research studies have delved into factors contributing to SD through the impetus generated by the interplay of economic development relationships, simultaneously aiming to minimize environmental pollution. Noteworthy research includes an

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exploration of the coordination between Green Finance and Green Economy towards SD goals [5], an exploration aimed at bolstering green finance to foster green growth [6]; a study on developing green finance to ensure environmental sustainability [7]; and an examination of the relationship between renewable energy and the Human Development Index [8]. These studies collectively emphasize the role of sustainability driven by motivators such as Green Finance, Green Energy, environmentally relevant technological advancements, and the mitigation of environmental pollution issues. Furthermore, these resources demand a substantial amount of financial investment and legal frameworks for operation. For instance, Germany has invested 50 billion USD in harnessing solar and wind energy, achieving a target of 65% renewable energy by 2021, while the Netherlands allocated 10 billion USD to develop eco-friendly public transportation and cycling infrastructure. These experiences demonstrate how strong financial and policy commitments can accelerate sustainability transitions. For ASEAN countries, although resource limitations and developmental gaps remain significant, these cases highlight the relevance of mobilizing financial inclusion to adapt global lessons into regionally appropriate strategies.

Another crucial resource is Foreign Direct Investment (FDI), which plays a pivotal role in driving economic development. However, investments in environmental and technological aspects (Green FDI) constitute a relatively low proportion of the total capital [9]. Green FDI tends to be more effective in countries with established green infrastructure and stability, such as China and the United States [10]. In the ASEAN region, while implementing these measures for sustainability is feasible, there are still numerous limitations and challenges, particularly in terms of resources. In recent studies such as those by Oanh and Dinh [11], Van and Le Quoc [12] and Dinh [13], financial inclusion (FI) plays a crucial role and is considered a potent catalyst capable of driving SD in emerging economies. FI, characterized by growth in both quantity and quality, creates favorable conditions for small and medium-sized enterprises as well as individuals. This expansive financial landscape is identified as a strong motivator with the potential to promote SD [14].

With a population accounting for 8.56% of the world's population and holding the third position in Asia, the ASEAN region is a significant demographic and potential resource hub. However, approximately half of the population in these countries lack bank accounts and the ability to access financial products, with 18% having limited access to any form of financial services beyond traditional banking accounts. Vietnam ranks second on the list of the 10 countries with the lowest banking access rates globally, with 69% of the total population lacking access to traditional banking services or similar financial organizations. Therefore, a FI strategy in Vietnam is crucial as a prerequisite to promoting SD. In this study, the research team investigates the impact of FI on SD in ASEAN countries. The obtained results serve as prior information for Vietnam. This serves as the basis for proposing policy implications for these regional nations while drawing lessons for Vietnam.

2. Literature Review

2.1. Theories of FI and SD

Considering the Cobb-Douglas function:

$$Y = A * L^a * K^b$$

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).

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 (Oanh, 2024). 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 shift reflects an acknowledgment of the intricate interplay between economic activities, environmental resources, and societal well-being in the pursuit of a more sustainable future. Building on these theoretical foundations, it is important to situate sustainable development within a broader conceptual framework. In 1987, The United Nations Brundtland Commission defines sustainable development as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs, highlighting the balance of economic, social, and environmental dimensions. SD entails harmonizing three crucial dimensions, commonly referred to as the triple bottom line: economic, social, and environmental. These dimensions are interconnected and require a delicate balance to attain SD [1], [2]. 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 [15].

Diamond [16] 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, Akerlof George [17] 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.

