

Article

Key Factors Influencing Fintech Development in ASEAN-4 Countries: A Mediation Analysis

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Abstract: Financial technology (FinTech) rapidly transforms financial landscapes across ASEAN-4 countries by enhancing financial inclusion and digital service accessibility. However, the key factors driving FinTech development in these economies remain ambiguous. While existing studies highlight the economic and technological aspects of FinTech adoption, limited research distinguishes the unique conditions shaping FinTech's evolution in developing ASEAN markets. This study bridges this gap by identifying economic and non-economic determinants and exploring their mediating effects. This research aims to investigate the primary drivers of FinTech development in ASEAN-4, emphasizing the roles of financial access and technological readiness as mediators in fostering a sustainable FinTech ecosystem. Utilizing structural equation modeling (SEM) with SmartPLS3, this study analyzes secondary data from 2008 to 2018, evaluating macroeconomic indicators, banking conditions, internet penetration, innovation levels, population dynamics, and human development factors. General banking conditions, access to finance, and technological readiness significantly impact FinTech development. Additionally, financial accessibility and technological infrastructure mediate the influence of economic stability, innovation, and digital penetration on FinTech growth. This study underscores policymakers' and stakeholders' need to enhance digital infrastructure and financial accessibility to accelerate FinTech growth. Strengthening financial ecosystems will drive digital transformation and economic resilience in emerging ASEAN economies.



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1. Introduction

The advancement of the internet and communication technologies, particularly smartphones, has fueled the growth of e-commerce and financial technology (FinTech). This has led to various innovations and the involvement of new stakeholders in payment processing [1]. FinTech integrates digital innovations to create lasting value, provide firms with competitive advantages, reduce operational costs, expand customer reach, and improve risk management efficiency [2]. Moreover, it has significantly impacted financial markets by reshaping capital flows, reducing information asymmetry, and addressing problems such as moral hazard and adverse selection [3].

FinTech is increasingly recognized as a transformative force in global banking and finance, influencing billions of people and economies worldwide [4]. A well-developed FinTech ecosystem—defined as the broader enabling environment that supports FinTech growth, including infrastructure, regulation, innovation networks, financial institutions, and consumer readiness—can attract talent, inspire innovation, and foster growth across financial subsectors including electronic payments, wealth management, trading platforms, insurance, and regulatory compliance [5]. During the COVID-19 pandemic, FinTech played a vital role in delivering targeted fiscal support, especially to unbanked populations, while reducing the need for physical transactions [6]. Given this critical role, understanding the key drivers of FinTech development—referring specifically to the measurable growth and adoption of FinTech products and services—is vital for stakeholders seeking to promote inclusive financial innovation.

Within the ASEAN region, FinTech has witnessed remarkable growth. In 2018 alone, FinTech investment surged by over 40%, making it one of the fastest-growing digital finance markets globally [7]. The region's low levels of traditional banking penetration, openness to digital solutions, and strong government support have contributed to this expansion [8,9]. FinTech services such as crowdfunding, neobanks, and InsurTech are rapidly scaling due to entrepreneurial momentum and increased investor confidence [10]. According to Karim et al. [11], ASEAN's USD 2.3 trillion market and 600 million consumers present vast business opportunities, with 76% of surveyed FinTech executives identifying the region's large client base as their primary motivation for entry. ASEAN's strong focus on digital transformation and financial inclusion continues to support its position as a regional FinTech hub.

Despite this upward trajectory, the literature reveals limited research that systematically examines the determinants of FinTech development in ASEAN's developing economies. The driving factors for FinTech development are highly varied [12], encompassing a broad spectrum of elements that collectively contribute to the sector's growth. However, prior studies often emphasize global or developed markets, offering limited insights into the structural conditions of middle-income Southeast Asian nations. For instance, Haddad and Hornuf [13] studied economic and non-economic influences on FinTech but did not distinguish between levels of national development. Similarly, Anh [14] analyzed the Vietnamese FinTech sector, using Singapore as a benchmark. However, drawing on Singapore's advanced FinTech landscape may not reflect the economic realities or institutional readiness of a developing country like Vietnam.

This study aims to fill that gap by focusing specifically on the key economic and non-economic factors influencing FinTech development in five middle-income ASEAN countries: Indonesia, Malaysia, Thailand, the Philippines, and Vietnam. These countries, while diverse in structure, share similar economic status and face comparable challenges in their efforts to advance digital finance. Furthermore, this research explores the mediating roles of access to finance, technological readiness, and the human development index (HDI) to better understand how broader economic and institutional factors influence FinTech development. Through this approach, this study seeks to provide a clearer picture of the mechanisms that drive FinTech growth in developing economies and to generate context-sensitive insights that can inform policy, investment, and ecosystem strategies across the region.

This research contributes practically by offering region-specific evidence to guide policymakers, regulators, and FinTech stakeholders in strategic decision making. Theoretically, it expands on the existing literature by introducing a mediation analysis framework to explore indirect relationships often overlooked in FinTech studies. By examining both direct and mediated pathways, this study advances our understanding of how FinTech

ecosystems emerge and scale in the context of emerging economies—an area that remains underexplored in the current academic discourse.

2. Literature Review

2.1. FinTech Development

FinTech has long been a central topic of discussion in the financial industry, political and regulatory circles, and academic research. In the decade since the financial crisis, FinTech startups have introduced innovative solutions to traditional banking, insurance, and asset management, using advanced technology to address issues in financial services, particularly in customer experience and insight [1]. FinTech involves using digital technologies in financial services, fundamentally redefining how financial entities operate [3]. This transformation presents both challenges and opportunities, offering greater flexibility, enhanced functionality in certain banking areas, and service aggregation [15,16].

