Pambekti, Galuh Tri; Lestari, Irna Puji

Article

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ISRA international journal of islamic finance

Provided in Cooperation with:
International Shariʿah Research Academy for Islamic Finance, Kuala Lumpur

Reference: Pambekti, Galuh Tri/Lestari, Irna Puji (2024). Unlocking green productivity through green lending, digitalisation and financial literacy. In: ISRA international journal of islamic finance 16 (2), S. 88 - 108. https://journal.inceif.edu.my/index.php/ijif/article/download/701/485/2526. doi:10.55188/ijif.v16i2.701.

UNLOCKING GREEN PRODUCTIVITY THROUGH GREEN LENDING, DIGITALISATION AND FINANCIAL LITERACY

Galuh Tri Pambekti
Department of Sharia Accounting, Faculty of Islamic Economics and Business, UIN Sunan Kalijaga, Indonesia
Irna Puji Lestari
Department of Islamic Economics and Halal Industry, Faculty of Graduate School, Gadjah Mada University, Indonesia

Received
9 January 2024

Revised
21 May 2024
19 June 2024
26 June 2024

Accepted
26 June 2024

ABSTRACT

Purpose — This study aims to measure green productivity in the agricultural sector, specifically on Sumatra Island, with some driving factors such as green lending from rural banks (both conventional and Sharīʿah), digitalisation, and the intermediation of financial literacy.

Design/Methodology/Approach — The study employs panel data from 154 regencies on Sumatra Island for the period 2018 to 2022. Data Envelopment Analysis was employed to generate agricultural green total factor productivity, followed by regression estimation to see the influence of each determining factor.

Findings — This study reveals the significant impact of green lending on green productivity. However, in Sharīʿah rural banks, which adhere strictly to Sharīʿah rules, this impact is positive only when moderated by financial literacy. On the other hand, digitalisation is also found to influence green productivity, but the effect weakened when the level of financial literacy could not be controlled.

Originality/Value — To the best of the author's knowledge, this study is the first to observe green productivity in the agricultural sector within a dual economic system that fosters both Islamic and conventional financial practices at the regional level.

Practical Implications — This study implies that governments and banks should integrate green lending and digitalisation across various levels of financial literacy.

Keywords — Agricultural green productivity; Digitalisation; Financial literacy; Green bank lending

Article Classification — Research paper

ISRA International Journal of Islamic Finance (IJIF)
Vol. 16 • No. 2 • 2024
pp. 88-108

eISSN:
2289-4365

DOI:
doi.org/10.55188/ijif.v16i2.701

INTRODUCTION

Green productivity is a crucial driver for sustainable economic development, fostering ecological advancement and improving societal well-being (Yang *et al.*, 2022; Li, Chang *et al.*, 2023). In the agricultural sector, achieving green productivity involves implementing strategic practices such as prudent fertiliser use, crop rotation, cover cropping, and enhanced erosion management for eco-friendly farming (Yang *et al.*, 2022). However, these environmentally conscious efforts require substantial upfront investments, compelling farmers to actively seek financial support for adopting supportive technologies (Mo *et al.*, 2023; Shen *et al.*, 2023). The transition to green practices introduces uncertainties and risks (Nasution *et al.*, 2021), underscoring the need for flexible lending mechanisms with an insurance safety net, primarily accessible through banking institutions (Budiasa, 2020; Fang *et al.*, 2021). Despite its pivotal role, global agricultural bank credit has declined from 2.77 per cent in 2013 to 2.26 per cent in 2022, as reported by the Food and Agriculture Organization of the United Nations (2023).

Regionally, bank financing in Indonesia, particularly in North Sumatra, has exhibited sluggish growth in micro and small business working capital credit, known as *Kredit Usaha Rakyat* (Bank Indonesia, 2022). The first quarter of 2022 recorded a negative credit growth of -0.8 per cent, attributing this decline to sub-optimal credit fund distribution and the cautious stance of banks in extending credit to specific sectors. Recognising the vital role of agriculture at the regional level, the key catalyst for advancing green lending lies in rural banks, encompassing both Sharīʿah-based (Bank Perkreditan Rakyat Syariah (BPRS)) and conventional (Bank Perkreditan Rakyat (BPR)) institutions (Susamto *et al.*, 2023). These banks, authorised for financial services, have been steadily growing, particularly in Sumatra, with 677 BPRs and 48 BPRS by the end of 2022 (OJK, 2022a, 2022b). The untapped potential can be leveraged to enhance green productivity in Sumatra by providing accessible capital to farmers lacking sufficient collateral for traditional loans (Huang *et al.*, 2022).

Furthermore, Zhang *et al.* (2021) advocate for a holistic approach to global green productivity, emphasising the need to consider not only economic factors but also technological dimensions. While many researchers categorise green bank lending as an economic factor, there is a growing recognition of the technological facet, particularly in the realm of digitalisation (Song & Li, 2020; Wang *et al.*, 2023; Zhang *et al.*, 2023). The transformative impact of digitalisation on overall production is underscored by Zhang and Dong (2023), who highlight its effectiveness. Liu, Li *et al.* (2023) further accentuate the positive effects of digitalisation, noting its role in facilitating financial inclusion in rural areas and in fueling green productivity through financing in eco-friendly technologies.

