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The Role of Fintech and Digital Transformation in Renewable Energy Growth in Indonesia

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Abstract

Renewable energy is an alternative energy that can be used to increase economic growth and people's welfare while saving the earth. This study aims to identify the role of fintech and digital transformation as a long-term financing scenario for renewable energy growth, from both the production and consumption sector. This study uses time series data from January 2019 to September 2022 with a two-stage test. First, conducting the ARDL model estimation to find the nexus between fintech, digital transformation, and renewable energy in the short and long term. Secondly, a regression analysis was performed to capture the moderating effect of digital transformation which intermediates the influences of fintech on renewable energy. The findings conclude that fintech, digital transformation, and renewable energy have integrated relationships in the short and long term both in the production and consumption sectors. The finding also provides various recommendations for enhancing renewable energy growth, particularly through the use of accelerated fintech by digital transformation.

Key words : Renewable Energy, Biodiesel, Fintech, Digital Transformation, ARDL Models

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INTRODUCTION

Conventional energy sources, such as fossil fuels, are frequently associated with environmental destruction and ecological degradation (Mendonça et al., 2020). Carbon dioxide produced by the combustion of fossil fuels additionally serves as the main factor causing global temperature rise, or what we call a global warming phenomenon (Guo et al., 2021). It is necessary to develop safer and cleaner alternative energy sources that can be produced sustainably to overcome this environmental problem. As a result, worldwide governments are mainly concentrating their attempts on encouraging the expansion of renewable energy sources. (Guo et al., 2021), one of which is through the processing of vegetable materials, such as biodiesel (Herjanto & Widana, 2016; Neupane, 2023). The advancement of renewable energy is also a solution to eliminate the burden of large environmental costs in a long-term model of extensive economic development, especially for developing countries (Arena et al., 2018), such as Indonesia. Renewable energy is also an urgent need for economic development in the financial sector nowadays (Puschmann, Hoffmann, & Khmarskyi, 2020).

The financial industry's vocation in conserving renewable energy process encourages the expansion of production and commercial activities, increase energy demand and consumption (Liu et al., 2022), and promote a low-carbon energy transition (Chenet, Ryan-collins & van Lerven, 2019). To achieve this sustainable development agenda, the United Nations ratified the "Paris Climate Agreement," as a global agreement in dealing with climate change, with a projected total investment of USD 100 billion. To maintain an efficient system and a sustainable economy, the United Nations also estimates that global investment in the energy system will reach USD 1.6 to 3.8 trillion per year during 2020-2050. This means that a low-carbon energy transition needs a long time to implement (Schumacher, Chenet, & Volz, 2020). Therefore, to promote the acceleration of renewable energy implementation, technological support is needed as the most innovative, sophisticated, and effective tool (Khan et al., 2022).

Technology has transformed digitally in various sectors. In the financial sector, this is marked by the emersion of financial technology (fintech). Previous studies have linked the role of fintech in renewable energy financing. For example, Dorfleitner and Braun (2019) discovered that fintech enables investment and financing access to renewable energy sectors. Fintech, which combines big data and artificial intelligence substantially facilitates the financing of renewable energy to stimulate green economy conversions (Wang et al., 2022), both in production and consumption. Schletz, Franke, and Salomo (2020) argue that the delay in energy efficiency intervention due to certain market conditions can be overcome by changing energy systems design through blockchain technology, which is widely used in fintech.

Several studies also examine the financing function for renewable energy through green finance. Tu and Rasoulinezhad (2021) demonstrate green bonds as an alternative capital fund for many energy efficiency projects. Azhgaliyeva and Liddle (2020) emphasized that green bonds are crucial to enhancing energy efficiency. Similar findings are clarified by Liu et al. (2022) in the scope of ASEAN countries. Moreover, it should also be noted that fintech is a platform provider for green finance (Cen & He, 2018; Muganyi, Yan, & Sun, 2021), thus it certainly has a superior role in facilitating renewable energy financing, especially by offering ease and speed characteristics. However, the involvement of fintech in supporting renewable energy financing has not been considered in existing research, giving rise to a research gap that needs to be bridged.

This assumption is also supported by Nassiry (2018) who states that Fintech plays an important role in unlocking green financing, one of which is through the use of ecology by channeling renewable energy (Deng, Huang, & Cheng, 2019). In addition, in this digital era, the combination of the internet and multilateral financial institutions would effectively support renewable energy financing (Butu et al., 2021). According to Liao and Ren (2020), this is a reasonable argument that technological advancements can contribute to improved energy conservation.

Technological advances driven by digital transformation are enabling exciting new ways to connect across networks (Koetsier, 2020). Digital transformation become the innovation process to increase the potential for off-grid electrification, from feasible projects to investment-worthy (CODES, 2021). Digital transformation acquired by fintech supports carbon crowd-financing through blockchain credit mechanisms, internet connected mobile payment options, credit scoring models, and new business concepts such as pay-as-you-go (Thompson, 2017; CODES, 2021). This model has opened up new options to achieve universal energy access for all levels of society, both in urban and rural areas (Liaw & Sa'ad, 2020). Therefore, it can be argued that digital transformation become an intermediary for financing renewable energy through Fintech.

Against the above background, this study aims to identify the short-term and long-term nexus between renewable energy growth, fintech, and digital transformation in Indonesia. This study will also identify the role of digital transformation as an intermediary between fintech activity and renewable energy growth. This study at least contributes threefold. First, this study will be the first to identify the driving factors of renewable energy growth in the digital era, especially in Indonesia, the largest potential country for renewable energy in the world (Sahara et al., 2022) specifically in biodiesel production. Secondly, this study will analyze the relationship (short and long term) between fintech and renewable energy in two aspects; production and consumption, thereby providing a more comprehensive picture of the growth potential of renewable energy. Third, this study applies Autoregressive Distributed Lag (ARDL) analysis which is suggested by many researchers as the most optimal method for simultaneously estimating short and long-run connections and also presents the strength of the estimation coefficients in the long term (Menegaki, 2019). Furthermore, this study also offers a regression perspective in strengthening and understanding the findings.

This study is presented in several sections. Section 1 is the Introduction that explores the background of the problem and research objectives. Section 2 presents the conceptual framework that also summarizes the literature review. Section 3 explains the methodology and also describes empirical models and research data. Section 4 analyzes the results and discussion. Section 5 offers the policy recommendation. Finally, the conclusion and advice for further research are presented in the last section.