However, viewed from another angle, excessive promotion of FI may lead individuals to borrow from banks and other financial institutions to purchase energy-intensive products such as cars, refrigerators, microwaves, washing machines, and air conditioners. This could significantly escalate the consumption of energy sourced from non-renewable sources, consequently increasing CO₂ and other greenhouse gas emissions. Moreover, as the level of FI rises, economic growth becomes increasingly reliant on heightened energy consumption from fossil fuels, ultimately resulting in a rise in CO₂ emissions into the atmosphere [18], thereby compromising sustainability. This underscores the intricate relationship between FI and SD. Related studies by Yang, et al. [19], Wang, et al. [20] and Zheng, et al. [21] have demonstrated correlations between FI and SD. Recent studies conducted by Dinh [13] and Van and Le Quoc [12] examining financial development in various countries have found that FI has a positive impact on SD in nations with low levels of FD, but a negative impact in those with high levels of FD. Therefore, the authors anticipate that FI will contribute to promoting SD in ASEAN countries. In the case of Vietnam, where financial inclusion has expanded rapidly but remains uneven across regions and income groups, FI is anticipated to contribute positively to sustainable development by improving access to formal finance, supporting inclusive growth, and facilitating poverty reduction.

H1: *Financial inclusion positively affects sustainable development in ASEAN countries.*

H2: *Financial inclusion positively affects sustainable development in Vietnam.*

2.2. Research Gaps

Regarding measurement, many studies commonly adopt the Principal Component Analysis (PCA) method to measure FI, integrating various indicators such as the number of commercial bank branches per 1000 km² (CBBP), the number of commercial bank branches per 1000 adults (CBP), the number of ATMs per 1000 km² (ATMKM), the number of ATMs per 1000 adults (ATM), and others, to form the FI variable [22]. However, the global economy is currently undergoing significant changes due to the rapid progress of information and digital transformation [23, 24]. The robust development of the Internet and widespread adoption of digital solutions have led to substantial changes in all aspects of life [25]. Therefore, contemporary FI reflects its dynamic nature by integrating technology-related variables. With the emerging changes in quantity, policymakers expect FI to drive SD [21]. Thus, in the recent study, we construct a measurement of FI based on 7 components, including the number of commercial bank branches per 100,000 adults (CBB), the number of commercial bank branches over 1000 km² (CBBKM), the number of ATMs over 1,000 km² (ATMKM), the number of ATMs per 100,000 adults (ATMP), outstanding loans from commercial banks (OLCB), outstanding balance of deposits at commercial banks (ODCB), and mobile cellular subscriptions per 100 people (MCS).

Regarding the research scope, investigations into the correlation between FI and environmental quality or the connection between FI and technological innovation are predominantly focused on provinces and cities within China. Studies conducted by Liu, et al. [26] Yang, et al. [19], and Wang, et al. [20] exemplify this trend. Conversely, research on the relationship between FI and economic growth has been extensive, encompassing various geographical areas. For instance, Shen, et al. [27] conducted a study involving 105 countries globally, while Khera, et al. [28] investigated 52 developing countries. Additionally, Chinoda and Kapingura [29] focused on countries in the Sub-Saharan Africa region, and Daud [30] examined the topic across 84 countries worldwide. However, there is currently no existing study that explores the relationship between FI and SD specifically in ASEAN countries, including Vietnam. This gap underscores the need for further research in this area to understand how FI influences SD within the context of ASEAN nations.

In previous research, conventional frequentist methods have been predominantly utilized for hypothesis testing. However, the Bayesian approach, while less common, presents an alternative methodology. This approach, though, is not without its challenges. Bayesian methods are dependent on specific assumptions that might not consistently mirror real-world circumstances, potentially resulting in inaccuracies in inference and predictions. Unlike frequentist methods, which treat parameters as fixed but unknown values, Bayesian methodology views parameters as random variables and assigns them distributions, capturing the uncertainty surrounding these parameters. This distinction allows Bayesian models to adapt and update as more data becomes available, offering flexibility that frequentist approaches may lack. Numerous studies, including works by Gelman and Hill [31] and Kruschke [32] have explored the strengths and limitations of Bayesian methods. One notable advantage is the method's resilience to sample size variations, meaning that the accuracy of Bayesian models is less contingent on the volume of data available. Additionally, Bayesian methodology addresses certain model shortcomings such as autocorrelation and endogeneity, as noted by Kim and Quoc [33], Le Quoc [34], Le Quoc [35], Quoc, et al. [36], Oanh and Ha [37] and Quoc, et al. [38]

In the present study, we employ the Bayesian method to assess the impact of (FI) on SD within the ASEAN region. This approach allows for the formulation of policy implications suitable for these countries in general and specifically for Vietnam, overcoming the limitations of traditional frequentist methods.