However, it is essential to acknowledge that numerous studies stress the crucial role of financial literacy in the success of financing programmes (Xu *et al.*, 2020; Endris, 2022; Widyastuti *et al.*, 2023). Financial literacy not only simplifies public access to banking services (Mahmood-ur-Rahman, 2022) but also enriches the credit portfolio of the community, providing farmers with diverse alternatives to enhance their productivity (Disney & Gathergood, 2013). While Guo *et al.* (2022) identify the positive impact of green finance, including green credit, and the digital economy on green productivity, they have not explored the role of financial literacy. Similarly, Shen *et al.* (2023), despite incorporating

digital and financial inclusion aspects into their green productivity model, have yet to consider the influence of financial literacy. In light of these gaps in the existing literature, this study stands out by comprehensively examining the role of financial literacy in strengthening the impact of green lending as financial support and the influence of digitalisation as technical support in promoting green productivity.

Based on this background, this research specifically aims to investigate the potential of green lending in BPR and BPRS—integrated with digitalisation and moderated by financial literacy—to unlock the potential for green agricultural productivity by focusing on Sumatra Island. Sumatra is considered representative of green productivity characteristics in Indonesia due to its high production levels of crops. Using accumulated data from the Indonesian Central Statistics Agency, five provinces in Sumatra are among the top ten largest rice-producing provinces in Indonesia (Faperta UMSU, 2022), indicating that a significant portion of the largest rice-producing provinces in Indonesia is located in Sumatra.

This research offers at least three potential contributions. First, it will be the first to observe green productivity in the agricultural sector within dual economic systems—considering both Sharīʿah and conventional banks, represented by green lending in BPRS and BPR, respectively. BPRs operate as interest-based conventional banks, while BPRS, adhering to Sharīʿah principles, include a Sharīʿah Supervisory Board that ensures Sharīʿah compliance in financial transactions. Second, this research specifically examines green productivity at the sub-regional level, focusing on districts in Sumatra Island, providing a more detailed picture of the application of financing variations according to the characteristics of each region. Lastly, the research will report on the effectiveness of green lending at different literacy levels, serving as a reference for developing financial literacy programmes at the regional level.

The paper is accordingly organised into five sections. The introduction in section one sets the context and outlines the objectives of the study. The literature review in section two summarises pertinent previous research and theoretical frameworks. The methodology in section three explains the research design, data collection, and analysis techniques. The results and discussion in section four present and interpret the findings in relation to the research questions and existing literature. Finally, the conclusion in section five highlights the key insights and provides practical and policy recommendations.

LITERATURE REVIEW

Green Productivity and the Potential of Green Lending in the Agricultural Sector

In the realm of green productivity, this research has focused on green total factor productivity as a critical measure, integrating economic and environmental indicators to assess conventional productivity factors (Coomes *et al.*, 2019; Li, Chang *et al.*, 2023; Li & Lin, 2023). The methodological approach adopted centred on the agricultural sector, referred to by many researchers as agricultural green total factor productivity (AGTFP) (Liu, Li *et al.*, 2023). AGTFP is crucial for understanding input utilisation efficiency and the broader development of green agriculture (Alem, 2023; Liu, Li *et al.*, 2023). In the context of Indonesia, an agrarian country where agriculture significantly influences national economic development (Nasrullah &

Ovitasari, 2022; Warr, 2023), measuring green productivity in this sector provides a comprehensive overview and identifies opportunities for improvement (Shen *et al.*, 2023). The assessment of AGTFP requires consideration of limited resources, energy in the agricultural production process, and its environmental impacts. Employing the non-parametric approach of Data Envelopment Analysis, as commonly utilised by other researchers (Kryszak *et al.*, 2021; Streimikis & Saraji, 2022; Liu, Li *et al.*, 2023; Liu, Zhang *et al.*, 2023), this study elucidates the methodological intricacies in the pursuit of a nuanced understanding of green productivity within the agricultural landscape.

Shifting the focus to financial instruments, green lending, synonymous with green financing or green loans (Al-Qudah *et al.*, 2022; Azad *et al.*, 2022; Zhou *et al.*, 2022), serves as a sustainable means to finance environmentally positive projects (Sharma *et al.*, 2022; Yucel *et al.*, 2023). This embodies a sustainable business approach, integrating social and environmental considerations into decision-making (Biancone & Radwan, 2019; Xu *et al.*, 2022). In the agricultural domain, studies reveal that agricultural credit lending positively impacts agricultural green total factor productivity (Wang *et al.*, 2022). Access to agricultural credit is correlated with increased fertiliser use and higher agricultural productivity (Assouto & Houngbeme, 2023). Green bank credit is effective in encouraging farmers to adopt green production technologies (Zhou *et al.*, 2022). Regional banks, particularly BPR and BPRS, play a pivotal role in green lending, acting as catalysts for positive change by directing resources towards projects with beneficial impacts on the economy, the environment, and local communities (Ronaldo & Suryanto, 2022; Xu *et al.*, 2022). This synergistic approach aims to maximise the achievement of green productivity.