As newcomers to the financial industry, FinTechs emerged due to specific triggers. Theories related to FinTech evolution factors [17–20] identify these triggers as divided into two categories: the demand side, which includes shifts in consumer preferences and technological evolution, and the supply side, which involves changes in market structure. This dual influence highlights the dynamic nature of FinTech development and underscores the importance of understanding the multifaceted factors driving its growth.

In this study, the factors examined as FinTech development drivers encompass economic and non-economic elements. Economic factors include macroeconomic indicators, general banks' conditions, and finance access. These aspects play a crucial role in shaping the financial landscape in which FinTech companies operate, influencing their ability to secure funding, scale their operations, and integrate into existing financial systems. On the other hand, there are non-economic factors such as internet usage, the level of innovation, technological readiness, total population, and the human development index. This dual focus on economic and non-economic elements highlights the complex interplay of conditions that foster the growth of FinTech.

2.2. Macroeconomic Indicator

Macroeconomic indicators such as gross domestic product (GDP) and inflation play pivotal roles in the development of FinTech. Yartey [21] highlights that income levels, particularly GDP, serve as a strong proxy for capital market development. This view is supported by Haddad and Hornuf [13] which reveals that GDP is a key element in forming the economic development ecosystem that triggers the emergence of FinTech in a country. In advanced economies and capital markets, the demand for FinTech startups is significantly greater due to better access to the necessary financing for their growth and development. Additionally, individuals in these developed economies are more likely to require services such as asset management and financial education tools [13].

In Lithuania, GDP and the financial stability of banks exert a notably strong influence on the growth of the FinTech sector, as demonstrated by Taujanskaitė and Kuizinaitė [22]. Mustafa et al. [23] also emphasized that a stable macroeconomic environment is crucial for the sound functioning of the financial sector, with key indicators such as GDP significantly affecting financial inclusion. Aggarwal and Goodell [24] found that GDP per capita, urbanization, trade, and financial inclusion are strong determinants of mobile phone technology adoption, a key enabler for FinTech services.

Research by Bobbo et al. [25] in the USA shows that while economic growth positively influences FinTech development, inflation has a negative impact. This is because high inflation rates can erode purchasing power and create economic instability, which is detrimental to the growth of FinTech services. Conversely, Mumtaz and Smith [26] found that inflation

significantly influences FinTech by driving the increased use of foreign exchange products, particularly in countries with less stable currencies.

Economic theories suggest that favorable economic conditions lead to an increased demand for credit, which in turn fosters the development of the FinTech credit market. Wang et al. [27] indicated that as the economy grows and GDP per capita rises, the demand for credit from both traditional banks and FinTech platforms increases. Their research also shows that economic and technological development indicators boost FinTech credit, with economic indicators having a stronger positive effect in countries with lower inflation rates.

Moreover, GDP is directly linked to mobile technology, as businesses utilize mobile technology to facilitate transactions, potentially enhancing FinTech development and boosting production activities within a country [26]. A well-developed economic environment is essential for vibrant FinTech development, as factors such as economic growth, policy, tax rates, ease of doing business, and costs influence FinTech companies. These companies tend to locate where these conditions best meet their business needs due to their high international mobility [28].

2.3. Condition of General Bank

FinTech is revolutionizing the competitive landscape of the banking industry, disrupting traditional value chains of financial institutions [29]. Over the past decade, the banking sector has experienced declining profitability due to reduced leverage, fee income, and net interest margins. These trends, accelerated by the 2008 financial crisis, have coincided with advances in digital technology that have increased competitiveness by enabling mobile service distribution [30].

Research by Haddad and Hornuf [13] highlights that the health of general banks in a country significantly influences FinTech development. To address the challenges posed by technology-driven firms, banks are adopting innovations from FinTechs to gain new advantages. They have established FinTech incubators and accelerators to foster innovation while retaining control through minority stakes in these developed or supervised firms [31].

Research by Taujanskaitė and Kuizinaite [22] also shows that the financial stability of banks plays a crucial role in the growth of the FinTech sector. Banks are actively engaging with FinTech companies by launching incubation programs, establishing venture funds, and forming strategic partnerships [15]. Collaborating with FinTech startups can help banks improve existing business models, especially as the financial services industry transitions from traditional banking to shadow banking [32,33].

A robust banking system and openness to financial innovations create significant opportunities for FinTech growth [34]. Cornelli [35] have found that FinTech credit is more advanced in countries with lower levels of banking intermediation and coverage. While banks negatively impact FinTech development in developing countries, they positively influence it in developed nations. In developed financial markets, banks with significant market power are likely to collaborate with FinTech companies, viewing them not as threats but as sources of innovation and consultancy. This collaboration leads banks to support FinTech development through specialized accelerators or startups [36].

2.4. Internet Use

The advancement of information and communication technology (ICT), especially the Internet of Things, is significantly impacting various facets of human life and business transformation [37]. Internet usage is a crucial medium connecting FinTech companies with customers, influencing the marketing and operational capabilities of these firms. Kowalewski and Pisany [36] found that higher internet usage in a country enhances FinTech marketing opportunities, demonstrating a positive impact of technology-related factors

on FinTech development. Their research indicated that the coefficients for mobile-cellular telephone usage and fixed broadband subscriptions are positive and statistically significant.

The proliferation of smartphones and improved internet speeds have enabled the real-time delivery of financial services to customers via mobile devices, further boosting FinTech adoption [1]. Haddad and Hornuf [13] identified that the number of internet users and customers significantly stimulates FinTech development. The ability to leverage big data and advanced analytics, powered by internet connectivity, allows FinTech companies to offer personalized financial solutions and improve risk assessment models. Secure internet servers and widespread mobile phone usage create a robust infrastructure for FinTech startups to flourish [13].