3. Data and Methodology

3.1. Data

The Sustainable Development Goal Index (SDGI) is constructed by integrating 17 indicators (see Appendix 1) and has been endorsed by the European Joint Research Centre. It has also been applied in previous studies and is widely recognized as one of the most comprehensive and standardized measures for assessing a country's sustainable development performance [1], [2], [38], [39]. While the SDGI inevitably simplifies complex realities—such as potential trade-offs among goals or differences in national data quality—it remains the most reliable and widely adopted tool for cross-country analysis, making it highly suitable for this study.

According to Oanh and Dinh [11], Oanh, et al. [40], Le Quoc [41], and Huy and Quoc [42] FI cannot be adequately captured by a single variable, as it encompasses various dimensions. Therefore, in our study, we construct the FI variable based on the integration of 7 indicators: CBB, CBBKM, ATMKM, OLCB, ODCB, and MCS. Data normalization is a crucial technique that standardizes information across different criteria. One method, introduced by Nguyen The, et al. [43], is the minimum-maximum normalization method, which prepares the data for analysis and enables comparison among variables. In our study, we normalize the FI index values using the following formula to ensure that they fall within the range [0;1]:

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

Furthermore, we integrated control variables into our analysis. The measurement details of these variables and their respective data sources are provided in table 1. Urbanization (UR) is included to control for the effects of population concentration on sustainable development, as urban areas typically provide better access to infrastructure, education, and public services, but also intensify environmental pressure and resource consumption [1]. Population growth (POP)

reflects demographic dynamics that may place increasing pressure on natural resources, public services, and environmental carrying capacity, potentially constraining sustainable development if productivity gains do not keep pace [1]. Economic growth (GDP) is incorporated to capture the scale effect of economic expansion, which can enhance fiscal capacity and living standards but may also undermine sustainability when growth is driven by resource-intensive and carbon-intensive activities [1]. Foreign direct investment (FDI) is included because it facilitates capital accumulation, employment, and technology transfer; however, its impact on sustainable development is theoretically ambiguous, depending on whether investment flows into green or pollution-intensive sectors [1]. Trade openness (OPEN) controls for global economic integration, which can promote efficiency and access to cleaner technologies, while simultaneously increasing environmental pressure through scale and composition effects [1]. Inflation (INF) is introduced as an indicator of macroeconomic stability, since high and volatile inflation can distort investment decisions, weaken purchasing power, and hinder long-term sustainable development efforts [1]. The research model is articulated as follows:

$$SDGI_{i,t} = \beta_0 + \beta_1 FI_{i,t} + \beta_x X_{i,t} + \varepsilon_{i,t} \tag{1}$$

Table 1. Description of variables.

Variables	Symbol	Measurement	Studies	Data source
<i>Dependent variable</i>				
Sustainable development	SDGI	Integrated 17 criteria in Appendix 1 (Points).	[1], [2], [38]	SDGINDEX
<i>Independent variables</i>				
Financial inclusion	FI	Calculation using the PCA method.	Calculations by the authors	WDI
Urban population	UR	Urban population/Total population (%).	[1]	WDI
Inflation rate	INF	Annual CPI growth rate (%).	[1]	WDI
Population growth rate	POP	Annual population growth rate (%).	[1]	WDI
Economic growth rate	GDP	Annual GDP growth rate (%).	[1]	WDI
Foreign direct investment	FDI	Net inflows of foreign direct investment as a percentage of GDP.	[1]	WDI
Trade Openness	OPEN	The proportion of total exports and imports relative to GDP, commonly known as the trade-to-GDP ratio, is a significant economic metric.	[1]	WDI