The Role of Digitalisation on Green Productivity

Digitalisation refers to the use of digital technology and platforms (Ritter & Pedersen, 2020) to create value and enable innovation (Gradillas & Thomas, 2023). In the context of green productivity, digitalisation helps reduce resource use, optimise supply chains, monitor energy consumption, and implement smart solutions for effective resource management (Antikainen *et al.*, 2018; Santarius *et al.*, 2020). Numerous empirical studies have demonstrated the positive impact of digitalisation on green productivity. Chen *et al.* (2023) revealed that the digital economy and green technology had a significant positive effect on agricultural green total factor productivity. Liu and Liu (2023) emphasised that digitalisation positively promotes green agricultural productivity by efficiently connecting production, operation, and consumption for traceable quality and measurable environmental impact. Hong *et al.* (2023) underscored the positive influence of the digital economy on the advancement of local green agriculture. In practice, digitalisation assists in reducing raw material usage, thus decreasing waste and fuel consumption, and subsequently lowering the carbon footprint (Xinfa & Jinglin, 2022). Use of the internet by farmers helps them obtain useful information about agricultural operations, thereby positively impacting fertiliser and pesticide inputs (Na & Kang, 2023). In many rural areas, digitalisation that is inclusively integrated into financial access demonstrated a major impact on agricultural productivity growth by promoting information channels and fostering innovation in green technologies (Liu, Li *et al.*, 2023).

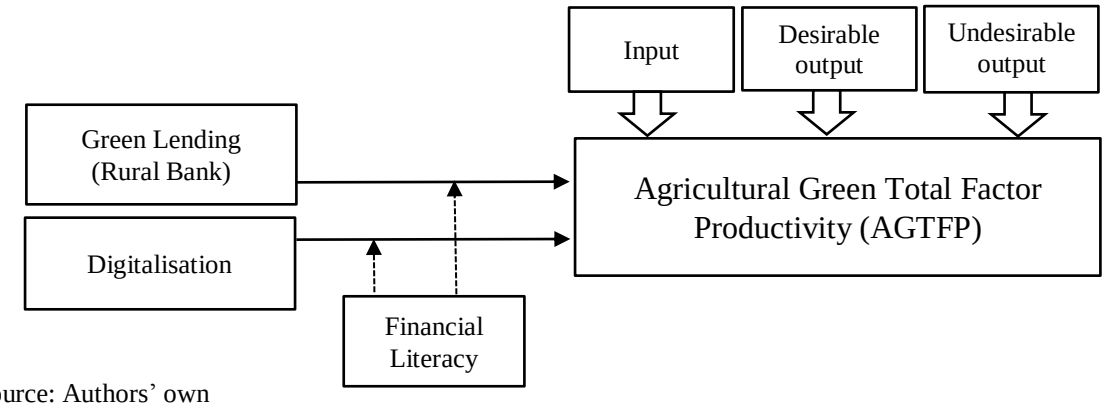
The Intermediation of Financial Literacy

Financial literacy plays a significant role in promoting green lending and other green bank services (Lee & Huruta, 2022; Hou & Fang, 2023; Neacșu *et al.*, 2023), especially in rural financial institutions (Atahau *et al.*, 2023). Good financial literacy is necessary for farmers to access and manage banking funds wisely (Siddik *et al.*, 2023), especially when they are striving to adopt sustainable farming practices (Mondejar *et al.*, 2021). At the same time, financial literacy also optimises the benefits of digitalisation, for example, by assisting farmers in making smart decisions on how to invest their funds in green technologies that can enhance agricultural productivity and sustainability (Yang *et al.*, 2022). With a strong understanding of managing financial resources and technology wisely, farmers can enhance agricultural productivity while maintaining a healthy environment (Lee & Teo, 2015; Cen & He, 2018; Siddik *et al.*, 2023). This initiative can also support sustainable economic growth in rural areas, improve the well-being of farmers, and reduce negative environmental impacts (Streimikis & Saraji, 2022; Li, Chang *et al.*, 2023).

A Model of Agricultural Green Total Factor Productivity

Based on this conceptual framework, this research proposes an integrative model to optimise the achievement of agricultural green total factor productivity (AGTFP) in Sumatra Island by involving rural banks' green financing as financial support and digital solutions as technical support. To enhance their respective functions, financial literacy is positioned as an intermediary role. The research model is illustrated in detail in **Figure 1**.

Figure 1: Integrative Model of AGTFP



Source: Authors' own

METHODOLOGY

This study employed a sample dataset comprising 154 regencies in Sumatra in the period 2018 to 2022, resulting in a total of 770 observations. The analytical technique was conducted in two stages: Data Envelopment Analysis (DEA) to measure AGTFP and the generalised method of moments (GMM) regression to examine the influence of contributing factors to AGTFP.

