IMPACT OF GREEN BORROWING ON NATIONAL INNOVATION OF SELECTED ASEAN COUNTRIES: THE ROLE OF ECONOMIC GROWTH AND AGRICULTURAL SECTOR

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Abstract: ***This study examines the impact of green borrowing on national innovation across six ASEAN countries during 2018-2023. Using secondary panel data and the SmartPLS approach, the study differentiates the impacts of green bonds and green loans on national innovation through the mediating roles of economic growth and the agricultural sector. The results indicate that green bonds significantly promote economic growth and, in turn, strongly enhance national innovation. The effect of green loans on economic growth is mediated significantly through the value of the agricultural sector. These findings suggest that the environmental effectiveness of green finance depends on sectoral targeting and policy alignment to support innovation-driven sustainable development.***

• Keywords: *green borrowing, economic development, PLS, agricultural sector, national innovation, ASEAN.*

JEL codes: Q56, O16, O31

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1. Introduction

ASEAN is among the regions most affected by climate change globally. According to ADB (2021), ASEAN would experience an 11% reduction in GDP in 2100 without a climate change adaptation and mitigation plan. ASEAN has implemented a series of initiatives to facilitate green capital in the region. However, ASEAN's green capital remains minimal compared to that in developed regions. OECD (2025) indicates that the ASEAN green bond market accounts for less than 2.5% of global issuance, while the EU and North America account for more than 75%. ADB (2021) also emphasized that ASEAN needs at least USD 210 billion in green investment per year to meet the energy transition roadmap, while current mobilization capacity is only about 20-25% of the required level. This large gap underscores the urgent need for a deeper understanding of the transmission channels through which green finance drives economic growth and innovation—especially in ASEAN countries with markedly different market conditions and levels of financial and institutional development.

Although the number of studies on green finance worldwide has increased sharply in the past decade, most current work focuses on developed economies or markets with relatively complete green finance ecosystems, such as the EU, the US, and China (Tong et al., 2025; Ma et al., 2019; Pang et al., 2022). These studies have also failed to explain the transmission channels through which green borrowing—especially green bonds and green loans—drives economic growth and national innovation. Most international studies have assessed only the overall impact of green finance, without separating the relative roles of green bonds and green loans. Green bonds, market-based instruments, are typically characterized by greater transparency, broader investor participation, and external verification (Climate Bonds Initiatives, 2022), while green loans are usually smaller-scale, flexible, and easy to access (World Bank Group, 2021). Therefore, differentiating the impact of green bonds from that of green loans on national economic development and innovation will provide a comprehensive understanding of green finance in ASEAN. Moreover, the majority of green bond and green loan flows in the ASEAN region are mainly allocated to infrastructure, clean transport, and renewable energy (ADB, 2023; OECD, 2025), while the agricultural sector, playing a vital role in food security, food supply chain, and economic resilience to climate change, is neglected (Taniushkina et al., 2024). The existing literature on green finance in ASEAN does not adequately address the importance of the agricultural sector

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and its mediating role in the relationship between green finance and national innovation. Addressing these gaps, this study investigates the differential effects of green bonds and green loans on national innovation in ASEAN, with particular attention to the mediating roles of economic development and agricultural-sector dynamics.

2. Literature review and hypothesis development

2.1. The impact of Green Borrowing on National Innovation and the mediating role of Economic Development

Green finance has emerged as a key mechanism for addressing environmental challenges while promoting sustainable economic development. Within this domain, green borrowing comprising green bonds and green loans represents a form of debt-based financing aligned with environmental objectives and green taxonomies (Volz, 2018; Mohanty et al., 2023; Ning et al., 2023). It reflects both policy-driven financial interventions and market-based instruments that influence resource allocation and financing conditions (Li et al., 2025; Wang & Shao, 2024). As a form of financial innovation, green borrowing helps reduce information asymmetry, improve risk-sharing mechanisms, and enhance capital allocation efficiency (Wen et al., 2025; Laeven et al., 2009).

The relationship between financial innovation and national innovation capacity has been widely discussed in the literature. The endogenous growth framework suggests that financial innovation stimulates technological progress by lowering financing costs and increasing returns to R&D investment (Laeven et al., 2009; Michalopoulos et al., 2009). However, financial innovation may also generate trade-offs by increasing systemic risk, depending on institutional and economic conditions (Beck et al., 2016). From a systemic perspective, the national innovation systems (NIS) framework highlights the role of financial institutions in shaping innovation outcomes by directing resources toward high-risk, long-term projects (Lundvall, 1992; Nelson, 1993; Hall & Lerner, 2010). Green borrowing, therefore, can be understood as a financial innovation embedded within the NIS that supports environmentally oriented technological development (OECD, 2020).