Crowdfunding, which involves individuals or companies as their users, is one of the most important collaborations between fintech and sustainable finance in providing a certain amount of capital through online platforms (Kabulova & Stankevičienė, 2020). Crowdfunding helps green companies get financing and funds more fastly, inexpensively, and cost-effectively (Vergara & Agudo, 2021). Renewable energy-based crowdfunding offers investors the opportunity to invest their money sustainably (Abokyi et al., 2019; Khan, Yaseen, & Ali, 2019). In general, Fintech also has contributed to transforming agricultural, forestry, and fisheries business processes to become more sustainable (Hommel & Bican, 2020). Fintech activities are promoted through crowdfunding, digital payment systems, and digital marketplaces that bring together all business stakeholders (farm owners, property developers, shareholders, and customers). Fintech provides accountability, resource involvement, and public participation in the renewable energy sector (Deng, Huang, & Cheng, 2019; Macchiavello & Siri, 2020).

According to the World Bank (2018), market access to energy-based assets is still unstable in terms of structure, registration procedures, and regulations, in an inefficient economic system. Simultaneously, the rapid technology environment will evolve, opening up new opportunities and challenges for energy-based assets that use complex elements, instruments, and types (Gimpel, Rau, & Röglinger, 2018; Pavlyk, 2020; Tolliver et al., 2021). Furthermore, as stated by the World Bank (2018) blockchain, smart contracts, big data, the Internet of Things (IoT), and several technological breakthroughs show valuable possibilities for addressing the energy market's needs in the post-2020 generation.

Energy is becoming a new and distinct physical commodity for digital assets in representing the entitlement of commodity assets (Blakstad & Allen, 2018), numerous materials (e.g. energy content), and various outcomes (e.g. biodiesel, biofuels, and energy access). All processes of renewable energy will be interrelated with production and life cycle (Gimpel, Rau, & Röglinger, 2018; Puschmann, Hoffmann, and Khmarskyi, 2020). Thus, technologies (e.g. blockchain) can provide a digital mechanism to separately record and track the flow of information related to renewable energy units.

Chen (2018) has explored several technological approaches to renewable energy, one of these is using blockchain to strengthen the effectiveness of renewable energy stock market strategies by proposing an efficient payment system, promoting carbon trading and credit, enabling energy market networks, improving peer-to-peer lending access to trade in renewable energy and accelerating international financial transfers. Raberto et al. (2019) confirm this by stating that investment opportunity assistance in the renewable energy sector can create more efficient energy production transitions.

Energy as one of the important factors in production is considered a dominant contributor to economic growth which has been extensively discussed in prior studies. Different perspectives come from Neoclassical economists and Neoclassical Growth Theory experts. Neo-classical economists argue that labor and capital can be recognized and valued as fundamental components of growth. Meanwhile, the Neo-classical Growth Theory considers energy has a neutral role and therefore only becomes a secondary factor in the production process (Ghali & El-Sakka, 2004; Soytas & Sari, 2007). On the other hand, biophysicists and ecologists adhere to energy's significance and involvement in determining the income of civilization, with the assumption that an economy that depends on energy is strongly influenced by variations in energy consumption. (Cleveland et al., 1984; Dale, Krumdieck & Bodger, 2012). Thus it is concluded that energy production is also related to energy consumption. Every individual who earns income in the energy-economy ecosystem would use his income for consumption activities in energy production. For example, households consumption of renewable energy products using consumer financing facilities through fintech.

We argue that fintech financing in the production sector can increase renewable energy production. In the household sector, fintech financing also encourages the high consumption of renewable energy products. Thus, fintech can facilitate the financial needs of the energy ecosystem both in the production and consumption sectors (Khan, Yaseen, & Ali, 2019). This assumption is in line with the historical neoclassical economic model, which regards energy as a medium of production and consumption. Production can only succeed with consumption. As a result, energy is imperative for long-term production and consumption (Beaudreau, 1995; Ozturk, 2010).

Digital transformation is the procedure of rebuilding the utilization of technological innovations to boost production and operational performance and make it a major competitive advantage (Li, Jin, & Gao, 2023). Digital transformation stimulates innovation and carries out major changes in the financial industry, which then gives rise to fintech (Barroso & Laborda, 2022).

Increased accessibility and transferability of fintech facilitated by digital transformation have resulted in the creation of new values (Breidbach, Keating, & Lim, 2020). Digital transformation also helps fintech providers overcome long-term challenges when engaging in financial intermediation, such as the existence of asymmetric information, market uncertainty, incomplete market instruments, and reduced production costs (World Bank, 2022).

On the other hand, digital transformation also creates various sustainable business models that provide added value to clients and businesses by balancing human and economic requirements (Hu, Zhou, & Zhang, 2022). With digitally transformed technology and innovation, resource waste can be reduced (Li, Jin, & Gao, 2023).

Most studies conclude that digital transformation enhances the efficiency of energy use (Ishida, 2015; Lahouel et al., 2021). The latest technological implementation in companies or industries allows efficient monitoring of energy use and the prevalence of energy allocation (Feng et al., 2017; Wen, Lee, & Song, 2021). Digital transformation also removes obstacles for industry players in parsing isolated and unverified data as a basis for establishing energy efficiency strategies.

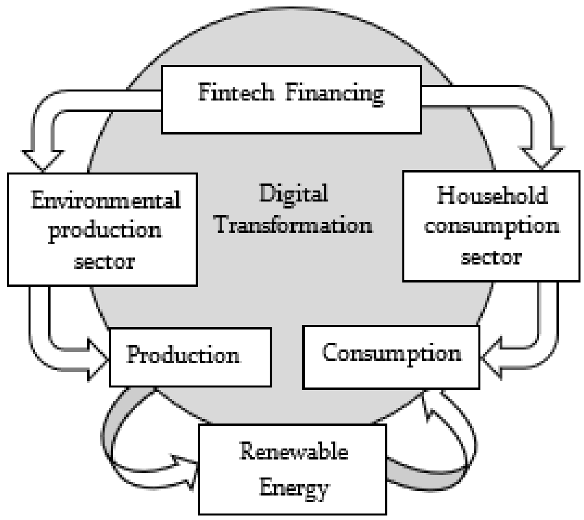

Figure 1. Framework of renewable energy production and consumption

On the consumer side, digital transformation is driving better energy demand and accelerating consumer sustainable behavior to make adjustments to the variability of renewable energy sources (Xing, Sizov, & Gundersen, 2022).

We then propose scenarios of sustainable renewable energy production and consumption with the support of fintech and intermediation of digital transformation with the framework shown in Figure 1.