3.2. Methodology

From a Bayesian perspective, we formulate a linear regression using a probability distribution framework as follows:

$$y \sim N(\beta^T X, \sigma^2 I) \tag{*}$$

The generation of the output (y) is not solely determined by a probability distribution; moreover, the model parameters are assumed to be sampled from a distribution. The posterior probability of the model parameters, conditioned on the inputs and outputs, is expressed as follows:

$$P(\beta|y, X) = \frac{P(y|\beta, X)P(\beta|X)}{P(y|X)} \tag{**}$$

Where: P (y|β, X) is the probabilities of the data, P(β|X) is a prior probability distribution, P(y|X) is a standard constant that can be removed, and P (β|y, X) is the posterior probability distribution of the model parameters for the inputs and outputs. As a result, equation (**) is frequently reduced to:

$$P(\beta|y, X) = P(y|\beta, X)P(\beta|X) \tag{***}$$

The following three phases will be followed using Bayesian regression when examining the potential association between marginal interest income and explanatory factors. To begin with, we assume that the coefficients are normally distributed a priori, with a mean (means) of zero for each coefficient. The coefficients produced by Bayesian analysis are more likely to have values near zero than non-zero values, according to this type of a priori specification. Above all, we avoid adding bias to the Bayesian conclusions of research hypotheses, either positive or negative. Second, we

assume normal distributions for the likelihood functions of the coefficients, with parameters obtained from equations (1). Lastly, we use the Gibbs Sampler and Markov Chain Monte Carlo (MCMC) methods to estimate and simulate 12,500 times, respectively, to determine the posterior distributions of the coefficients. We will not be eligible for the first 2,500 withdrawals, as per normal. In many different domains, the MCMC technique is widely employed to tune complicated models [44]. In the current study, we conducted research the impact of FI on SDGI in ASEAN countries (including 8 countries: Indonesia, Lao PDR, Myanmar, Malaysia, Philippines, Singapore, Thailand, and Vietnam) during 2004-2022 using the Bayesian method.

4. Findings from the Study

4.1. PCA Outcomes

The PCA results in table 2 show that ATM density by area (ATMKM) is the dominant contributor to the FI index, with an exceptionally high loading of 0.9875, indicating that geographical access to ATMs explains nearly all the variation in the principal component. In contrast, commercial bank branches per km² (CBBKM) have a much smaller loading of 0.1533, while branches per population (CBB) contribute almost nothing (0.0005), suggesting that branch-based access is far less influential than ATM coverage. Other indicators play only a marginal role: ATMs per population (ATMP) load at 0.0051, mobile cellular subscriptions (MCS) at 0.0140, outstanding deposits (ODCB) at 0.0242, and outstanding loans (OLCB) at 0.0227. These low values indicate that digital access and credit–deposit depth contribute little to regional financial inclusion. Overall, the numerical evidence confirms that FI in ASEAN remains strongly driven by physical financial infrastructure, while digital finance and credit channels have yet to become key drivers during the study period

Table 2. PCA result.

FI	CBB	CBBKM	ATMP	ATMKM	MCS	ODCB	OLCB
	0.0005	0.1533	0.0051	0.9875	0.0140	0.0242	0.0227

4.2. Bayesian Regression Results for ASEAN Countries

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4.2.1. Descriptive Statistical Results

The descriptive statistics (table 3) reveal notable variation across ASEAN countries during 2004–2022. The Sustainable Development Goal Index (SDGI) records an average value of 64.80 with a standard deviation of 5.53, ranging from a minimum of 52.23 to a maximum of 74.74. This indicates that while certain ASEAN members have achieved relatively high levels of sustainable development, others still lag significantly behind. FI shows an average of 0.497 with a standard deviation of 0.266, ranging from 0.00 to 1.00, reflecting both progress and disparity in access to financial services. The minimum value illustrates countries with very limited financial access in the early stages, whereas the maximum demonstrates relatively advanced inclusion. Overall, these figures highlight the heterogeneity of development outcomes in the region, emphasizing the importance of understanding how FI interacts with sustainability under diverse national contexts.