The positive correlation between internet usage and FinTech growth is also evident in the way that digital platforms facilitate broader financial inclusion. Sahay et al. [6] observed that enhanced digital infrastructure, characterized by widespread internet access and mobile phone penetration, leads to increased adoption of digital payment systems and credit services. This digital ecosystem not only supports existing financial institutions in reaching underserved populations but also empowers new FinTech entrants to introduce innovative products and services. Consequently, countries with higher internet penetration rates are better positioned to harness the benefits of FinTech innovations, driving economic growth and improving financial accessibility for their populations.

2.5. Level of Innovation

Innovation serves as a fundamental driver of FinTech development, influencing the financial sector in numerous ways. The innovation ecosystem presents both opportunities and threats, as noted by Adner [38], emphasizing that while financial innovation can enhance service offerings, it also disrupts traditional financial systems. FinTech is a direct output of such innovation, embodying modern financial services that leverage technological advancements to meet the evolving needs of consumers and businesses.

The evolution of FinTech has garnered significant attention over time due to the dual nature of financial innovation—creating new opportunities while posing challenges to the existing financial industry [38]. Innovation in FinTech can take various forms, including technical, commercial, organizational, social, and financial. Specifically, financial innovation emerges from the growth of FinTech companies, which introduce novel solutions to enhance efficiency, accessibility, and personalization in financial services [39].

Gao [40] indicates that the innovative capacity of a region significantly influences its FinTech development. For instance, higher mobile phone subscriptions and well-developed communication infrastructure are crucial determinants of FinTech growth, as highlighted by Stolbov and Shchepeleva [12]. Their findings suggest that regions with a greater propensity for innovation are more likely to foster a thriving FinTech market. Additionally, Gao [40] points out that a high volume of innovations and a strong innovative capacity are key drivers of FinTech advancement in the United States, underscoring the importance of an innovation-rich environment for the sector's development.

Innovation can promote financial inclusion by creating more accessible and user-friendly financial services. The development of mobile banking, peer-to-peer lending platforms, and digital payment systems exemplifies how innovative solutions can address the needs of underserved populations. Sahay et al. [6] highlighted that innovations in digital infrastructure are strongly linked to increased use of FinTech services, particularly in regions with limited traditional banking infrastructure.

2.6. Total Population

Total population plays a critical role in shaping the scope and scalability of FinTech development, especially in emerging economies. A larger population base implies a greater potential market for financial services, offering FinTech companies opportunities to expand and diversify their user base [41]. This demographic potential is particularly significant in developing countries, where traditional banking infrastructure often remains inaccessible to large segments of the population. As such, FinTech services can bridge the financial inclusion gap by reaching unbanked and underbanked communities [42].

Moreover, total population is not merely a quantitative measure—it reflects underlying demographic characteristics that can influence FinTech adoption. For instance, younger populations tend to be more tech-savvy and open to digital solutions. The FinTech 3.5 stage, as described by Haddad and Hornuf [13], highlights emerging economies with large youth segments, rising mobile penetration, and growing demand for convenience over traditional financial norms. These populations are often more responsive to the user experience and accessibility that FinTech platforms offer. Additionally, in developing countries where physical banking infrastructure may be limited or deteriorating, FinTech solutions serve as vital alternatives [16].

Rapid population growth also creates both challenges and opportunities. On one hand, it places pressure on financial systems to expand inclusion efforts. On the other hand, it allows FinTech firms to leverage alternative data and advanced analytics to serve customers lacking formal credit histories [43]. As more people in growing urban areas gain access to mobile devices and internet connectivity, the demand for seamless, digital financial services increases. This trend is especially pronounced among younger demographics, who are often key drivers of digital financial transformation [44–46].

Although the prior literature has not always found a direct or consistent relationship between total population and FinTech development, its role as a foundational market condition in developing economies remains important. In this study, total population is retained as a predictor variable due to its theoretical relevance in framing demand-side market potential and digital adoption readiness.

2.7. Access to Finance

Access to finance is a pivotal factor in the development and growth of the FinTech sector. Kowalewski and Pisany [36] highlight that improving access to finance can substantially enhance FinTech development. Long-term growth in the FinTech sector necessitates facilitating access to financing, as securing funding for expansion remains a major hurdle for scaling up businesses [47]. This is particularly true in developing countries, where financial institutions are difficult to access, and mobile payment services have emerged as vital tools for financial inclusion [48].

Haddad and Hornuf [13] emphasize that access to financing is critical for promoting the formation of FinTech companies and serves as an indicator of financial market development. When traditional bank financing is obstructed, companies often seek alternative funding sources, such as FinTech platforms, to grow their businesses. Research by Kliber [34] indicates that the determinants of FinTech funding are similar to those of other startups, though entrepreneurs in emerging markets face greater constraints due to uncertainties and limited credit availability. Ensuring adequate access to finance is fundamental to fostering a robust and dynamic FinTech ecosystem, especially for startups and young companies that may struggle to raise capital during crises [34].

In this study, access to finance is also examined as an important mediating variable in the relationship between macroeconomic indicators, condition of general banks, and FinTech growth. As noted by Haddad and Hornuf [13], access to financing can stimu-

late the formation of FinTech firms, suggesting that favorable economic indicators can create an environment where financial institutions are more willing to provide necessary funding. Beck et al. [49] found that national economic indicators, including inflation and economic growth, significantly influence companies' ability to secure financing from banks, particularly for small and medium-sized enterprises. Similarly, Aggarwal and Goodell [24] identified GDP as a critical determinant of access to capital financing, venture capital, and debt. A stable economy enhances trust, reducing financing obstacles and facilitating smoother access to financial resources for businesses, which in turn can drive FinTech development by providing the necessary capital for innovation and growth.