METHOD

This study uses a quantitative approach with monthly time-series data from January 2019 to September 2022. The selection of the observation period is emphasized due to the availability of renewable energy data in Indonesia which has been released since 2019. The research was conducted in two stages as presented in Figure 2.

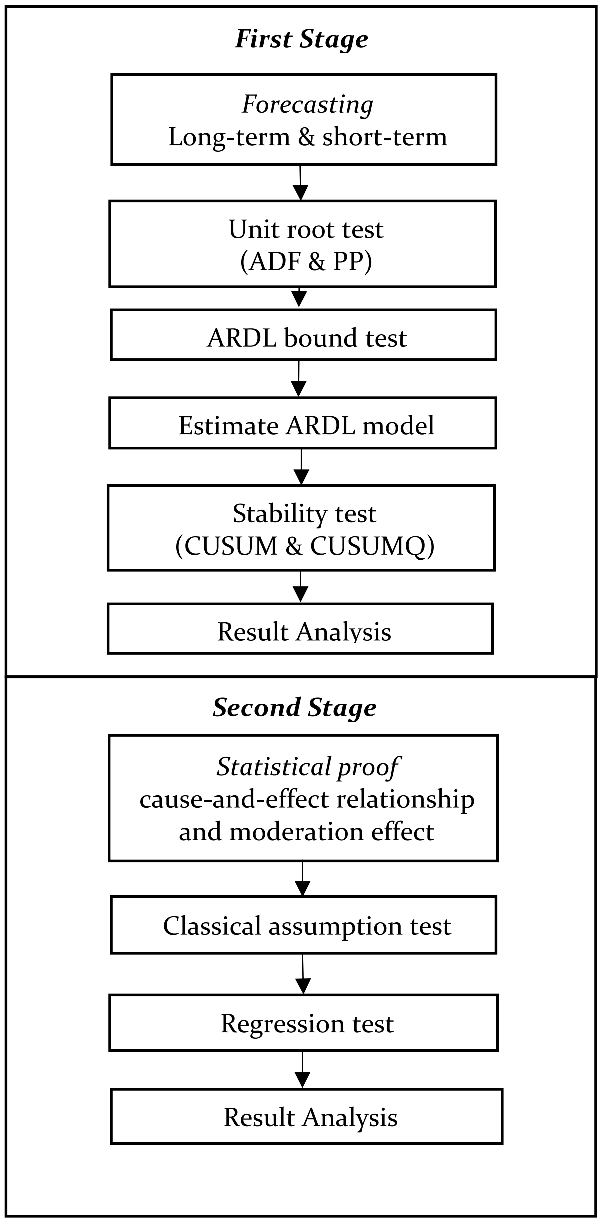

Figure 2. Two-stage Research Method

This study uses renewable energy as the dependent variable, which is tested separately from the production and consumption aspects. The explanatory variables are Fintech which is also tested separately from the production and consumption aspects; and digital transformation which also applies as a moderating variable. To support the robustness of results and avoid the omitted variables, this study also uses a control variable, namely inflation.

The first stage in this research applied the Autoregressive Distributed Lag (ARDL) model which has also been used in several studies related to energy sustainability and financial development (Ünlü et al., 2022; Vo et al., 2022). ARDL model in this study was performed to identify a dynamic relationship scenario between the production and consumption of renewable energy, the production and consumption of fintech financing and digital transformation, both in the short and long term. The ARDL approach can be applied relatively to short-term time-series data to estimate long-term and short-term model components simultaneously (Narayan, 2004).

The ARDL model equation applied in this study is explained as follows:

$$\Delta REP_t = \beta_{0i} + \beta_{1i} REP_{i,t-1} + \beta_{2i} FinP_{i,t-1} + \beta_{3i} DT_{i,t-1} + \sum_{j=1}^{p} \delta_{ij}\, \Delta REP_{i,t-j} + \sum_{j=0}^{q1} \varphi_{1ij}\, \Delta FinP_{i,t-j_1} + \sum_{j=1}^{q2} \varphi_{3ij}\, \Delta DT_{i,t-j_1} + \mu_i + \varepsilon_{it} \quad (1)$$

$$\Delta REC_t = \beta_{0i} + \beta_{1i} REC_{i,t-1} + \beta_{2i} FinC_{i,t-1} + \beta_{3i} DT_{i,t-1} + \sum_{j=1}^{p} \delta_{ij}\, \Delta REC_{i,t-j} + \sum_{j=0}^{q1} \varphi_{1ij}\, \Delta FinC_{i,t-j_1} + \sum_{j=1}^{q2} \varphi_{3ij}\, \Delta DT_{i,t-j_1} + \mu_i + \varepsilon_{it} \quad (2)$$

Where i = 1, 2, ..., n and t = 1, 2, ..., t. Whereas ε_{it} is the error term and Δ is the first difference operation. Furthermore, the long-term relationship is represented by β_{ki} (k=1,2,3,4) while the short-term sum symbol is represented by the error correction term.

The variables and measurements used in this study are shown in Table 1.

Table 1. Variables and Measurements

Variables	Proxy	Measurements
Renewable Energy	Biodiesel production (REP_t)	Total monthly biodiesel production (source: www.aprobi.or.id)
	Biodiesel consumption (REC_t)	Total monthly biodiesel consumption (source: www.aprobi.or.id)
Fintech	Fintech financing in production sectors ($FinP_t$)	Total monthly fintech financing in the agricultural, forestry, and fisheries sectors (source: OJK)
	Fintech financing in consumption sectors ($FinC_t$)	Total monthly fintech financing in the household sector (source: OJK)
Digital Transformation	Internet penetration ratio to economic conditions (DT_t)	$\frac{Telco_t}{User_t} x \frac{IKE_{m,t}}{IKE_t}$ • $Telco_t$: Communication spending year-t • $User_t$: Internet users in year-t • $IKE_{m,t}$: Indonesia Economic Condition Index of month-m (m=1 s.d. 12) in year-t • IKE_t : Total Economic Condition Index in the year-t
Inflation	Inflation (INF)	Log (Inflation)

ARDL model estimation begins with a validation mechanism through the unit root test to detect the stationary in the time-series data set. Furthermore, to see the stability of the ARDL model, graphic plotting was carried out using CUSUM and CUSUMQ statistics.