DEA Model

AGTFP is measured using slacks-based measure DEA (DEA-SBM) developed by Tone (2001). This model is employed to avoid measurement errors in the production function under subjective settings and to address issues when desirable and undesirable outputs change in the same proportion (Tone, 2001; Streimikis & Saraji, 2022; Ma *et al.*, 2023). The Decision-Making Unit used is the regency in Sumatra, which assesses AGTFP using the equation adapted from Streimikis and Saraji (2022) as follows:

$$\rho_t = \min \frac{1 - \frac{1}{I}\sum_{i=1}^{I}\frac{s_i^x}{x_i^t}}{s_i^x, s_j^G, s_l^B \; 1 + \frac{1}{J+L}\left(\sum_{j=1}^{J}\frac{s_j^G}{x_j^t} + \sum_{j=1}^{J}\frac{s_l^B}{x_l^t}\right.}$$

$$\sum_{k=1}^{K}\lambda_k X_i^k + S_i^t = X_i^t, i = 1,2,\dots,I;$$

$$\sum_{k=1}^{K}\lambda_k G_j^k - S_j^t = G_j^t, i = 1,2,\dots,I;$$

$$\sum_{k=1}^{K}\lambda_k B_l^k + S_l^t = B_l^t, i = 1,2,\dots,L;$$

$$\lambda_k \geq 0, k = 1,2,\dots,K;$$

$$s_i^x, s_j^g, s_l^b \geq 0 \quad \text{.....(1)}$$

where $X = (x_1, \dots, x_I) \in R_+^I$ is the input vector, $G = (g_1, \dots, g_J) \in R_+^J$ is the desirable output vector, and $B = (b_1, \dots, b_L) \in R_+^L$ is the undesirable output vector. Meanwhile, λ^k is the intensity vector, and $k = (k_1, \dots, K)$ is the DMU index. Furthermore, $0 \leq \rho_t \leq 1$ with $\rho_t = 1$ indicates total efficiency, where $t = 1, 2, \dots, K$. The observation at time -t represented by the input-output (x_i^t, g_i^t, b_i^t) is indicated on the production frontier at that point $(x_i^t - s_i^{x^*},\ g_j^t + s_j^{g^*},\ b_l^t - s_l^{b^*})$, and $s_i^{x^*},\ s_j^{g^*}, and\ s_l^{b^*}$ are the optimal values of $s_i^x, s_j^g, and\ s_l^b$. Input and output indicators are shown in **Table 1**.

Table 1: Input and Output DEA Variables

Indicators	Description	Measurement
Input		
LAB	Capital required for labour provision (Xu & Deng, 2022)	The working population multiplied by the minimum wage of each regency (in billion Rupiah (Rp))
CAP	Productive capital for agriculture (Xu & Deng, 2022; Ma *et al.*, 2023)	The ratio of total investment financing in the agriculture and forestry sectors divided by the welfare weight of farmers in each regency from the farmer exchange rate (in percentage). Welfare weight measures the welfare of farmers as proxied by the farmers' terms of trade. Farmer exchange rate, as defined by Indonesia's Central Bureau of Statistics, is an indicator for assessing the purchasing power of farmers in rural areas.

Table 2: Input and Output DEA Variables (Cont.)

Indicators	Description	Measurement
LAND	The availability of agricultural land (Ma *et al.*, 2023; Liu *et al.*, 2021)	The total harvested area of crops (in hectares)
Desirable output		
PROD	The total agricultural yield (Huang *et al.*, 2022; Ma *et al.*, 2023)	The total production yield of crops (in tonnes)
Undesirable output		
GHG	The environmental impact of agricultural activities (Liu *et al.*, 2021; Liu, Li, *et al.*, 2023)	The greenhouse gas emission ratio per capita (in Gg CO_2e)

Source: Authors' own

GMM Regression

GMM regression is conducted using the one-step difference technique, driven by the limitation of the sample size and a relatively short observation period (only five observation periods), making the one-step procedure an advantage (Hwang & Sun, 2018). The regression equation is as follows:

$$AGTFP_{i,t} = \alpha + \beta AGTFP_{i,t-1} + \delta_1 GL_{i,t} + \delta_2 GLS_{i,t} + \delta_3 DIG_{i,t} + \delta_4 FL_{i,t} + \delta_5 GL_{i,t} * FL_{i,t} + \delta_6 GLS_{i,t} * FL_{i,t} + \delta_7 DIG_{i,t} * FL_{i,t} + \delta_8 ControlVariable_{i,t} + \mu_{i,t} + \sigma_{i,t} + \varepsilon_{i,t} \quad \text{.....(2)}$$

where $\mu_{i,t}$ represents the specific consequences of the regency/city, $\sigma_{i,t}$ is the specific consequences of the observation year and $\varepsilon_{i,t}$ is the error term. The explanation of each variable for this method and its measurements is summarised in more detail in **Table 2**.