From an environmental economics perspective, green borrowing influences innovation through both incentive-based and regulatory mechanisms. The theory of directed technical change posits that financial and policy incentives redirect innovation toward environmentally sustainable technologies (Acemoglu et al., 2012). In parallel, the Porter hypothesis suggests that environmental constraints can stimulate innovation by encouraging more efficient production and technological upgrading. By lowering the cost of capital for green investments and embedding environmental criteria into financial instruments, green borrowing supports eco-innovation and accelerates technological transformation.

Recent studies emphasize the importance of transmission channels in linking green finance to innovation outcomes. Green borrowing contributes to economic development by financing renewable infrastructure, energy-efficient technologies, and structural transformation (Liu & Li, 2025). This, in turn, enhances absorptive capacity by increasing investment in human capital, R&D, and innovation-supporting institutions (Cohen & Levinthal, 1990; Furman et al., 2002). However, the effectiveness of green finance also depends on sectoral allocation. Evidence suggests that green capital is not evenly distributed, with limited allocation to climate-sensitive sectors such as agriculture, despite their vulnerability (UNCTAD, 2021). This imbalance may reduce the overall effectiveness of green borrowing in promoting innovation.

Overall, prior studies indicate that green borrowing can influence national innovation both directly and indirectly through economic development and structural conditions. However, the existing literature lacks empirical evidence on how different green borrowing instruments operate through these channels in ASEAN economies, particularly regarding the mediating role of economic development.

Building on the above literature, this study aims to examine the impact of green borrowing on national innovation capacity in ASEAN countries, focusing on the mediating role of economic development. Our study combines the policy framework and financial market perspectives to develop a country-level definition of green borrowing. Green borrowing refers to debt-based financing for projects aligned with investors' green taxonomy. Green borrowing encompasses green loans (direct borrowing from international financial organizations) and green bond issuance (from both the public and private sectors).

The "green" characteristic of these financial sources highlights the innovative aspect of green borrowing compared to conventional lending.

In the ASEAN context, the Global Innovation Index findings further support the expectation that, once economies reach a sufficient level of development, targeted policies and structural reforms can amplify innovation performance. Therefore, it is plausible to hypothesize that higher levels of development enhance a country's capacity to generate and absorb innovation, suggesting that economic development acts as a mediating mechanism through which green borrowing influences national innovation capability.

H1: Green borrowing shows a significant impact on national innovation capacity, and the development level of an economy mediates this impact.

2. The impact of Green Borrowing on Economic Development and the transmission channel of the agricultural sector

Green borrowing plays an important role in promoting economic development by mobilizing capital toward environmentally sustainable activities. According to neoclassical growth theory, cumulative capital is a key driver of economic growth (Solow, 1956; Swan, 1956), and green borrowing contributes to this process by facilitating the transfer of green technologies, enhancing labor productivity, and supporting investment in environmentally aligned projects. By improving access to financial resources and reducing financing costs, green borrowing promotes sustainable economic activities that generate environmental benefits while supporting economic growth.

Empirical studies generally support the positive relationship between green finance and economic development. Scholtens (2006), Ning et al. (2022), and Praveen et al. (2025) find that green bonds and green loans contribute to economic growth by lowering financing barriers and increasing investment in environmentally beneficial sectors. Zhao et al. (2022) report similar findings for BRIC countries, emphasizing the role of green finance in supporting energy-efficiency investments. Green financing instruments also provide preferential financing conditions that reduce the cost of capital for green projects (Ning et al., 2022), while Wang et al. (2022) highlight their importance in economies with limited capital for the green transition. However, the impact of financial innovation is not uniformly positive. The endogenous growth model (Laeven et al., 2009) suggests that the effectiveness of green borrowing depends on the degree of sectoral dependence on external finance, whereas empirical studies (Kapidani & Luci, 2019; Beck et al., 2016) indicate that financial innovation may generate adverse effects through resource misallocation and sectoral bias.