Furthermore, this research explores how access to finance mediates the relationship between the condition of general banks and FinTech development. Aggarwal and Goodell [24] also explored how the health and quality of bank credit determine the ease of financing access. The stability and quality of banks influence their capacity to extend credit, with healthier banks more likely to distribute greater amounts of financing, whether in the form of ventures, capital, or debt. When banks are financially robust, they can better support the financial needs of businesses, including those in the FinTech sector. This mediating role of access to finance highlights the importance of a stable banking system in fostering a supportive environment for FinTech innovation and expansion, emphasizing the need for policies that strengthen both economic stability and banking health to promote FinTech development.

2.8. Technology Readiness

Technology readiness is a pivotal factor in the development of FinTech. Recent studies indicate that the digital revolution has fundamentally transformed financial markets and services, fostering substantial growth in the FinTech sector [50,51]. Kliber et al. [34] found that these technological factors have positively impacted the sector, underlining the importance of robust technological infrastructure for FinTech development.

Emerging technologies such as artificial intelligence, big data, blockchain, and cloud computing have driven rapid advancements in FinTech [52]. Research by Wang et al. [27] highlights the critical role of technological infrastructure in FinTech growth, demonstrating that improved network facilities, including grassroots internet sites and expanded coverage, enable remote areas to benefit from the internet, thereby strengthening the foundation for FinTech development. Additionally, the correlation between technology readiness and FinTech growth is evident as FinTech companies leverage advanced technology and data analytics to target niche markets, enhance consumer satisfaction, and cater to lower-income groups [6].

Countries with strong information and communications technology (ICT) service clusters and overall ICT readiness experience more rapid FinTech formation, as globally competitive ICT providers attract FinTech entrepreneurs and accelerate industry growth [53]. The availability of the latest technology in an economy is another key driver of FinTech demand. FinTech startups depend on these technologies to develop faster payment services, streamline operations, enhance information sharing, and reduce banking transaction costs [13].

This research also examines technology readiness as a mediating variable in the relationship between internet use, level of innovation, and FinTech development. Manyika and Roxburgh [37] emphasized that internet usage is foundational to a country's technological infrastructure ecosystem, facilitating business transformation and enhancing technological readiness. The proliferation of internet access enhances the ability of FinTech companies to offer their services more effectively. When coupled with high technology readiness, which includes secure internet services and advanced network infrastructure, the positive impact of internet use on FinTech development is significantly amplified. The availability and use of the internet form the backbone of technological readiness, enhancing the positive effects of internet usage on FinTech development [54].

Innovation, encompassing advancements in artificial intelligence, blockchain, big data, and cloud computing, is a driving force behind FinTech growth. However, the successful implementation and scaling of these innovations depend heavily on the technological infrastructure available. Razavi et al. [54] found that the availability of the latest technology, internet customers, and the absorption of company technology are pivotal in enhancing technological readiness. Hence, regions with high technological readiness are better equipped to support and benefit from innovative FinTech solutions, making the relationship between innovation and FinTech development more robust [52,53].

2.9. Human Development Index

The human development index (HDI) is a composite indicator reflecting a country's average achievements in health, education, and standard of living—key dimensions that influence digital adoption and financial inclusion capacity [55]. In the context of FinTech, the HDI serves as a proxy for human capital quality, which is a critical driver of innovation, technological absorption, and entrepreneurship.

Higher HDI levels are typically associated with more educated and digitally literate populations, capable of adopting and engaging with FinTech services. Several studies have demonstrated the link between human development and mobile technology adoption, a core infrastructure for digital finance [24]. In countries with emerging markets and micro-enterprise structures, the HDI supports both supply and demand dynamics in FinTech: it enhances consumer readiness while also improving the quality of FinTech startup teams, which in turn increases their attractiveness to investors [47,56].

The HDI also reflects a country's institutional and policy environment. Strong education systems, flexible labor markets, and supportive public infrastructure contribute to a talent pool that FinTech firms can leverage for growth [28,57]. Therefore, the HDI is not only an outcome of socio-economic development but also a key enabler of technological transformation in the financial sector.

This study further explores the HDI as a mediating variable between total population and FinTech development. As population size increases, pressures on public services—such as education and healthcare—can negatively impact HDI outcomes, particularly in low- and middle-income countries. Zgheib et al. [58] and other scholars have shown that population growth can correlate with lower HDI scores due to resource constraints, thereby indirectly affecting FinTech readiness. By including the HDI as a mediator, this study aims to understand how human development conditions amplify or moderate the impact of population dynamics on FinTech growth in the ASEAN context.

2.10. Theoretical Framework and Hypotheses

FinTech has emerged as a transformative force in the financial sector, redefining traditional banking, payment systems, and financial services. As FinTech development gains momentum in ASEAN-4 countries and Vietnam, it is essential to understand the underlying factors that drive its expansion. This study integrates economic and non-economic perspectives to examine FinTech growth, emphasizing the mediating role of financial access, technological readiness, and the human development index.

Economic factors such as macroeconomic indicators, banking conditions, and access to finance shape the financial environment in which FinTech operates. Simultaneously, non-economic factors, including internet penetration, innovation levels, population dynamics, and human development, contribute to technological adoption and digital transformation. The proposed research model (Figure 1) explores these relationships, hypothesizing direct and mediated effects on FinTech development. The hypotheses formulated in this study

provide a structured framework for examining these linkages, offering insights into the mechanisms that drive FinTech growth in emerging economies.