In the second stage, a regression test was employed to strengthen the assumption of a significant influence between fintech and renewable energy and also to prove the intermediary role of digital transformation on this effect. This assumption is supported by several researchers who have linked the interaction of digital transformation with fintech (Boratyńska, 2019; Barroso & Laborda, 2022). The regression test is equipped with a classic assumption test such as autocorrelation, heteroscedasticity, normality, and omitted variables.

The regression equation in this study is determined as follows:

$$REP_m = \alpha_0 + \beta_1 FinP_t + \beta_2 DT_t + \beta_3 FinP_t * DT_t + \beta_4 INF_t + \varepsilon_m \quad (3)$$

$$REC_m = \alpha_0 + \beta_1 FinC_t + \beta_2 DT_t + \beta_3 FinC_t * DT_t + \beta_4 INF_t + \varepsilon_m \quad (4)$$

RESULT AND DISCUSSION

The initial results present descriptive statistical findings for all variables categoriz-ed by year with analysis using mean, standard deviation, minimum, and maximum values as shown in Table 2

Table 2 shows that the average biodiesel production in 2020 and 2021 has decreased compared to 2019, but increased in 2022. Meanwhile, the average biodiesel consumption shows an increasing trend from year to year. A similar trend is also found in the average fintech financing in the production sector (agriculture, forestry, and fisheries) which continues to increase from year to year, with the highest average financing in 2022. The average fintech financing for consumption in the household sector has also experienced a significant increase from 2019 to 2022. Furthermore, the average digital transformation shows a sloping trend with a slight decrease in 2020 and 2021. The reasonable explanation comes from the Covid-19 pandemic which hampered the growth of digital technology innovation so that it could not meet the high communication needs of society and industry. Moreover, the average inflation is quite fluctuating where a decrease occurs in 2020 and 2021, then begins to increase in 2022.

Table 2. Descriptive Statistics Result

Variables	Year	Mean	Std. Deviation	Min	Max
	2019	836616.8	55173.78	788238	935901
REP	2020	716097.8	38804.84	632926	757426
	2021	748293.6	69812.74	615942.5	818400.7
	2022	957128.6	63100.85	861655.8	1056868
	2019	496387.5	152644.6	53891	698971
REC	2020	690583.9	72458	514547	790456
	2021	723645	73415.6	638895	830000
	2022	840893.2	28527.84	797546.5	892841
	2019	29.5	10.7	15.4	48.1
	2020	70.0	12.1	52.2	92.1
FinP	2021	151.2	33.5	91.8	211.6
	2022	187.7	37.2	117.4	230.0
	2019	110.7	40.1	57.5	180.4
FinC	2020	262.3	45.3	195.6	345.0

Variables	Year	Mean	Std. Deviation	Min	Max
	2021	513.7	70.9	406.9	668.1
	2022	831.3	81.6	708.4	937.1
DT	2019	2.3	0.1	2.1	2.3
	2020	1.3	0.4	0.8	2.0
	2021	1.4	0.2	1.0	1.7
	2022	1.9	0.2	.7	2.1
INF	2019	3.0	0.3	2.5	3.5
	2020	2.0	0.6	1.3	2.9
	2021	1.6	0.2	1.3	1.9
	2022	3.7	1.3	2.1	5.9

* monthly data in 2022 only until September

The unit root was identified through Augmented Dickey–Fuller (ADF) and Phillips Perron (PP) tests. The test begins with determining the most optimal lag value through the optimum lag test using the Likelihood Ratio (LR), Akaike Information Criterion (AIC), Hannan Quinn Information Criterion (HQ-IC), Final Prediction Error (FPE), and Schwarz Bayesian Information Criterion (SBIC).

The unit root test result provided in Tables 3 and 4 indicates that there are no unit roots found in all variables confirming that all variables are not stationary at the first difference level or integration order I(1) at a significance level of 1% and 5%.

Based on this unit root test result, we ascertain that the estimation of the ARDL model is possible to continue.

Table 3. Unit Root Test Results (ADF)

Variable	Lag	ADF level	ADF 1st difference	Order
REP	1	-0.603 (0.870)	-5.590* (0.000)	I(1)
REC	1	-1.806 (0.376)	-6.511* (0.000)	I(1)
FinP	2	-0.096 (0.9499)	-3.691* (0.004)	I(1)
FinC	1	-0.590 (0.8732)	-3.526** (0.007)	I(1)
DT	2	-1.524 (0.522)	-3.317** (0.014)	I(1)

Table 4. Unit Root Test Results (PP)

Variable	Lag	PP level	PP 1st difference	Order
REP	1	-1.149 (0.695)	-8.864* (0.000)	I(1)
REC	1	-2.357 (0.154)	-9.347* (0.000)	I(1)
FinP	2	-0.549 (0.882)	-10.349* (0.000)	I(1)
FinC	1	-0.540 (0.884)	-6.043* (0.000)	I(1)
DT	2	-1.554 (0.507)	-4.789* (0.001)	I(1)

The ARDL bound test was performed along with diagnostic procedures to validate model estimation (Pesaran, Shin, & Smith, 2001). Bound tests are carried out by identifying the F-statistics within the upper and lower limits.

If the estimated value of the F-statistic is less than the lower limit, this indicates that there is no long-term cointegration.

Table 5 shows that the ARDL model met the diagnostic requirements for both the REP and REC equations, where no autocorrelation, no heteroscedasticity, residuals are normally distributed, and no omitted variables. The REP (1,0,0) and REC (1,0,0) models show an F-statistic value higher than the upper limit at the 90% and 95% confidence levels, implying that there is a long-term cointegration in these two ARDL models.

According to Pesaran, Shin, and Smith (2001), if a long-term cointegration is found, the estimation of long-term and short-term relationships can be continued based on the error correction model (ECM). The estimated ARDL-based ECM is carried out separately for dependent variables of REP and REC.

Table 6 first displays the estimated ARDL-based ECM model in the production sector (REP). Based on this statistical evidence, fintech financing in the agriculture, forestry, and fisheries sectors has a significant positive relationship with renewable energy production both in the short-term and long term. Likewise, digital transformation also shows a positive relationship in the short and long run to renewable energy production.

An increase of fintech financing in the production sector by 1% causes renewable energy (biodiesel) production to increase by 46.45% in the short term, *ceteris paribus*. In line with this, an increase of fintech financing in the production sector by 1% causes renewable energy (biodiesel) production to increase by 97.33% in the long term, *ceteris paribus*. Fintech can increase its short and long-term financing in the production sector to improve the production of renewable energy raw materials (e.g., palm oil and soybean oil) thereby providing supply chain guarantees for industries that produce renewable energy.