Table 3: Variables and Measurement

Variables	Representation	Measurement
Dependent Variable		
$AGTFP_{i,t}$	Agricultural Green Total Factor Productivity	DEA scores generated from MaxDEA Lite 12.0.8
Independent Variable		
$GL_{i,t}$	Green Lending in BPR	The agricultural sector lending amount of BPR (in billion Rp) is divided by the population of each regency (Data source: OJK)
$GLS_{i,t}$	Green Lending in BPRS	The agricultural sector lending of BPRS (in billion Rp) is divided by the population of each regency (Data source: OJK)
$DIG_{i,t}$	Digitalisation	The percentage ratio of household telecommunication consumption in a province is divided by the population in each regency (Data source: BPS)
Interaction Variable		
$FL_{i,t}$	Financial Literacy	The conventional financial literacy index was added to the Islamic financial literacy index (Data source: OJK)
Control Variable		
$GRDP_{i,t}$	Gross Regional Domestic Product	Natural logarithm of Gross Regional Domestic Product in Sumatra in billions (Data source: BPS)
$POV_{i,t}$	Poverty Rate	Percentage of the population living in poverty per regency (Data source: BPS)
$INF_{i,t}$	Inflation	Inflation per province (Data source: BPS)

Source: Authors' own

RESULTS AND DISCUSSION

Descriptive Finding

The results of the descriptive statistics in **Table 3** indicate that GHG emissions in Sumatra Island from 2018 to 2022 show a decreasing trend, with the lowest average in 2022 at 0.013 Gg CO_2e. The decreasing trend is also reported for PROD and LAND, reaching the lowest point in 2021. Conversely, CAP and LAB have experienced an increasing trend throughout the years. On the financing side, GL shows a gradually increasing trend, while GLS exhibits a dynamic trend. This is also observed in DIG, which displays a dynamic trend. On the other hand, LIT shows a relatively constant increase, especially in 2019, 2020 and 2021, due to the absence of government to conduct the financial literacy surveys, hence the scores remained the same in those three years.

Table 4: Descriptive Statistics (N=770)

Variables	Year	Mean	SD	Variables	Year	Mean	SD	Variables	Year	Mean	SD
GHG	2018	1.813	4.039	LAND	2018	16272.49	25455.33	FL	2018	40.111	6.409
	2019	2.006	4.298		2019	14628.39	24186.24		2019	51.700	9.682
	2020	0.584	1.312		2020	15132.33	25432.48		2020	51.700	9.682
	2021	0.101	0.167		2021	13846.74	22796.10		2021	51.700	9.682
	2022	0.013	0.032		2022	14202.71	23285.54		2022	62.973	12.940
PROD	2018	81922.77	131319.71	GL	2018	0.0051	0.0099	GRDP	2018	9.321	0.997
	2019	70981.22	117608.49		2019	0.0055	0.0105		2019	9.368	0.996
	2020	75294.30	127161.06		2020	0.0054	0.0102		2020	9.361	0.995
	2021	70467.29	118387.52		2021	0.0056	0.0104		2021	9.399	1.003
	2022	73412.67	126058.50		2022	0.0063	0.0120		2022	9.450	1.014
LAB	2018	424.68	417.37	GLS	2018	0.0009	0.0017	POV	2018	11.155	5.127
	2019	461.59	458.45		2019	0.0007	0.0011		2019	10.771	4.969
	2020	514.75	509.06		2020	0.0013	0.0019		2020	10.627	4.879
	2021	529.62	526.68		2021	0.0011	0.0015		2021	10.940	4.878
	2022	546.20	550.50		2022	0.0010	0.0015		2022	10.274	4.643
CAP	2018	96.56	4.28	DIG	2018	0.0302	0.0280	INF	2018	1.441	1.313
	2019	97.39	6.42		2019	0.0339	0.0311		2019	1.563	1.331
	2020	105.60	9.26		2020	0.0358	0.0315		2020	1.563	1.470
	2021	111.42	16.73		2021	0.0379	0.0327		2021	1.307	1.137
	2022	119.16	13.37		2022	0.0338	0.0287		2022	3.622	2.870

Source: Authors' own

DEA Result

Overall, **Table 4** indicates that the AGTFP scores in all of Sumatra over the five years of observation are moderate, with a score of 0.462, signifying that green productivity is not yet optimally efficient. At the provincial level, only three provinces show relatively good productivity above 0.5, namely South Sumatra (0.513), North Sumatra (0.504), and Bangka Belitung (0.502).

Table 5: AGTFP Scores in Provinces in Sumatra for the years 2018–2022

Province	Score
Aceh	0.495
Bengkulu	0.383
Jambi	0.378
Bangka Belitung	0.502
Riau Islands	0.451
Lampung	0.468
Riau	0.379
West Sumatra	0.428
South Sumatra	0.513
North Sumatra	0.504
ALL SUMATRA	0.462

Note: The DEA model is run with a slacks-based measure, output-oriented, and variable returns to scale (VRS).
Source: Authors' own

The AGTFP trends are also displayed annually per province in **Figure 2**. Provinces with relatively active annual growth rates are observed in Aceh, South Sumatra, and North Sumatra. Additionally, the Ogan Komering Ulu Timur district in South Sumatra Province shows super-efficient productivity (with scores of 1) in 2018, 2019 and 2022. This super-efficiency indicates that green productivity in agricultural operations has efficiently utilised its resources without waste and achieved maximum output based on inputs and environmental factors. **Figure 2** also illustrates that 2021 was the year with the lowest trend in green productivity in each province on the island of Sumatra. This trend aligns with the low economic activity that occurred that year due to the COVID-19 pandemic.