Table 3: Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
SDGI	152	64.7992	5.5301	52.2348	74.7386
FI	152	0.4966	0.2656	0.0000	1.0000
UR	152	51.2790	22.8883	26.2420	100.0000
POP	152	1.2406	0.8298	-4.1703	5.3215
OPEN	152	127.3506	100.6549	11.8554	437.3267
INF	152	4.7054	4.9886	-1.1387	35.0246
GDP	152	5.3589	3.2912	-9.5180	15.3180
FDI	152	5.6350	6.6085	-0.9697	29.6904

4.2.2. Bayesian Regression Outcomes

The Bayesian regression results for ASEAN countries, presented in [table 4](#), indicate that financial inclusion (FI) exerts a strong positive effect on the Sustainable Development Goal Index (SDGI), with a coefficient of $\beta = 15.531$. The posterior probability of FI positively influencing SDGI is extremely close to 1.000 ($\approx 100\%$), based on Markov Chain Monte Carlo (MCMC) simulations ([table 5](#)). This suggests a consistently positive relationship between FI and sustainable development across all simulated iterations, in line with the findings of Van and Le Quoc [12], Dinh [13]. In addition, the results show that UR, OPEN, and INF contribute positively to SD, whereas POP, GDP, and FDI exhibit negative effects. The negative sign of GDP growth can be explained by the fact that, in many ASEAN countries, rapid economic expansion has historically been driven by resource-intensive and environmentally damaging activities—often referred to as a “brown economy.” While GDP rises, the environmental and social costs undermine progress toward sustainable development. Similarly, the negative effect of FDI reflects the reality that much of the region’s foreign investment has flowed into energy-intensive and pollution-heavy industries such as mining, coal-based power generation, and carbon-intensive manufacturing. Although FDI generates jobs and boosts short-term growth, its environmental and social externalities reduce overall sustainability performance, thus lowering the SDGI.

In contrast to the frequentist approach, the regression results table shows the regression coefficients. The Bayesian approach using the Metropolis–Hasting’s algorithm (MH) simulates the regression model 10,000 times, obtaining a regression coefficient each time. Therefore, the regression results table will display the mean value (Mean). Additionally, Bayesian analysis provides standard errors (Std. Dev) for the regression coefficients and Monte-Carlo standard errors.

From [table 4](#), it can be seen that the average acceptance rate is 0.8933, reaching an absolute and better acceptance rate than the required 0.1. The minimum efficiency (Average efficiency: min) in the models is 0.4888, surpassing the acceptable threshold of 0.01; consequently, all models fulfill the stipulated requirements. The Monte-Carlo standard errors (MCSE) for all parameters are notably small, as per Flegal, et al. [45]. They assert that a lower MCSE value indicates a more resilient MCMC chain. According to their recommendations, an MCSE value less than 6.5% of the standard deviation is deemed acceptable, and less than 5% is considered optimal. Therefore, the analysis results presented in [table 4](#) indicate that the average Rc value of the model is 1.0000, signifying the satisfaction of convergence criteria for the MCMC chain. Thus, it can be inferred that the Bayesian simulation results are robust.

Table 4: Bayesian Regression Results for ASEAN Countries

Dependent variable: SDGI		
Independent variables	Mean	MCMC
FI	15.531 [13.5439; 17.5816]	0.0061
UR	0.0575 [0.0232; 0.0944]	0.0001
POP	-2.4064 [-0.8455; 0.3758]	0.0018
OPEN	0.0130 [0.0027; 0.0230]	0.0000
INF	0.0496 [-0.0475; 0.1518]	0.0003
GDP	-0.0471 [-0.1930; 0.1051]	0.0005
FDI	-0.0344 [-0.1711; -0.1001]	0.0004
Cons	52.7485 [50.3214; 54.9166]	0.0092
Var	6.8381 [5.1832; 9.0496]	0.0081
Avg acceptance rate	0.8944	
Avg efficiency: min	0.4888	
Rc Mean	1.0000	

Table 5 reports the posterior probabilities of the effects of explanatory variables on the Sustainable Development Goal Index (SDGI). Financial inclusion (FI) shows an absolute probability of 1.000, confirming a robust positive impact on SDGI. Urbanization (UR) and trade openness (OPEN) also exhibit very high probabilities of positive effects (0.9996 and 0.9936, respectively), while inflation (INF) shows a moderate positive probability (0.8397). In contrast, population growth (POP), GDP growth, and foreign direct investment (FDI) display probabilities of negative effects of 0.7804, 0.7419, and 0.6907, respectively. The low Monte Carlo standard errors (MCSE) indicate high estimation precision and reliable convergence of the Bayesian simulations.