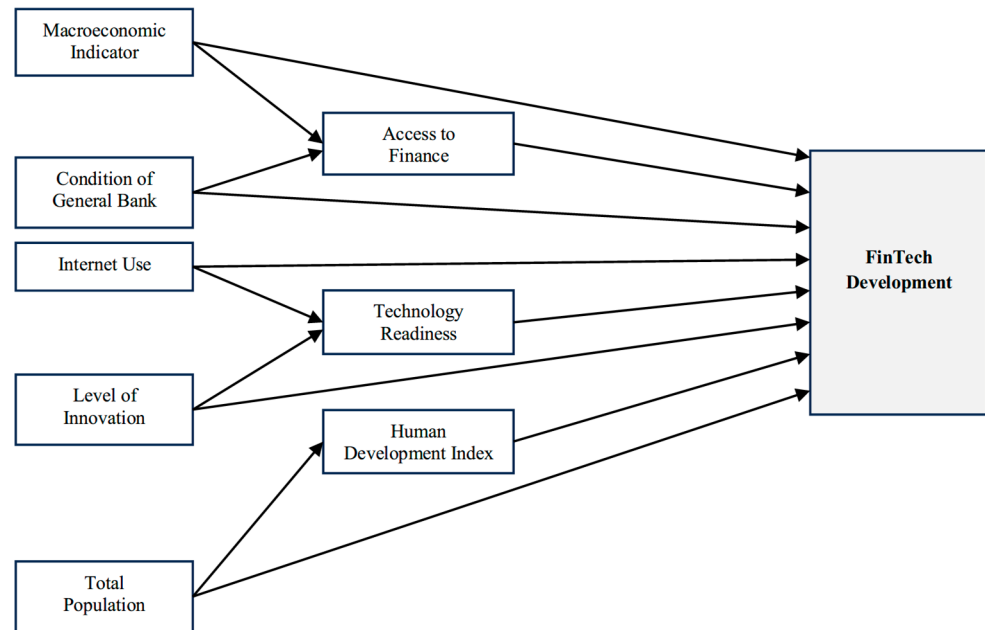


Figure 1. Conceptual framework showing direct and mediated relationships influencing FinTech development in ASEAN-4 countries.

- H1.** *Macroeconomic indicators positively influence access to finance;*
- H2.** *Macroeconomic indicators positively influence FinTech development;*
- H3.** *The condition of the general bank positively influences access to finance;*
- H4.** *The condition of the general bank positively influences FinTech development;*
- H5.** *Internet use positively influences technology readiness;*
- H6.** *Internet use positively influences FinTech development;*
- H7.** *Level of innovation positively influences technology readiness;*
- H8.** *Level of innovation positively influences FinTech development;*
- H9.** *Total population negatively influences the human development index;*
- H10.** *Total population negatively influences FinTech development;*
- H11.** *Access to finance positively influences FinTech development;*
- H12.** *Technology readiness positively influences FinTech development;*
- H13.** *The Human Development Index positively influences FinTech development;*
- H14.** *Access to finance mediates the relationship between macroeconomic indicators and FinTech development;*

H15. Access to finance mediates the relationship between the condition of the general bank and FinTech development;

H16. Technology readiness mediates the relationship between internet use and FinTech development;

H17. Technology readiness mediates the relationship between the level of innovation and FinTech development;

H18. The human development index mediates the relationship between total population and FinTech development.

3. Materials and Methods

3.1. Research Materials

This study focuses on the ASEAN-4 countries—Indonesia, Malaysia, Thailand, and the Philippines—along with Vietnam. These countries were selected due to their classification as developing nations and similar middle-income status. This study utilizes secondary data from publicly available and published reports, covering the period from 2008 to 2018. Detailed proxy measurements for each variable and their corresponding data sources are outlined in Table 1.

Table 1. Summary of variable measurement.

Variable	Measurement	Source
Macroeconomic indicator	(1) Gross domestic product (GDP) (2) Inflation rate	World Bank, World Development Indicators World Bank, World Development Indicators
Condition of general bank	(1) Growth of commercial banks (2) Bank health level	World Economic Forum (WEF), The Global Competitiveness Report International Monetary Fund (IMF) The Financial Access Survey
Internet use	(1) Number of internet users (2) Broadband internet subscribers	World Economic Forum (WEF), The Global Competitiveness Report World Bank, World Development Indicators
Level of innovation	Level of technological innovation	World Economic Forum (WEF), The Global Competitiveness Report
Total population	Total population	World Bank, World Development Indicators
Access to finance	Venture capital financing.	World Economic Forum (WEF), The Global Competitiveness Report
Technology readiness	Technology readiness	World Economic Forum (WEF), The Global Competitiveness Report
Human development index	Human development index (HDI)	United Nations Development Programme (UNDP), Human Development Reports
FinTech development	Number of FinTech companies	Publication of each country's website

Three composite variables are used in this study: macroeconomic indicators, the condition of general banks, and internet use. Composite variables combine two or more related measures to enhance statistical analysis and interpretation [59]. The use of composite variables is a common practice to control the Type I error rate, handle multicollinearity in regression analysis, or organize multiple highly correlated variables into more digestible or meaningful information [60]. These composite variables are calculated based on index values provided by the Indonesian Central Statistics Agency, following the methodology established by the UNDP. The composite index formula is expressed as follows:

$$\text{Composite Variable} = \sqrt[n]{\text{Index X}(1) \times \text{Index X}(2) \dots} \quad (1)$$

Each component index ranges between 0 (worst condition) and 1 (best condition). The values are rescaled to a range of 0 to 100 to enhance interpretability, as recommended by the Indonesian Central Statistics Agency. The component indices are calculated using the following formula:

$$\text{Index } X(i) = \frac{X(i) - X(i)\min}{X(i)\max - X(i)\min} \quad (2)$$

where

$X(i)$: Indicator-I;

$X(i)\max$: Maximum value $X(i)$;

$X(i)\min$: Minimum value $X(i)$.