Figure 2: Sumatra Island AGTFP Trend 2018–2022

Figure 3: Sumatra Island AGTFP Trend 2018–2022 (Cont.)

Source: Authors' own

Regression Analysis

Unit Root Test

The GMM regression test begins with a unit root test to ensure that the estimation results in the model are reliable and free from spurious regression (Maddala & Wu, 1999). In this study, unit root tests are conducted using the Augmented Dickey–Fuller (ADF) test and the Phillips–Perron (PP) test. Results in **Table 5** indicate that all variables are stationary at the first-order difference (I-1), confirming that each indicator sequence is stable and has no unit root.

Benchmark Regression

GMM regression is performed in four model estimates, as shown in **Table 6**. Model estimation (1) is run through the conventional scheme, involving only green lending in BPR and other non-financing explanatory variables. Conversely, model estimation (2) is run through the Sharīʿah scheme, involving green lending in BPRS and other non-financing explanatory variables. To assess the strength of green lending in the dual economic scheme of conventional and Sharīʿah banks, model estimation (3) is executed. Furthermore, model estimation (4) is conducted to

examine the predictive function of all determinant variables, including the interaction variables of financial literacy.

Table 6: Results of the Unit Root Test

	ADF		PP			ADF		PP	
	I-0	I-1	I-0	I-1		I-0	I-1	I-0	I-1
AGTFP	806.50***	1456.39***	956.28***	1644.99***	FL	251.71	363.11**	269.91	599.87***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.992)	(0.017)	(0.943)	(0.000)
GL	54.98	973.30***	77.60	1059.86***	GRDP	77.63	637.92***	83.07	719.21***
	(1.000)	(0.000)	(1.000)	(0.000)		(1.000)	(0.000)	(1.000)	(0.000)
GLS	875.15***	359.75**	975.87***	596.99***	POV	689.39***	1125.50***	1146.62***	1385.60***
	(0.000)	(0.023)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
DIG	727.89***	1435.70***	1070.07***	1503.07***	INF	689.62***	1408.16***	656.27***	1586.45***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)

Significance level at * p < 0.1, ** p < 0.05, *** p < 0.01
Source: Authors' own

Table 6 shows that Lag.AGTFP is not significant in all four model estimations, indicating that green productivity in the previous period does not influence the level of green productivity in the current period. This result is reasonable as green productivity can be influenced by external factors, such as green lending, digitalisation, and financial literacy, as assessed in this study. As expected, GL has a significant positive impact on AGTFP in both separate and combined factor tests. A one per cent increase in GL is estimated to enhance AGTFP by 176.7 per cent to 357.6 per cent. Conversely, GLS exhibits a significant negative effect on AGTFP. A one per cent increase in GLS is predicted to decrease AGTFP by at least 35.61 per cent. Surprisingly, the interaction variable FL can reverse the negative impact of GL into a significant positive effect on AGTFP. A one per cent increase in GLSxFL can potentially boost AGTFP by approximately 11 per cent. A robust and positive predictor is shown by DIG on AGTFP in all four estimation models. A one per cent increase in DIG can contribute to increasing AGTFP by at least 28.25 per cent in the conventional scheme, 10.80 per cent in the Sharīʿah scheme, 21.67 per cent in the dual economic scheme, and 73.16 per cent in the model involving financial literacy. However, the impact of DIG, when interacted with FL (DIGxFL), may have a negative effect on AGTFP. This is possible due to the high literacy drive to access digital technology, increasing energy consumption, and offering opportunities for non-green products available on digital platforms. FL itself statistically exerts a significant influence on AGTFP, but the impact varies for each schema type. In the conventional scheme, FL has a positive effect on AGTFP, whereas in the Sharīʿah scheme, FL has a negative effect on AGTFP. However, as a moderating role, FL weakens GL and strengthens GLS in their impact on AGTFP. These results suggest the assumption that the level of financial literacy provides different incentives for communities or prospective customers to choose green lending in BPR and BPRS.

Table 7: GMM Regression Results

Dependent: AGTFP	(1) Conventional Scheme	(2) Sharīʿah Scheme	(3) Dual Economic Scheme	(4) All Factors
L.AGTFP	0.153	0.115	0.163	0.0166
	(0.310)	(0.303)	(0.164)	(0.905)
GL	176.7**		109.5***	357.6**
	(0.010)		(0.006)	(0.014)
GLS		-35.61**	-11.65	-658.9***
		(0.025)	(0.402)	(0.005)
DIG	28.25**	10.80*	21.67**	73.16**
	(0.045)	(0.066)	(0.039)	(0.015)
FL	0.00450*	-0.0108**	0.00275**	0.0185**
	(0.072)	(0.032)	(0.014)	(0.011)
GLxFL				-2.363**
				(0.031)
GLSxFL				11.00***
				(0.008)
DIGxFL				-0.845**
				(0.013)
GRDP	0.148	1.360	0.142	-0.360
	(0.709)	(0.391)	(0.689)	(0.309)
POV	-0.298	0.268*	-0.0560**	-0.108**
	(0.255)	(0.077)	(0.025)	(0.025)
INF	0.0308	-0.0152	-0.00533	-0.0213**
	(0.274)	(0.527)	(0.225)	(0.030)
Year dummies	YES	YES	YES	YES
Region dummies	YES	YES	YES	YES
Diagnostic test:				
AR(1) p-value	0.570	0.486	0.697	0.095
AR(2) p-value	0.170	0.166	0.216	0.431
Sargan p-value	0.339	0.128	0.142	0.312
Hansen p-value	0.101	0.103	0.104	0.412
Obs.	459	459	459	459
No. of Group (Region)	153	153	153	153
No. of Instrument	20	19	23	17