Table 5. ARDL *bounds test* and *diagnostic test* result

Equation 1.	**REP = F (FinP, DT)**			
Lag order	**(1,0,0)**			
Critical Bounds	**95% Lower**	**95% upper**	**90% Lower**	**90% upper**
F-stat = 6.111	3.79	4.85	3.17	4.14
Diagnostic Test	***p-value***	***interpretation***		
Breusch-Godfrey test	0.6486	*No autocorellation*		
White Heteroscedast. test	0.3702	*Homokedasticity*		
Jarque Bera test	2.9e-26	*Normal distribution*		
Ramsey RESET test	0.0221	*No omitted var*		
Equation 2.	**REC = F(FinC, DT)**			
Lag order	**(1,0,0)**			
Critical Bounds	**95% Lower**	**95% upper**	**90% Lower**	**90% upper**
F-stat = 5.508	3.79	4.85	3.17	4.14
Diagnostic Test	***p-value***	***interpretation***		
Breusch-Godfrey test	0.7293	*No serrial corellation*		
White Heteroscedast. test	0.5680	*Homokedasticity*		
Jarque Bera test	4.8e-44	*Normal distribution*		
Ramsey RESET test	0.0056	*No omitted variables*		

Table 6. Long-term and short-term ARDL models

ARDL – REP (1,0,0)			
Variable	*Short-term coefficients*		
	Coeff.	T-Stat.	Prob.
FinP	464.4755	3.65	0.001
DT	5493.967	2.89	0.006
Variable	*Long-term coefficients*		
	Coeff.	T-Stat.	Prob.
FinP	973.2986	3.56	0.001
DT	11512.49	4.19	0.000

ARDL - REC (1,0,0)			
Variable	*Short-term coefficients*		
	Coeff.	T-Stat.	Prob.
FinC	187.1293	2.88	0.006
DT	-3238.568	-1.34	0.187
Variable	*Long-term coefficients*		
	Coeff.	T-Stat.	Prob.
FinC	335.9399	3.91	0.000
DT	-5813.972	-1.41	0.166

Furthermore, the result also indicates that an increase in digital transformation by 1% causes renewable energy production of biodiesel to increase by 54.93% in the short term, and 115.12% in the long term, *ceteris paribus*. This finding can be concretely applied through renewable energy research and development by utilizing various digital channels. Table 6 also provides statistical evidence of a positive relationship in the short-term and long-term between renewable energy consumption (REC) and fintech financing activities in the household consumption sector. An increase of fintech financing in the consumption sector by 1% causes renewable energy consumption to increase by 18.71% in the short term and 33.59% in the long term, *ceteris paribus*.

However, the ARDL model finds that digital transformation has a negative relationship with renewable energy consumption in the short term and long term. This finding is quite reasonable because renewable energy-based products are not widely offered through digital channels, such as e-commerce. Currently in Indonesia, the purchase of biodiesel products can only be made through official agents appointed by the government.

We also performed CUSUM and CUSUMQ stability tests to identify the stability of the variable coefficients and detect a structural break in the ARDL model. The CUSUM and CUSUMQ statistics are set at a 5% significance level. If the plot statistics stay within critical limits, the ARDL coefficients are implemented in this method.

Figure 3 and Figure 4 shows that the CUSUM and CUSUMQ graph for REP model does not exceed the critical limit at the 5% significance level. Thus, there is no structural break, hence the long-run coefficients in the REP model are stable.

Figure 5 and Figure 6 also show that the CUSUM and CUSUMQ graph for REC model does not exceed the critical limit at the 5% significance level. Thus, it also concluded that the long-term coefficients in the ARDL model of renewable energy consumption (REC) is stable. CUSUM and CUSUMQ statistic results of this study confirm that the model is stable, robust, reliable, and valid.

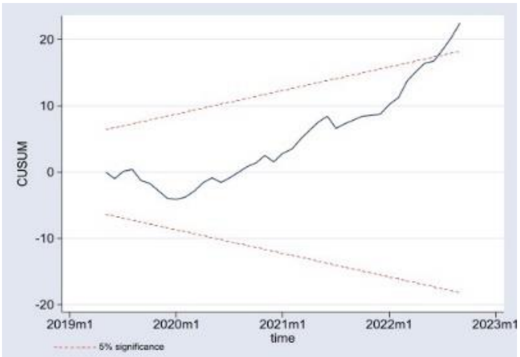

Figure 3. CUSUM plot on REP model

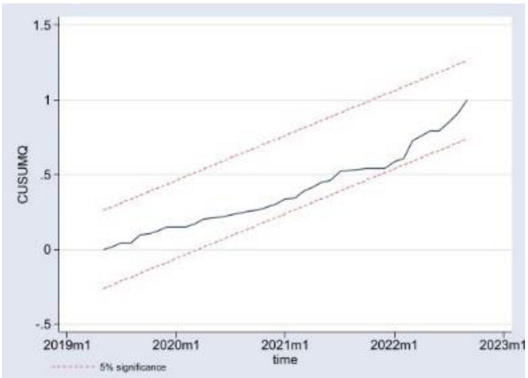

Figure 4. CUSUMQ plot on REP model

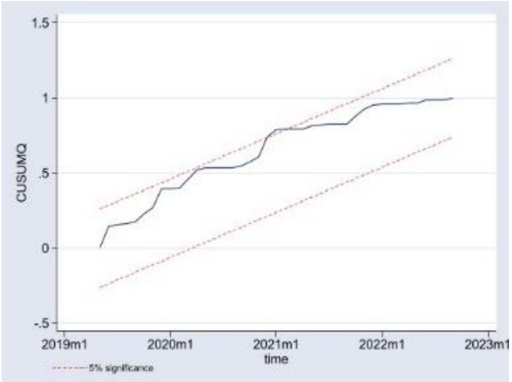

Figure 5. CUSUM plot on REC model

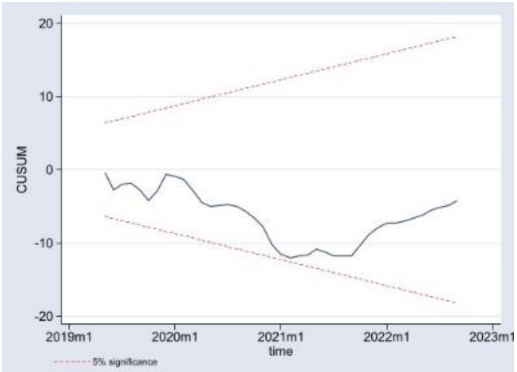

Figure 6. CUSUMQ plot on REC model

This study also conducted a linear regression test by first testing the endogenous and exogenous variables and then adding the moderating variables and control variables one by one. As previously stated, the endogenous variables for renewable energy production (REP) and renewable energy consumption (REC) are tested separately. The regression test is followed by the classic assumption to avoid autocorrelation, heteroscedasticity, normality, and omitted variables in the model.