3.2. Research Methods

To analyze the data, this study begins with descriptive statistical analysis to summarize the characteristics of the observed variables. Table 2 presents values for mean, median, minimum, maximum, standard deviation, and coefficient of variation. These indicators provide an overview of the distribution and variability of each variable included in the structural model.

Table 2. Descriptive statistics for all observed variables used in the SEM analysis.

Variable	Mean	Median	Minimum	Maximum	Standard Deviation	Variance Coefficient
Macroeconomic indicator (Index)	0.262291	0.223877	0.000000	0.689103	0.158248	0.025042
Condition of general bank (Index)	0.286365	0.304157	0.000000	0.813720	0.233322	0.054439
Internet use (Index)	3.649091	3.500000	2.700000	4.900000	0.578911	0.335138
Level of innovation (Index)	3.765455	3.900000	2.300000	4.800000	0.718336	0.516007
Total population (Item)	107,769,162	90,753,472	27,236,006	267,663,435	76,775,673	5,894,504,024,873,580
Access to finance (Index)	0.388732	0.363510	0.000000	0.853706	0.263182	0.069265
Technology readiness	3.796364	3.600000	3.000000	5.000000	0.495522	0.245542
HDI (Index)	0.710182	0.694000	0.640000	0.810000	0.046911	0.002201
FinTech development (Index)	0.180544	0.122098	0.000000	1.000000	0.192964	0.037235

For hypothesis testing, this study applies structural equation modeling (SEM) using SmartPLS 3.3 software. SEM is particularly suitable for analyzing complex models that involve multiple relationships among variables, including both direct and indirect effects. It allows simultaneous estimation of structural paths and provides insight into the mediating mechanisms included in the model.

Given that this study relies entirely on secondary data sourced from standardized, published databases, a formative measurement model is used rather than the more common reflective model. In a formative model, each indicator is assumed to contribute uniquely to the meaning of the latent construct, rather than being caused by it. This is appropriate in macro-level research where constructs such as access to finance, technological readiness, and macroeconomic indicators are represented by composite or single indicators derived from validated indices.

All constructs in this study are measured using single indicators derived from validated and publicly available secondary data sources. While SEM typically favors multi-indicator constructs, the use of single-item measures is justified in this context due to the macro-level nature of the research and the availability of standardized proxies. In a formative modeling approach, single indicators are appropriate when they directly represent the theoretical construct and are based on reliable empirical data. Each indicator used in this study reflects a distinct aspect of FinTech development or its determinants and aligns with how these concepts are operationalized in economic and policy-oriented research.

As the model is formative and based on index-level variables, this study does not estimate a separate measurement model (as is standard in reflective SEM). Instead, the analysis focuses on evaluating the structural model, assessing explanatory power through R^2 values, predictive relevance using Q^2 , and the strength of effects using f^2 .

4. Results

4.1. Structural Model Evaluation

The structural model evaluation was conducted to assess the strength of the relationships between latent variables and to determine the influence between variables in the model. The model's explanatory power was first evaluated using R-square and Q-square values, which indicate the coefficient of determination and predictive relevance, respectively. As shown in Table 3, macroeconomic indicators and the condition of general banks explain 44.1% of the variance in access to finance. Internet use and the level of innovation account for 46.3% of the variance in technological readiness. The total population explains 35.5% of the variance in the human development index. All independent variables collectively explain 68.5% of the variance in FinTech development. The Q-square values for all models are greater than 0, confirming their predictive relevance.

Table 3. R-square and Q-square values.

Variable	R-Square	Q-Square
Access to finance	0.441	0.427
Technology readiness	0.463	0.129
Human development index	0.355	0.352

The f-square effect size was also examined to determine the magnitude of influence that independent variables have on dependent variables. Following the categorization by Hair et al. [61], the effect sizes of 0.02, 0.15, and 0.35 correspond to small, moderate, and large influences, respectively. As detailed in Table 4, macroeconomic indicators have a moderate influence on access to finance, while the condition of general banks exerts a large influence. Similarly, the level of innovation has a moderate effect on technological readiness, whereas internet use has a large effect. The total population significantly influences the human development index. Among all variables influencing FinTech development, the condition of general banks and access to finance demonstrate a moderate effect, whereas other factors exhibit a small effect size.

Table 4. Effect size f-square.

Variable	Access to Finance	Technology Readiness	Human Development Index	FinTech Development
Macroeconomic indicator	0.258			0.003
Condition of general bank	0.404			0.158
Internet use		0.569		0.003
Level of innovation		0.168		0.038
Total population			0.551	0.006
Access to finance				0.149
Technology readiness				0.116
Human development index				0.034

4.2. Direct Effect Hypothesis Test

The hypothesis testing results for direct effects (Table 5 and Figure 2) confirm that macroeconomic indicators and the condition of general banks positively affect access to finance, supporting H1 and H3. Internet use and the level of innovation positively influence technological readiness, supporting H5 and H7. The total population negatively affects the human development index, supporting H9. Furthermore, only the condition of general

banks, access to finance, and technology readiness directly and positively impact FinTech development, supporting H4, H11, and H12.

Table 5. Direct effect hypothesis test.