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

SDGI		
Variables	Mean [Std. Dev]	MCSE
SDGI: FI>0	1.0000 [0.0000]	0.0000
SDGI: UR>0	0.9996 [0.0208]	0.0001
SDGI: OPEN>0	0.9936 [0.0780]	0.0004
SDGI: INF>0	0.8397 [0.3703]	0.0021
SDGI: _cons>0	1.0000 [0.0000]	0.0000
SDGI: POP<0	0.7804 [0.4139]	0.0024
SDGI: GDP<0	0.7419 [0.4375]	0.0027
SDGI: FDI<0	0.6907 [0.4622]	0.0027

4.2.3. The results of POLS and FGLS

The findings presented in table 6 indicate that there are no significant differences in the regression coefficients between the frequentist and Bayesian approaches. In both cases, the increase in FI consistently corresponds to the promotion of SD, with coefficient signs and magnitudes demonstrating a high degree of alignment. This consistency reinforces the robustness and credibility of the results. Beyond this convergence, the Bayesian approach provides additional analytical advantages by allowing the computation of posterior probabilities for the effects of independent variables, as illustrated in table 5.

Table 6: Regression Results Employing the Frequentist Approach

Variables	POLS		FGLS	
	Regression Coefficients [Std]	Prob	Regression Coefficients [Std]	Prob
FI	13.7246 [0.9846]	0.0000***	17.7563 [0.6673]	0,0000***
UR	0.0053 [0.0155]	0.7300	0.0813 [0.0126]	0,0000***
POP	-0.6156 [0.2862]	0.0330**	0.1219 [0.2306]	0.5970
OPEN	0.0185 [0.0047]	0.0000***	0.0096 [0.0037]	0.009***
INF	-0.0537 [0.0448]	0.2320	-0.0133 [0.0240]	0.5810
GDP	-0.2342 [0.0661]	0.0010***	-0.0722 [0.0364]	0.0470**
FDI	-0.0136 [0.0632]	0.8300	-0.1075 [1,3866]	0.035**
Cons	57.6964 [0.9680]	0.0000****	52.1147 [0.6552]	0.0000***

These probability-based insights enhance the interpretive depth of the analysis and move beyond the binary significance testing of frequentist methods. Moreover, they serve as valuable prior information for the Vietnam-specific analysis, where contextual factors such as policy orientation, institutional quality, and sectoral investment patterns are expected to shape the FI–SD relationship in distinctive ways. Nevertheless, a limitation of the Bayesian approach is its reliance on prior assumptions, which—if not carefully justified—may introduce bias. To mitigate this, our study employed non-informative priors and robustness checks to ensure that the findings are driven primarily by the data rather than prior specifications.

4.3. Bayesian Regression Results for Vietnam

Similarly, table 7 - Bayesian regression results show that FI has a positive impact on SD with a regression coefficient (β) of 15.5448, and the probability of FI having a positive impact on SDGI is an absolute 100% (table 8). This indicates that FI is an indispensable factor in promoting SD. An interesting finding, different from the Bayesian regression results in other ASEAN countries, is that FDI has a positive impact on SD in Vietnam. This impact is evident with a probability of 71.79%.

Table 7. Bayesian Regression Results for Vietnam

Dependent variable: SDGI		
Independent variables	Mean	MCMC
FI	15.5448 [13.5500; 17.6302]	0.0524
UR	0.0453 [-0.2250; 0.3129]	0.0072
POP	-0.0730 [-1.2247; 1.0841]	0.0209
OPEN	0.0706 [-0.1151; 0.2405]	0.0049
INF	-0.1165 [-0.7565; 0.4597]	0.0149
GDP	-0.0015 [-0.5736; 0.5571]	0.0138
FDI	0.0353 [-0.5253; 0.6335]	0.0142
Cons	50.6370 [42.0549; 54.6999]	0.1539
Var	0.7927 [0.2037; 2.5023]	0.0310
Avg acceptance rate	0.6249	
Avg efficiency: min	0.0918	
Rc trung bình	1.0000	

From [table 7](#), it can be observed that the average acceptance rate is 0.6249, which is better than the required threshold of 0.1. The minimum efficiency (Avg efficiency: min) among the models is 0.0918, exceeding the allowable threshold of 0.01. Thus, the model meets the requirements. The average value of Rc for the model is 1.0000, indicating that the MCMC chain satisfies the convergence requirement. Therefore, it can be concluded that the Bayesian simulation results are robust.