The agricultural sector represents a critical but constrained channel in the relationship between green finance and economic development. In early stages of development, agricultural productivity supports economic growth by ensuring food security, releasing labor, and generating savings for industrial investment (Johnston & Mellor, 1961; Timmer, 2002). Empirical evidence confirms that agricultural value-added contributes significantly to GDP growth in low-income economies (Bravo-Ortega & Lederman, 2005; Christiaensen et al., 2011). However, as economies transition to higher income levels, this relationship may weaken or reverse, particularly when agricultural growth is driven by extensive production rather than technological upgrading, leading to structural inefficiencies and increased vulnerability to external shocks (Ramey & Ramey, 1995; Diao et al., 2010). In this context, sustainable development requires productivity-driven agricultural transformation integrated with technological progress and structural upgrading (World Bank, 2008).

From an environmental economics perspective, the effectiveness of green borrowing depends critically on sectoral allocation. In ASEAN economies, green finance remains concentrated in sectors such as energy, transport, and urban development, while agriculture receives only a marginal share of sustainable capital. The Climate Bonds Initiative (2019) reports that land-use sectors, including agriculture and forestry, account for approximately 3% of total green finance allocation, reflecting substantial underinvestment. Structural constraints, including high information asymmetry, weak environmental metrics, and limited collateral, further restrict agricultural access to green capital (Li & Wang, 2022). In addition, regulatory mechanisms such as green credit screening may unintentionally limit financing to sectors that are difficult to monitor, generating adverse short-term effects (Wang et al., 2020). Institutional factors reinforce this pattern, as the ASEAN Taxonomy prioritizes sectors with clearer emissions-reduction pathways, increasing

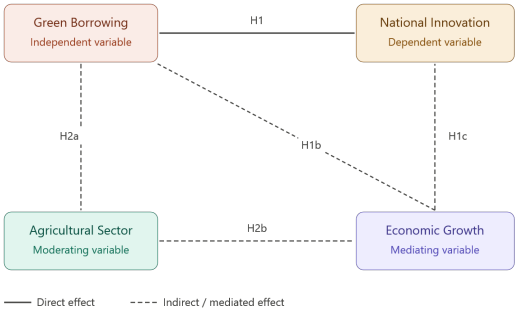
compliance costs and limiting absorptive capacity in agriculture (Nguyen & Phan, 2025).

Overall, the existing literature suggests that green borrowing promotes economic development, but its effectiveness is mediated by sectoral allocation, with agriculture serving as a constrained transmission channel. Structural biases in green finance may lead to underinvestment in climate-sensitive sectors, thereby weakening the contribution of green borrowing to sustainable and innovation-driven growth in ASEAN economies.

Given these structural financial biases and regulatory frictions, existing theory and empirical evidence strongly support the expectation of a negative relationship between green loans and agricultural development in ASEAN.

H2: Green borrowing has a positive direct impact on economic development; however, this impact is negatively mediated through agricultural sector development.

The conceptual framework of the study is shown below:



3. Data and Methodology

This paper examines the impact of green borrowing on national innovation in ASEAN countries, using secondary data on green borrowing across 6 ASEAN countries for the period 2018-2023. The dataset was collected from the Climate Bond Initiative, the World Bank, the World Intellectual Property Organization (WIPO), and from reports issued by these organizations. The Smart-PLS approach is used to examine the proposed hypotheses because it is particularly effective for analyzing data that do not meet the assumption of normality and for testing complex models with mediating effects. To improve the reliability of the estimate, a bootstrap procedure is applied.

Green bonds and green loans are treated as exogenous constructs, while economic growth (GDP per capita) and agricultural value added serve as mediating variables, and national innovation is proxied by the Global Innovation Index (GII).

Table 1. Explanation of variables in the empirical model

Variable	Type & Code	Determination	Data source
Green Bond	Formative, GB	This variable measures each country's annual issuance of green bonds. The study collects data on Green Bond issuance in each country (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam). Value is exchanged from local currency to USD.	Climate Bond Initiative
Green Loan	Formative, GL	This variable measures the annual issuance of Green Loans by each country. The study collects data on the issuance of Green Loans in each country (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam). Value is exchanged from local currency to USD.	Climate Bond Initiative
Agri_Value	Formative, Agri_Value	This variable measures the added value from agricultural, forestry, and fishery activities. Value is measured in USD and transformed into ln (Agri_Value)	World Bank Data
EG	Formative, GDP per capita	The sum of gross value added by all resident producers in the economy, plus any product taxes (less subsidies) not included in the valuation of output, divided by mid-year population. Growth is calculated using constant-price GDP data in local currency.	World Bank Data
Innovation	Formative, GII_Score	The Global Innovation Index (GII) is a comprehensive metric that measures a country's innovation capacity and performance. Score ranges from 0 to 100, with higher scores indicating stronger innovation ecosystems.	WIPO