Hypothesis	Path Coeff.	T-Statistic	p-Values	Decision
Macroeconomic indicator → Access to finance	0.385	3.982	0.000	Supported
Macroeconomic indicator → FinTech development	−0.050	0.286	0.775	Not Supported
Condition of general bank → Access to finance	0.482	5.301	0.000	Supported
Condition of general bank → FinTech development	0.319	2.385	0.017	Supported
Internet use → Technology readiness	0.560	6.693	0.000	Supported
Internet use → FinTech development	0.040	0.329	0.743	Not Supported
Level of innovation → Technology readiness	0.305	3.930	0.000	Supported
Level of innovation → FinTech development	0.195	1.269	0.205	Not Supported
Total population → Human development index	−0.596	9.517	0.000	Supported
Total population → FinTech development	0.084	0.519	0.604	Not Supported
Access to finance → FinTech development	0.316	2.496	0.013	Supported
Technology readiness → FinTech development	0.309	2.432	0.015	Supported
Human development index → FinTech development	−0.298	1.180	0.239	Not Supported

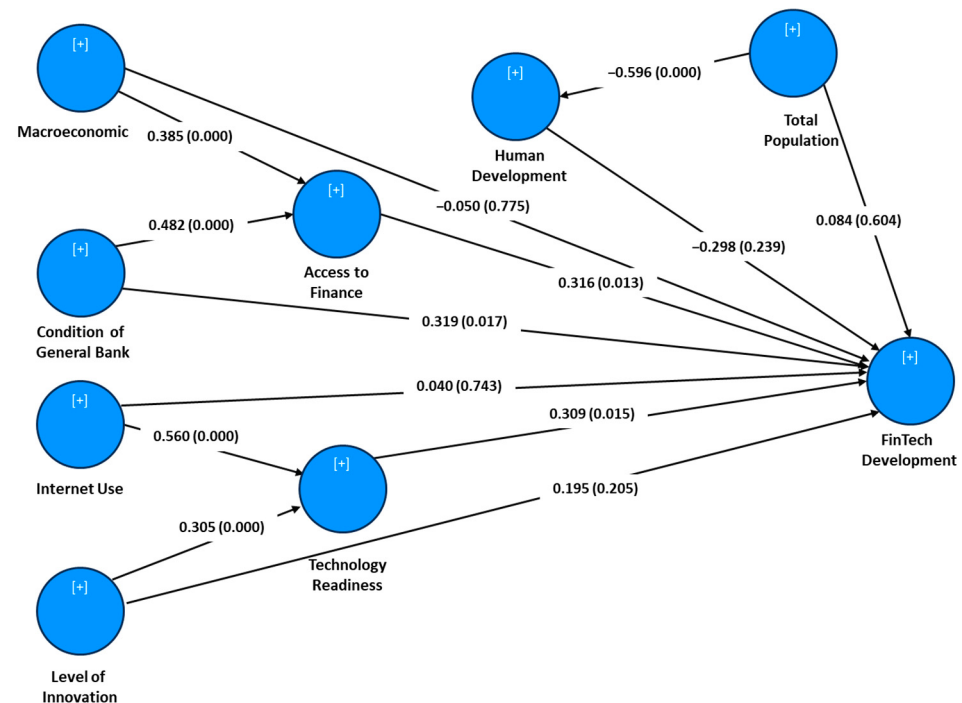


Figure 2. Hypothesis test results.

4.3. Mediation Hypothesis Test

Furthermore, the mediation hypothesis test results (Table 6) indicate that four out of five mediation hypotheses are significant (H14, H15, H16, and H17). Access to finance fully mediates the relationship between macroeconomic indicators and FinTech development and partially mediates the relationship between the condition of general banks and FinTech development. Technology readiness is proven to fully mediate the relationship between internet use and the level of innovation in FinTech development. The human development index cannot mediate the total population and FinTech development relationship.

Table 6. Mediation effect hypothesis test.

Hypothesis	Model	Path Coeff.	p-Values Direct Effect	p-Values Indirect Effect	Information
H14	(a) Macroeconomic indicator → Access to finance	0.385	0.000	0.042	a and b are significant, c is not significant = full mediation
	(b) Access to finance → FinTech development	0.316	0.013		
	(c) Macroeconomic indicator → FinTech development	−0.050	0.775		
H15	(a) Condition of general bank → Access to finance	0.482	0.000	0.017	a, b, and c are significant = partial mediation
	(b) Access to finance → FinTech development	0.316	0.013		
	(c) Condition of general bank → FinTech development	0.319	0.017		
H16	(a) Internet use → Technology readiness	0.560	0.000	0.028	a and b are significant, c is not significant = full mediation
	(b) Technology readiness → FinTech development	0.309	0.015		
	(c) Internet use → FinTech development	0.040	0.743		
H17	(a) Level of innovation → Technology readiness	0.305	0.000	0.034	a and b are significant, c is not significant = full mediation
	(b) Technology readiness → FinTech development	0.309	0.015		
	(c) Level of innovation → FinTech development	0.195	0.205		
H18	(a) Total population → Human development index	−0.596	0.000	0.253	a is significant, b and c are not significant = no mediation
	(b) Human development index → FinTech development	−0.298	0.239		
	(c) Total population → FinTech development	0.084	0.604		

5. Discussion

This research confirms the positive influence of the condition of general banks on FinTech development, aligning with prior studies [13,22,31]. Strong and stable banks create a conducive environment for FinTech growth by fostering innovation through incubators, accelerators, and strategic partnerships [13]. Banks also retain influence through minority stakes in FinTech startups and venture funding initiatives [22,31]. These findings reinforce the notion that traditional banks' health significantly impacts the FinTech sector's expansion.