Table 7 shows that fintech financing in the production sector has a positive significant influence on renewable energy production. This finding supports research by Tan et al. (2023) that the fintech development contributes positively to natural resources management, one of which is through the production of renewable energy.

Table 7. Benchmark Regression Result of Renewable Energy Production

	(1)	(2)	(3)
	REP	REP	REP
FinP	700.1***	1617.2***	739.0
	(0.000)	(0.010)	(0.342)
DT	11139.9***	5446.2***	4077.2*
	(0.000)	(0.007)	(0.052)
FinP*DT		96.89***	58.45*
		(0.000)	(0.079)
Log_INF			75881.6*
			(0.088)
_cons	492050.2***	639755.6***	602049.2***
	(0.000)	(0.000)	(0.000)
Obs.	45	45	45
Adj.R2	0.625	0.722	0.735

Diagnostic Test	***p-value***	***interpretation***
Breusch-Godfrey test	0.2420	*No serrial corellation*
White Heteroscedast. test	0.3600	*Homokedasticity*
Jarque Bera test	0.6089	*Normal distribution*
Ramsey RESET test	0.1079	No omitted variables

p-values in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Positive significance was also found in the influence of digital transformation on renewable energy production. According to the findings of Ren, Li, and Liang (2023), digital transformation boosts the performance of renewable energy industries towards operational efficiency, lower costs, and high innovation success resulting in better production. Digital transformation has also proved to positively moderate the effect of fintech on renewable energy, although this effect is not found when inflation control variables are involved. This result indicates that fintech financing in the production sector can be optimized through digital transformation without considering the inflation rate. In the context of sustainability, high-speed digitalization helps fintech transform into green fintech (Macchiavello & Siri, 2020; Aboalsamh, Khrais & Albahussain, 2023) in supporting the renewable energy industries to get financing sources for their production efficiency (Liu et al., 2022).

On the contrary, the lack of digital access hinders the optimal distribution of fintech financing in many sectors (Barroso & Laborda, 2022). Thus, limiting the sustainable supply chain for the renewable energy ecosystem, particularly biodiesel.

Table 7 also shows the positive effect of inflation on renewable energy production. Inflation causes the rise of the price of goods, thus encouraging the industry to increase the production capacity for receiving a high level of capital gains, especially as a temporary effect (Peixoto, Martinho, & Mourao, 2022).

Furthermore, Table 8 shows the results of the REC model estimation. The first finding reveals a significant positive effect of Fintech financing on renewable energy consumption. This result confirms the study of Croutzet and Dabbous (2021), and also the study of Firdousi, Afzal, and Amir (2023) that fintech development contributed to increasing renewable energy consumption.

Table 8. Benchmark Regression Result of Renewable Energy Consumption

	(1)	(2)	(3)
	REC	REC	REC
FinC	330.0***	-411.4	-465.3
	(0.000)	(0.161)	(0.200)
DT	-5704.8**	-11849.5***	-11378.6***
	(0.026)	(0.001)	(0.005)
FinC*DT		30.18**	32.53**
		(0.012)	(0.033)
Log_INF			-19993.8
			(0.796)
_cons	691638.6***	855164.4***	862279.8***
	(0.000)	(0.000)	(0.000)
Obs.	45	45	45
Adj.R2	0.509	0.568	0.558

Diagnostic Test	***p-value***	***interpretation***
Breusch-G test	0.1078	*No serrial corellation*
White Heteros.test	0.9386	*Homokedasticity*
Jarque B. test	2.2e-41	*Normal distribution*
Ramsey test	0.1010	No omitted variables

p-values in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Meanwhile, digital transformation shows a significant negative influence on renewable energy consumption. This result supports a study by Lange, Pohl, and Santarius (2020) that digitalization causes an increase in income inequality, thereby reducing energy consumption demand. However, the moderation test displays the opposite result, that the interaction of digital transformation positively influences renewable energy consumption, which then eliminates the positive effect of fintech financing in the consumption sector. This is in line with Yu et al. (2022) that digital advancements expanded renewable energy consumption that could be promoted by digital finance, such as fintech. Digital transformation could expand people's access to the use of fintech, thereby opening greater opportunities for them to participate in the renewable energy transition through the energy market (Delina, 2023). Thus, the high interaction of digital transformation and fintech in the household sector can create a dynamic trend in renewable energy consumption.

In addition, Table 8 also reveals that there is no effect of inflation as a control variable on renewable energy consumption. For these findings, we argue that people prioritize basic needs consumption (such as food, clothing, children's school fees, etc.) in inflationary conditions, thereby eliminating renewable energy consumption. This finding is in line with Deka and Dube (2021) that inflation has no influence on renewable energy consumption in the long run.

Based on a comparison of the two regression results in Table 7 and Table 8, it indicates that fintech financing contributes more to increasing renewable energy production than increasing its consumption levels. In this case, fintech companies can maximize their crowdfunding function to bridge investors who have high environmental concerns to invest in renewable energy sectors. Fintech can also open up greater opportunities for financing renewable energy in various business lines; production, distribution, and consumption. For this reason, government regulation is needed to ensure the security of interactions between stakeholders involved in fintech financing on renewable energy.

Through massive digital transformation, fintech can immediately transition to green fintech by providing various financial services that support environmentally friendly projects and renewable energy. For example; financing for biodiesel, solar, wind, hydro, or geothermal energy; carbon footprint calculating machine; renewable energy insurance, claims management, and various cross-processes. The real practices can be run through robo-advisors, by assisting customers when investing in renewable energy through digital consulting advice. Supply chain funding solutions can also be offered through fintech which includes the possibility of digital financing for MSMEs in the agricultural, plantation, and livestock sectors in Indonesia.