4. Results and Discussion

The description statistics of variables are shown in the following table:

Table 2. Description Statistics of variables in the empirical model

Name	Mean	Median	Scale min	Scale max	Standard deviation	Excess kurtosis	Skewness
GB	868.099	502.550	0.000	4916.917	1223.774	4.720	2.241
GL	662.115	24.346	0.000	7822.569	1562.360	12.172	3.340
GDPca	17399.209	6913.051	3194.673	88428.702	26024.074	2.109	1.930
Agri_Value	23.543	24.348	18.480	25.695	2.299	1.190	-1.635
GII_Score	38.903	36.600	26.500	64.400	9.867	0.884	1.354

Table 4. Correlation matrix among these variables in the empirical models

	GB	GL	GDPca	Agri_Value	GII_Score
GB	1				
GL	0.4941***	1			
GDPca	0.6276***	0.7339***	1		
Agri_Value	-0.4503***	-0.7371***	-0.9665***	1	
GII_Score	0.4027**	0.6708***	0.9378***	-0.9682***	1

Note: (***) p-value <1%

Correlation analysis reveals strong positive relationships between GL and GDPca (r = 0.73) and between GII_Score and GDPca (r = 0.94), suggesting that wealthier, more innovative economies attract greater green finance. Conversely, Agri_Value exhibits strong negative correlations with GDPca (r = -0.97) and GII_Score (r = -0.97), confirming the inverse relationship between agricultural dependence and economic development. GB shows moderate positive correlation with GDPca (r = 0.63) but a weaker association with GII_Score (r = 0.40), indicating green bond markets may develop independently of innovation capacity.

The structural model was estimated using partial least squares structural equation modeling (PLS-SEM) with bootstrapping based on 5,000 resamples. Standardized path coefficients, p-values, and coefficient of determination (R^2) values are reported. The model explains 93.7% of the variance in National Innovation ($R^2 = 0.937$), 98.1% of the variance in Economic Growth ($R^2 = 0.981$), and 55.3% of the variance in Agricultural Value ($R^2 = 0.553$), indicating high explanatory power. Table 1 summarises the hypothesis testing results.

Table 5. Summary of Hypothesis Testing Results

Hypothesis	Path	β	p-value	Decision
H1	Green Bond → Innovation	−0.306	0.004***	Supported
H1b	Green Bond → Econ. Growth	−0.016	0.890	Not supported
H1c	Econ. Growth → Innovation	1.141	0.000***	Supported
H2a (GB)	Green Bond → Agri. Value	0.250	0.000***	Supported
H2a (GL)	Green Loan → Agri. Value	−0.681	0.006***	Supported
H2b	Agri. Value → Econ. Growth	−0.885	0.000***	Supported

*Note: *** p < 0.01; ** p < 0.05; * p < 0.10; ns = not significant. Coefficients are standardized; p-values derived from bootstrapping (5,000 samples).*

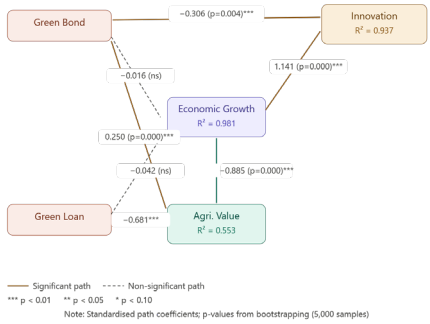


Table 5 presents the path analysis results for the structural model linking green borrowing to national innovation capability in ASEAN, with economic growth and agricultural value added as mediating variables. The findings partially support H1 and H2, revealing instrument-level heterogeneity between green bonds and green loans.