Note: GMM is run with robust standard errors using the xtabond2 command in Stata. The Arellano-Bond AR(2) test indicates no serial correlation with a p-value above 0.05 (Labra & Torrecillas, 2018). The Hansen test with a p-value above 0.05 does not reject the null hypothesis that instruments are uncorrelated with standard errors, confirming instrument validity in GMM. The Sargan statistic indicates no overidentification across all model estimates with a suggested cutoff value above 0.025 (Roodman, 2006). The number of instruments does not exceed the number of groups (<153). Significance level at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Authors' own

Panel Regression

Table 7 highlights the results of panel regression at high and low levels of financial literacy. In a high-level financial literacy setting, the influence of GLS is positive, and the influence of GL is negative on AGTFP. At low levels of financial literacy, both GLS and GL do not have a significant effect. This implies that high financial literacy encourages societies in Sumatra to increase their financing needs in BPRS compared to BPR.

Table 8: Panel Regression Results: Financial Literacy Level

Dependent: AGTFP	Conventional Scheme		Sharīʿah Scheme		Dual Economic Scheme	
	High Literacy	*Low Literacy*	*High Literacy*	*Low Literacy*	*High Literacy*	*Low Literacy*
GL	-2.152***	1.142			-2.575***	1.082
	(0.008)	(0.404)			(0.001)	(0.424)
GLS			0.763**	0.855	6.798**	3.331
			(0.030)	(0.690)	(0.018)	(0.580)
DIG	1.590***	0.648	1.197**	0.716	1.818***	0.677
	(0.006)	(0.256)	(0.019)	(0.039)	(0.002)	(0.238)
GRDP	0.000441	-0.007	-0.00333	-0.003	-0.00233	-0.009
	(0.965)	(0.545)	(0.738)	(0.752)	(0.821)	(0.431)
POV	-0.000637	.0002	0.000376	0.001	-0.000671	0.00003
	(0.691)	(0.876)	(0.809)	(0.452)	(0.680)	(0.983)
INF	-0.0185***	-0.008*	-0.00533*	-0.004	-0.0179***	-0.008*
	(0.000)	(0.074)	(0.084)	(0.255)	(0.000)	(0.079)
_cons	0.575***	0. 532***	0.474***	0.463***	0.597***	0.558***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year	YES	YES	YES	YES	YES	YES
Obs.	407	363	407	363	407	363
Adj.R^2	0.246	0.111	0.256	0.147	0.2451	0.109

Note: Regression is run via OLS robust standard errors. Significance level at * p < 0.1, ** p < 0.05, *** p < 0.01
Source: Authors' own

Discussion

The key findings of this study bring to light a pervasive inefficiency in green productivity across most regions of Sumatra, as indicated by an average efficiency score below the threshold of 0.5. This paper identifies significant challenges and promising opportunities for enhancing green productivity in Sumatra, emphasising the potential impact of strategic green lending interventions. The study reveals that green lending initiatives by rural banks (BPR) have a significant positive influence on green agricultural productivity in Sumatra. The support of these local banks is crucial for enabling farmers to adopt more efficient and sustainable practices, consistent with prior research by Afrin *et al.* (2017), Liu *et al.* (2023), Ong *et al.* (2023) and Siddik *et al.* (2023). This finding highlights the importance of targeted financial strategies in promoting sustainable agricultural practices and improving overall green productivity in the region. In contrast, BPRS faces a negative impact on green lending due to strict Sharīʿah compliance monitored by a Sharīʿah Supervisory Board. This careful oversight ensures that financial activities adhere to Islamic principles, emphasising considerations such as financing fertilisers made from impermissible (haram) materials. Achieving Sharīʿah compliance is challenging without financial literacy, underscoring the complex relationship between financial practices, religious principles, and environmental initiatives within Islamic finance.

Another significant revelation from this study highlights the profound impact of digitalisation on enhancing green productivity. Within the agricultural sector, digitalisation has emerged as a transformative force, enabling farmers to access information, technology, and markets with greater efficiency. This finding is consistent with the research conducted by Mondejar *et al.* (2021) and Li, Lin *et al.* (2023), which underscores the enhanced efficiency that digitalisation introduces to agriculture. Advanced technologies, such as sensors, the Internet of Things (IoT), and agricultural applications, have played a pivotal role in optimising resource

management (Brynjolfsson & Hitt, 2000), thereby contributing to improved planting strategies and more effective risk management, as highlighted by Al-Qudah *et al.* (2022). The integration of these digital solutions has the potential to propel Sumatra's agricultural sector towards more sustainable and productive farming practices.