On the other hand, while the negative influence of fintech on renewable energy consumption is concerning, it also signals the enormous potential for Indonesia to extend the renewable energy market to an international scale in order to meet global consumption needs. Digitalization can be utilized to reach these international markets more quickly and effectively. Even though the results of this study show that digital transformation has more impact on the production aspect than the consumption aspect of renewable energy, it is hoped that the measurable use of digitalization can balance the supply and demand of renewable energy. Moreover, if digitalization is optimized through the use of fintech. For example, connecting fintech in an automatic payment information system for the renewable energy production supply chain, or through the application of blockchain technology in energy production, consumption mapping, and capital and funding allocation.

CONCLUSION

This study aims to forecast the long-term and short-term relationship between fintech, digital transformation, and renewable energy growth both from a production and consumption perspective. The estimation results of the ARDL model prove the long-term and short-term relationship between fintech financing in the production and consumption sectors, digital transformation, and production and consumption of renewable energy. Thus, it can be concluded that financing scenarios through fintech should be considered as alternative funding for long-term and short-term renewable energy growth.

As an implication, on the production side, the government can encourage fintech to provide funding to MSMEs in the agriculture, forestry, and fisheries sectors thereby increasing their capital in generating the raw materials of renewable energy. On the consumption side, the government can issue various policies that urge people to consume renewable energy at the most ideal level. For example, by requiring the use of biodiesel for some percentage as a substitute for fossil fuel in public transportation.

This study also revealed that digital transformation plays an important role as an intermediary between fintech financing towards renewable energy growth in the production and consumption sectors. However, the regression results emphasize that the intermediary of digital transformation is more applicable in the production sector by considering the inflation rate. These results imply that the government should maintain the inflation rate so that it remains profitable for the production of renewable energy but also keeps market price stability for public consumption. Marketing offerings and distribution from small sectors to large biodiesel-producing industries can also be optimized through digital platforms facilitated by the government, such as through e-purchasing. In addition, the development of renewable energy requires the involvement of many parties, including at the global level, and may even require new institutional arrangements to create new contract models in the renewable energy sector. Therefore, harmonization of the Indonesian government's policies for the renewable energy ecosystem is very necessary, by involving databases from financial in-stitutions and companies in the renewable energy sector from various countries.

In general, this study has provided an overview of alternative renewable energy funding in Indonesia for current and future development. However, we acknowledge that this study is in its early stages, so several limitations of this study need to be addressed carefully. First, this study used a short observation period of 3 years. Some of the data and reports in this study, particularly regarding renewable energy, have only been released since 2019. This may have led to a lack of identification of some factors. In addition, the renewable energy proxy used is only limited to biodiesel, this is due to the availability and completeness of biodiesel data compared to other renewable energies such as biofuel and bioethanol. However, these limitations become opportunities in the future research agenda by examining related instrumental variables that are more relevant, richer proxies, and longer observation periods.

REFERENCES

Aboalsamh, H. M., Khrais, L. T., & Albahussain, S. A. (2023). Pioneering Perception of Green Fintech in Promoting Sustainable Digital Services Application within Smart Cities. *Sustainability*, 15(14), 11440. Available at: https://doi.org/10.3390/su151411440.

Abokyi, E. et al. (2019). Industrial growth and emissions of CO2 in Ghana: The role of financial development and fossil fuel consumption. *Energy Reports*, 5, 1339–1353.

Available at: https://doi.org/10.1016/j.egyr.2019.09.002.

Arena, M. et al. (2018). Unlocking finance for social tech start-ups: Is there a new opportunity space?. *Technological Forecasting and Social Change*, 127, 154–165. Available at: https://doi.org/10.1016/j.techfore.2017.05.035.

Azhgaliyeva, D. & Liddle, B. (2020). Introduction to the special issue: Scaling Up Green Finance in Asia. *Journal of Sustainable Finance & Investment*, 10, 1–9. Available at: https://doi.org/10.1080/20430795.2020.1736491.

Barroso, M. & Laborda, J. (2022). Digital transformation and the emergence of the Fintech sector: Systematic literature review. *Digital Business*, 2(2), 100028. Available at: https://doi.org/10.1016/j.digbus.2022.100028.

Beaudreau, B. C. (1995). The impact of electric power on productivity: A study of US manufacturing 1950–1984. *Energy Economics*, *17*(3), 231–236. Available at: https://doi.org/10.1016/0140-9883(95)00025-P.

Ben Lahouel, B. et al. (2021). Does ICT change the relationship between total factor productivity and CO2 emissions? Evidence based on a nonlinear model. *Energy Economics*, 101, 105406. Available at: https://doi.org/10.1016/j.eneco.2021.105406.

Blakstad, S. & Allen, R. (2018) *FinTech Revolution: Universal Inclusion in the New Financial Ecosystem*. 1st ed. 2018 edition. New York, NY: Springer.

Boratyńska, K. (2019). Impact of Digital Transformation on Value Creation in Fintech Services: An Innovative Approach. *Journal of Promotion Management*, 25(5), 631–639. Available at: https://doi.org/10.1080/10496491.2019.158554.

Breidbach, C. F., Keating, B. W. & Lim, C. (2020). Fintech: research directions to explore the digital transformation of financial service systems. *Journal of Service Theory and Practice*, *30*(1), 79–102. Available at: https://doi.org/10.1108/JSTP-08-2018-0185.

Butu, H. M. et al. (2021). Leveraging community based organizations and fintech to improve small-scale renewable energy financing in sub-Saharan Africa. *Energy Research & Social Science*, 73, 101949. Available at: https://doi.org/10.1016/j.erss.2021.101949.

Cen, T. & He, R. (2018). Fintech, Green Finance and Sustainable Development. *Advances in Social Science, Education and Humanities Research*, 291, 222–225.

Chen, D. B. (2018). Central Banks and Blockchains: The Case for Managing Climate Risk with a Positive Carbon Price. in *Transforming Climate Finance and Green Investment with Blockchains*. Elsevier and Academic Press. Available at: https://doi.org/10.1016/C2017-0-01389-7.

Chenet, H., ryan-collins, Josh & van Lerven, F. (2019). Climate-Related Financial Policy in a World of Radical Uncertainty: Towards a Precautionary Approach. in *Working Paper Series (IIPP WP 2019-13)*. UCL Institute for Innovation and Public Purpose. Available at: https://doi.org/10.2139/ssrn.3520224.

Cleveland, C. J. et al. (1984). Energy and the U.S. Economy: A Biophysical Perspective. *Science*, *225*(4665), 890–897. Available at: https://doi.org/10.1126/science.225.4665.890.

CODES (2021) *Accelerating Sustainability Through Digital Transformation Use Cases and Innovations*. Coalition for Digital Environmental Sustainability. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/40091/CODES_Supplement1.pdf?sequence=3 (Accessed: 26 January 2023).