H1 - Direct effects on innovation. Green Bond issuance exerts a significant negative direct effect on national innovation (β = −0.306, p = 0.004), providing partial support for H1. The negative sign is consistent with the capital reallocation hypothesis: in ASEAN economies, green bond proceeds are predominantly directed toward infrastructure, transportation, and energy transition projects whose innovation spillovers materialize over longer horizons rather than within the sample period. In contrast, Green Loans have no significant direct effect on innovation, providing no support for H1 for this instrument. This result suggests that green loan volumes in ASEAN remain insufficient to shift national innovation capacity, or that loan-financed projects are compliance-oriented rather than technology-enhancing. The positive and highly significant effect of economic growth on innovation (β = 1.141, p < 0.001) corroborates national innovation system theory and absorptive capacity arguments, whereby wealthier economies accumulate the institutional quality, human capital, and infrastructure necessary to sustain innovative activity.

H1 - Mediated effects through economic growth. The indirect path Green Bond → Economic Growth → Innovation is positive and significant (β = 0.285, p < 0.01), supporting the proposition that bond-financed green investment — particularly in clean infrastructure, energy transformation, and green production systems — enhances innovation capacity through macroeconomic growth. No equivalent mediation is observed for green loans: the path Green Loan → Economic Growth → Innovation is statistically non-significant, indicating that bank-based green instruments have yet to generate sufficient macroeconomic momentum to drive innovation in ASEAN. This result raises broader concerns about the effectiveness of bank-based green capital. Despite advances in responsible banking frameworks, green lending by commercial banks remains constrained by credit risk aversion and a limited pipeline of bankable green projects, reflecting an unresolved trade-off between profitability and environmental responsibility.

H2 - Agricultural sector as mediator. Strong evidence supports the mediation role of agricultural value added. The significant negative effect of agricultural value on economic growth (β = −0.885, p < 0.01) is consistent with structural transformation theory: economies with a heavier reliance on agriculture exhibit lower aggregate productivity and growth potential relative to industry- and service-oriented counterparts. Green loans exert a significant negative effect on agricultural value added (β = −0.681, p < 0.01), while no significant effect is found for green bonds, reflecting the sectoral concentration of green bond proceeds in infrastructure and energy rather than agriculture. The negative impact of green loans on agricultural value added may reflect limited absorptive capacity within ASEAN's agricultural sector, constrained access to formal credit, and structural misalignment between green loan eligibility criteria and prevailing agricultural production systems.

The indirect pathway Agri_Value → Economic Growth → Innovation is negative and significant (β = −1.010, p < 0.01), confirming that dominance of the agricultural sector inhibits national innovation

capacity. However, the full chain Green Loan → Agri_Value → Economic Growth → Innovation is positive and significant (β = 0.687, p = 0.005), indicating that green loans indirectly support development and innovation by accelerating structural transformation away from agriculture. The analogous pathway through green bonds is statistically insignificant, consistent with the observation that green bond capital largely bypasses the agricultural sector in ASEAN.

5. Policy Implications

The findings carry several actionable implications for policymakers, regulators, and financial market participants in ASEAN. First, the absence of a direct positive effect of green borrowing on national innovation underscores the need to redesign green finance taxonomies to explicitly incorporate innovation-enabling criteria. Current ASEAN green bond standards prioritize hard infrastructure and climate mitigation assets; expanding eligible use-of-proceeds categories to include clean technology development, green R&D, and digital transformation would better align green capital with long-run innovation objectives.

Second, the strong positive mediated pathway through economic growth (Green Bond → Economic Growth → Innovation) suggests that the quality of macroeconomic growth matters as much as the volume of green finance. Policymakers should therefore complement green bond market development with growth-enabling investments in human capital, institutional quality, and technology infrastructure, which constitute the absorptive capacity necessary to convert macroeconomic gains into innovation outcomes.

Third, the divergent sectoral effects of green bonds and green loans in the agricultural sector underscore the need for instrument-specific policy frameworks. Green loan eligibility criteria should be redesigned to reduce structural barriers faced by agricultural producers - including collateral requirements, environmental certification costs, and reporting burdens - to ensure that bank-based green capital does not systematically exclude agrarian communities. At the same time, the positive indirect effect of green loans through structural transformation (Green Loan → Agri_Value → Economic Growth → Innovation) suggests that targeted green lending can serve as a catalyst for productive sectoral reallocation, provided it is accompanied by social protection measures that cushion the transitional costs borne by agricultural workers and smallholders.

Finally, the non-significant macroeconomic effect of green loans reinforces the case for scaling up responsible banking frameworks beyond normative principles toward binding sectoral targets and innovation-linked green lending mandates, ensuring that commercial banks contribute meaningfully to ASEAN's sustainable development and innovation agenda.

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