In the era of digitalization, banks can transform potential threats from FinTech into opportunities by investing in infrastructure and skill development. Collaborations with FinTech startups—through service agreements, mergers, and acquisitions—further strengthen the financial ecosystem [39]. A well-capitalized and stable banking sector enhances public trust in financial institutions, indirectly supporting FinTech adoption by introducing financial literacy through traditional banking channels. Thus, a strong banking foundation facilitates FinTech proliferation, financial inclusion, and digital innovation.

This research highlights the critical mediating roles of access to finance and technology readiness in FinTech development. While macroeconomic indicators, internet usage, and innovation levels do not directly impact FinTech growth, their influence becomes significant when mediated by these factors. This finding underscores the necessity of policies that improve financial accessibility and technological infrastructure to sustain the FinTech sector in ASEAN-4 countries.

Access to finance significantly drives FinTech development, consistent with the findings of Kowalewski and Pisany [36], who emphasize that improving financial accessibility stimulates FinTech expansion. The ability to secure funding remains a critical challenge for scaling FinTech businesses [47]. This study supports Haddad and Hornuf [13], who argue that access to finance is not only vital for FinTech startups but also serves as an indicator of broader financial market development. Consequently, enhancing financial access fosters innovation, encourages entrepreneurship, and accelerates FinTech sector growth.

This research also finds that macroeconomic indicators influence FinTech development indirectly through access to finance. Economic factors such as inflation and growth shape

financial accessibility, with stable economies facilitating investor confidence and enabling smoother access to funding [49,62]. A favorable economic environment, characterized by strong policies, business-friendly regulations, and tax incentives, can attract both local and foreign investments in FinTech [28]. These factors collectively reduce financing barriers, creating an environment conducive to FinTech expansion.

The findings confirm that technology readiness plays a crucial role in FinTech development, aligning with prior research [13,34,53]. Countries with strong information and communications technology (ICT) infrastructures foster FinTech growth by attracting entrepreneurs and enabling digital transformation [53]. Wang et al. [27] further emphasize that technological infrastructure—such as internet coverage and network facilities—directly enhances FinTech adoption and innovation.

This research also establishes that technological readiness fully mediates the effect of internet usage on FinTech development. The most influential elements of technological readiness include the availability of advanced technology, internet penetration, and firms' abilities to integrate new technologies [54]. As digitalization accelerates, higher internet adoption enhances technological readiness, which subsequently fuels FinTech expansion [37].

Furthermore, technological readiness fully mediates the relationship between innovation and FinTech development. While innovation is crucial for financial technology advancements, its impact is significantly strengthened when a country possesses a strong technological infrastructure [52,53]. Without adequate ICT readiness, even the most innovative FinTech solutions face adoption barriers, highlighting the importance of digital infrastructure in supporting the sector's growth.

This study finds no significant effect of total population or human development index (HDI) on FinTech development. Although a larger population is often expected to drive FinTech adoption by increasing the customer base, the findings suggest that mere population size is insufficient to boost the sector without supporting financial and technological infrastructures.

Similarly, the HDI, which reflects a country's education, health, and living standards, does not directly correlate with FinTech development. While higher HDI levels could theoretically foster a more financially literate population, other factors—such as access to finance, technological readiness, and macroeconomic stability—play a more decisive role in shaping the FinTech landscape in ASEAN-4 countries. These results indicate that FinTech expansion requires an enabling ecosystem rather than simply demographic advantages or human capital improvements.

6. Conclusions

This research contributes to a deeper understanding of FinTech development in ASEAN-4 countries by identifying the significant roles of banking stability, access to finance, and technological readiness. While macroeconomic conditions, internet usage, and innovation do not exert a direct influence, their effects become substantial when mediated through access to finance and digital infrastructure. These findings underscore the importance of building financial and technological ecosystems that support the adoption and scaling of FinTech services.

Interestingly, this study challenges conventional assumptions regarding the direct impact of population size and human development on FinTech growth. The findings suggest that structural enablers—such as accessible financial services and digital readiness—play a more decisive role in fostering FinTech expansion than demographic or development metrics alone.

From a policy perspective, several practical implications emerge. First, governments should prioritize investment in digital infrastructure, especially in underserved regions, to close the connectivity gap that limits FinTech accessibility. Second, targeted financial inclusion policies—such as supporting mobile banking in rural areas or offering digital ID systems—can help integrate unbanked populations into the financial system. Third, encouraging partnerships between traditional banks and FinTech companies through regulatory incentives, sandboxes, or innovation hubs may accelerate collaborative innovation and reduce systemic resistance to change.

While this study offers valuable insights, it is subject to several limitations. First, the research relies solely on secondary data, which may vary in consistency and quality across countries and time periods. Second, the data span from 2008 to 2018 and, therefore, do not capture the rapid acceleration of FinTech development that occurred during and after the COVID-19 pandemic. Third, this analysis focuses on macroeconomic and structural variables, without incorporating institutional, regulatory, or micro-level behavioral factors—such as user trust, digital literacy, or privacy concerns—which are critical components of FinTech adoption. Finally, this study did not conduct regional sub-grouping analysis, which may limit its ability to capture country-specific differences in FinTech development within the ASEAN-4 region.

To build on the current findings, future studies could broaden the geographic scope to include additional ASEAN and non-ASEAN countries, enabling comparative analysis across various financial and regulatory environments. Incorporating institutional quality, regulatory frameworks, and behavioral variables such as consumer trust or tech-readiness could provide a more comprehensive understanding of FinTech adoption. Researchers are also encouraged to examine the post-COVID era, as the pandemic significantly altered digital finance trajectories across emerging markets. Finally, multi-group or country-level analysis could be used to explore the heterogeneity of FinTech development drivers across national contexts, offering more tailored policy guidance.

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