[Table 8](#) reports the posterior probabilities of the effects of explanatory variables on sustainable development in Vietnam. Financial inclusion (FI) exhibits an absolute probability of 1.000, confirming its robust positive impact on the SDGI. Urbanization (UR), trade openness (OPEN), and inflation (INF) show moderate probabilities of positive effects, at 0.7426, 0.6965, and 0.7179, respectively. Population growth and GDP growth are more likely to exert negative effects on sustainable development, with probabilities of 0.6817 and 0.6668. In contrast to the regional results, foreign direct investment (FDI) demonstrates a positive effect in Vietnam, with a probability of 0.7179. The relatively low MCSE values indicate acceptable estimation precision and reliable Bayesian inference.

Table 8: The probability results of the impact of variables on SD in Vietnam

SDGI		
Variables	Mean [Std. Dev]	MCSE
SDGI: FI>0	1.0000 [0.0000]	0.0000
SDGI: UR>0	0.7426 [0.4424]	0.0188
SDGI: OPEN>0	0.6965 [0.4845]	0.0047
SDGI: INF>0	0.7179 [0.4671]	0.0168
SDGI: cons>0	1.0000 [0.0000]	0.0000
SDGI: POP<0	0.6817 [0.4675]	0.0187
SDGI: GDP<0	0.6668 [0.4966]	0.0168
SDGI: FDI>0	0.7179 [0.4671]	0.0168

4.4. Discussion

The Bayesian regression results for ASEAN countries indicate that FI has a positive impact on SDGI, consistent with the findings of Van and Le Quoc [\[12\]](#). Overall, countries within the ASEAN bloc show a tendency to improve their level of FI, with an increasing FI index during the study period. To achieve these results, since 2004, these nations have implemented FD policies, encouraging commercial banks to play a pivotal role in expanding financial access for micro-enterprise [\[12\]](#). It can be observed that FI plays a vital role in encouraging economic participants to engage in the

economy, both as providers and users of capital on a broad scale, thereby fostering economic growth. Additionally, FI services create favorable conditions for community FD and shared economic models, contributing to income improvement, poverty reduction, and ultimately promoting SD.

The Bayesian regression results for Vietnam reveal that FI has a positive impact on SD, with a 100% probability of FI positively affecting the SDGI. In the initial phase, due to low-income levels, there was limited demand for banking services and a prevailing psychological aversion, with limited trust in financial institutions. This is understandable given that Vietnam's poverty rate is relatively high, with approximately 70% of the population falling into the economically secure group, leaving around 30% in the economically insecure and impoverished category. Acknowledging this situation, the country has made efforts to enhance FI in the subsequent period, currently ranking third in the region (after Singapore and Thailand). This improvement provides opportunities for the poor, near-poor, those with low incomes, and particularly challenging circumstances to develop their household economies. Consequently, it increases access to formal credit from the banking system, meeting the demand for consumer loans, supporting production development, reducing poverty, and addressing social inequality. On the other hand, with a population exceeding 100 million, of which over 60% are of working age, the increasing per capita income presents a growing opportunity for personal loans. This sector has the potential to generate significant returns for financial institutions, thereby promoting SD. An important and distinctive finding of the study is that, unlike in most ASEAN countries where FDI exhibits a negative effect on the SDGI, in Vietnam the effect is positive. This outcome can be explained by the structure and orientation of Vietnam's FDI inflows. A large share of investment has been directed toward labor-intensive manufacturing, export-oriented sectors, and, more recently, renewable energy projects. These investments have generated substantial employment opportunities, contributing to higher living standards and poverty reduction. At the same time, the technology transfer process associated with multinational corporations has enhanced domestic production capabilities and encouraged innovation. Importantly, the Vietnamese government has actively pursued institutional reforms and introduced policies to attract "green FDI," thereby channeling capital into sectors that minimize environmental harm. As a result, FDI not only supports economic development but also strengthens the social and environmental pillars of sustainability, explaining its positive contribution to the SDGI in Vietnam.