On the other hand, financial literacy significantly enhances green productivity in Sumatra and serves as a crucial intermediary in promoting green lending within BPRS. High levels of financial literacy help overcome barriers to green lending in BPRS, indicating that financially literate societies better understand Sharīʿah compliance concepts, thereby increasing the demand for green lending in BPRS. This enhanced financial literacy enables customers to utilise green lending more effectively (Erlanitasari *et al.*, 2019). Conversely, financial literacy reduces the impact of green lending in BPR. This may be because individuals with high financial literacy are more selective in their choice of banking products. Unlike BPRS, which is restricted to Sharīʿah-compliant financing, BPR offers a wider array of financing products, providing customers with more attractive options that best meet their needs and preferences. Customers' choices however may not always be related to green financing, thus, ultimately decreasing their green financing portfolio in BPR.

A crucial insight gleaned from this research is the nuanced relationship between financial literacy and the impact of digitalisation on green agricultural productivity. The findings suggest that higher levels of financial literacy can potentially weaken the positive influence of digitalisation, an observation that aligns with concerns raised by Endris (2022), Siddik *et al.* (2023) and Widyastuti *et al.* (2023). The rationale behind this phenomenon lies in the risks associated with combining high financial literacy and rapid digitalisation, which may inadvertently exclude individuals lacking access to technology or possessing insufficient understanding of financial concepts (Santarius *et al.*, 2020). This exclusion can lead to societal disparities, exacerbating social and economic inequalities. Therefore, the careful design of financial literacy enhancement programs is imperative, considering the varying levels of digital access in different regions. Strategic considerations in program development will play a pivotal role in ensuring equitable participation and maximising the positive impact of digitalisation on green agricultural productivity.

CONCLUSION

This study highlights the untapped potential of green lending in rural banks as a key driver for enhancing overall green productivity in Sumatra. The research underscores the crucial role of digitalisation and financial literacy intermediation in this process. To optimise green productivity in Indonesia, particularly in Sumatra, several strategic recommendations are proposed. At the macro level, Bank Indonesia could formulate comprehensive policies, including setting favourable interest rates for green lending. Regionally, direct funding or subsidies are suggested to strengthen the capital of BPR and BPRS engaged in green initiatives, potentially facilitated through sustainable government investment funds such as green venture funds or green grant funds. To ensure the authenticity of green lending practices, it is proposed that contracts between banks and the government be established, preventing greenwashing and directing funds toward essential green productivity resources such as green technology, renewable energy loans, and support for sustainable farming practices. Another recommendation is to accelerate digitalisation

in the agricultural sector, incorporating digital payment methods and creating a supervised digital platform to connect farmers and banks for eco-friendly agricultural transactions. The final recommendation urges the government, through Bank Indonesia and the Financial Services Authority (OJK), to spearhead financial literacy enhancement programmes encompassing sustainability concepts and environmental impacts. Public awareness campaigns involving experts and validated by sustainable financial literacy certifications are intended to equip banks and financial institutions with the ability to identify projects eligible for green lending, fostering a holistic approach to sustainable agricultural development in Sumatra.

Despite its urgency, this research constitutes an initial investigation into the green productivity model in Indonesia on a regional scale. Therefore, there is a possibility that factors such as social, economic and cultural diversity, which could not be fully explored in this study, may play a role. Hence, future research is recommended to broaden the scope by involving a national scale. Subsequent studies are also advised to examine the potential of green financing channelled through various financial institutions, such as the capital market and fintech.

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ABOUT THE AUTHORS

Galuh Tri Pambekti is a lecturer at the Faculty of Islamic Economics and Business, UIN Sunan Kalijaga, Yogyakarta, Indonesia. She is also a doctoral candidate at the Department of Islamic Economy and Halal Industry, Gadjah Mada University, Indonesia. Her research interests include Islamic finance, halal business and Islamic sustainability for halal supply chain. She is the corresponding author and can be contacted at: galuh.pambekti@uin-suka.ac.id

Irna Puji Lestari is a doctoral candidate at the Department of Islamic Economy and Halal Industry, Gadjah Mada University, Indonesia. She is also a government financial analyst at the Ministry of Religious Affairs of Indonesia. Her research interests include Islamic finance, behavioural finance and Islamic corporate governance.

DECLARATION

Credit Authorship Contribution Statement

- Galuh Tri Pambekti: Conceptualization, background, methodology, literature review, discussion, presentation of findings, editing.
- Irna Puji Lestari: Conceptualization, background, methodology, data analysis and interpretation, editing.

Declaration of Competing Interest
The authors affirm that they have no identified financial conflicts of interest or personal connections that might have impacted the research conducted.

Acknowledgement
The authors appreciate the valuable comments by the journal's editor and reviewers. This paper draws from a conference paper presented at the 4th Sumatra Economics (Sumatranomics) National Conference, and its publication has been fully funded by Bank Indonesia, North Sumatra.

Ethical Statement
The authors declare that they understand the Ethical Guidelines and have adhered to all the statements regarding ethics in publishing. They also confirm that this paper is original and has not been published in any other journal nor is under consideration by another publication.

Data Availability
Data will be made available on request by email to galuh.pambekti@uin-suka.ac.id

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Appendix
None