5. Conclusion and policy recommendation

5.1. Conclusion

The objective of this research is to investigate the impact of FI on SD in ASEAN countries (8 countries) during the period 2004-2022 using the Bayesian method. The obtained results, which we use as priors for Vietnam, show that FI has a positive impact on SD in ASEAN countries with a regression coefficient of 15.531, and in Vietnam, this coefficient is 15.5448. The probability of the positive impact of FI on SD is an absolute 100%. Comparing with traditional frequency methods such as POLS and FGLS, the results show similarities in terms of sign and regression coefficients with no significant differences. However, the Bayesian method provides additional probabilities of the impact of independent variables on the dependent variable. Furthermore, Bayesian analysis is advantageous in addressing endogeneity, self-correlation, and handling small sample sizes. In summary, FI is an essential component of economic development, poverty reduction, and achieving SD. It contributes to eradicating poverty and promotes SD. The importance of FI has been recognized by governments, policy planners, and international financial institutions. Therefore, identifying the country's position in the process of FI development towards SD is crucial.

5.2. Policy Recommendations

In general, ASEAN countries should prioritize bolstering FI as a key driver to advance SD. Beyond broad collaboration, governments and financial institutions can adopt practical measures such as expanding digital payment platforms, mobile banking, and QR code-based cross-border transactions to reach underserved populations. At the same time, regulatory sandboxes should be established to encourage fintech innovation while ensuring consumer protection. Another priority is the systematic promotion of financial education programs, particularly targeting women, rural households, and informal workers, in order to improve financial literacy and empower marginalized groups. FI policies should also emphasize equitable access through the design of inclusive financial products, such as microcredit and green loans, which can simultaneously address poverty alleviation and environmental objectives.

For Vietnam, there should be an effort to promote the development of products and create accessibility to areas that are underserved, specifically benefiting micro, small, and medium-sized enterprises from the expansion of sustainable financial products, thereby promoting SD. The application of the agency banking model has eliminated geographical barriers in areas where many communes and districts do not have bank branches. Encouraging the further development of this model is crucial. This can be encouraged by allowing all financial institutions under the management and supervision of the central bank to hire agents anywhere in the country, while clearly specifying the services that agents can provide and providing necessary guidelines on contracts between financial institutions and agents. This would increase the level of FI and strengthen SD.

5.3. The limitations and further research suggestion

One limitation of this study concerns the exclusion of Industry 4.0–related variables, such as digital transformation and fintech adoption, due to the limited availability of long-term data. Instead of dismissing these factors entirely, future research could employ methodological solutions to approximate their effects. For instance, proxy indicators such as mobile broadband subscriptions, digital payment transaction volumes, or e-commerce penetration may serve as substitutes for direct Industry 4.0 measures. Additionally, simulation approaches or scenario-based modeling could be used to capture the potential impact of emerging technologies on financial inclusion and sustainable development. By adopting these strategies, future studies can enrich the analysis and provide a more comprehensive understanding of the evolving role of Industry 4.0 in shaping sustainability outcomes.

6. Declarations

6.1. Author Contributions

Conceptualization: N.T.K. and L.Q.D.; Methodology: L.Q.D.; Software: N.T.K.; Validation: N.T.K. and L.Q.D.; Formal Analysis: N.T.K. and L.Q.D.; Investigation: N.T.K.; Resources: L.Q.D.; Data Curation: L.Q.D.; Writing—Original Draft Preparation: N.T.K. and L.Q.D.; Writing—Review and Editing: L.Q.D. and N.T.K.; Visualization: N.T.K.; All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.3. Funding

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6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

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.

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