Croutzet, A. & Dabbous, A. (2021). Do FinTech trigger renewable energy use? Evidence from OECD countries. *Renewable Energy*, 179, 1608–1617. Available at: https://doi.org/10.1016/j.renene.2021.07.144.

Dale, M., Krumdieck, S. & Bodger. (2012). Global energy modelling - A biophysical approach (GEMBA) Part 2: Methodology. *Ecological Economics*, 73, 158–167. Available at: https://doi.org/10.1016/j.ecolecon.2011.10.028.

Deka, A. & Dube, S. (2021). Analyzing the causal relationship between exchange rate, renewable energy and inflation of Mexico (1990–2019) with ARDL bounds test approach. *Renewable Energy Focus*, 37, 78–83. Available at: https://doi.org/10.1016/j.ref.2021.04.001.

Delina, L. L. (2023). Fintech RE in a global finance centre: Expert perceptions of the benefits of and challenges to digital financing of distributed and decentralised renewables in Hong Kong. *Energy Research & Social Science*, 97, 102997. Available at: https://doi.org/10.1016/j.erss.2023.102997.

Deng, X., Huang, Z. & Cheng, X. (2019). FinTech and Sustainable Development: Evidence from China Based on P2P Data. *Sustainability*, *11*(22), 6434. Available at: https://doi.org/10.3390/su11226434.

Dorfleitner, G. & Braun, D. (2019) *Fintech, Digitalization and Blockchain: Possible Applications for Green Finance*. Palgrave Studies in Impact Finance. Palgrave Macmillan, 207–237. Available at: https://econpapers.repec.org/bookchap/palpsifcp/978-3-030-22510-0_5f9.htm (Accessed: 26 January 2023).

Feng, Y. et al. (2017). Interval Analysis and DEMATEL-Based Reliability Apportionment for Energy Consumption Optimization With Energy Internet. *IEEE Access*, 5, 4769–4778. Available at: https://doi.org/10.1109/ACCESS.2017.2672758.

Firdousi, S. F., Afzal, A. & Amir, B. (2023). Nexus between FinTech, renewable energy resource consumption, and carbon emissions. *Environmental Science and Pollution Research*, *30*(35), 84686–84704. Available at: https://doi.org/10.1007/s11356-023-28219-z.

Ghali, K.H. & El-Sakka, M.I.T. (2004). Energy use and output growth in Canada: a multivariate cointegration analysis. *Energy Economics*, *26*(2), 225–238. Available at: https://doi.org/10.1016/S0140-9883(03)00056-2.

Gimpel, H., Rau, D. & Röglinger, M. (2018). Understanding FinTech start-ups – a taxonomy of consumer-oriented service offerings. *Electronic Markets*, *28*(3), 245–264. Available at: https://doi.org/10.1007/s12525-017-0275-0.

Guo, Y. et al. (2021). Asymmetric between oil prices and renewable energy consumption in the G7 countries. *Energy*, *226*(120319). Available at: https://ideas.repec.org/a/eee/energy/v226y2021ics0360544221005685.html (Accessed: 26 January 2023).

Herjanto, E. & Widana, I. K. (2016). Policy Analysis: Solar Substitution with Biodiesel. *Jurnal Pertahanan: Media Informasi ttg Kajian & Strategi Pertahanan yang Mengedepankan Identity, Nasionalism & Integrity*, *2*(2), 109–128. Available at: https://doi.org/10.33172/jp.v2i2.92.

Hommel, K. & Bican, P.M. (2020). Digital Entrepreneurship in Finance: Fintechs and Funding Decision Criteria. *Sustainability*, *12*(19), 8035. Available at: https://doi.org/10.3390/su12198035.

Hu, B., Zhou, & Zhang, L. P. (2022). A digital business model for accelerating distributed renewable energy expansion in rural China. *Applied Energy*, 316, 119084. Available at: https://doi.org/10.1016/j.apenergy.2022.119084.

Ishida, H. (2015). The effect of ICT development on economic growth and energy consumption in Japan. *Telematics and Informatics*, *32*(1), 79–88. Available at: https://doi.org/10.1016/j.tele.2014.04.003.

Kabulova, J. & Stankevičienė, J. (2020). Valuation of FinTech Innovation Based on Patent Applications. *Sustainability*, *12* (23), 10158. Available at: https://doi.org/10.3390/su122310158.

Khan, K. et al. (2022). Is technological innovation a driver of renewable energy?. *Technology in Society*, *70*, 102044. Available at: https://doi.org/10.1016/j.techsoc.2022.102044.

Khan, M. T. I., Yaseen, M. R. & Ali, Q. (2019). Nexus between financial development, tourism, renewable energy, and greenhouse gas emission in high-income countries: A continent-wise analysis. *Energy Economics*, *83*, 293–310. Available at: https://doi.org/10.1016/j.eneco.2019.07.018.

Koetsier, J. (2020). *Largest Distributed Peer-To-Peer Grid' On The Planet Laying Foundation For A Decentralized Internet*, *Forbes*. Available at: https://www.forbes.com/sites/johnkoetsier/2020/06/20/largest-distributed-peer-to-peer-grid-on-the-planet-laying-foundation-for-a-decentralized-internet/ (Accessed: 26 January 2023).

Lange, S., Pohl, J. & Santarius, T. (2020). Digitalization and energy consumption. Does ICT reduce energy demand?. *Ecological Economics*, *176*, 106760. Available at: https://doi.org/10.1016/j.ecolecon.2020.106760.

Li, G., Jin, Y. & Gao, X. (2023). Digital transformation and pollution emission of enterprises: Evidence from China's micro-enterprises. *Energy Reports*, *9*, 552–567. Available at: https://doi.org/10.1016/j.egyr.2022.11.169.

Liao, M. & Ren, Y. (2020). The "double-edged effect" of progress in energy-biased technology on energy efficiency: A comparison between the manufacturing sector of China and Japan. *Journal of Environmental Management*, 270, 110794. Available at: https://doi.org/10.1016/j.jenvman.2020.110794.

Liaw, J. O. H. & Sa'ad, M. F. bin (2020). Digital Diplomacy: The Role Of Social Media. *Solid State Technology*, *63*(6), 7511–7522.

Liu, H. et al. (2022). Impact of Green financing, FinTech, and financial inclusion on energy efficiency. *Environmental Science and Pollution Research*, *29*(13), 18955–18966. Available at: https://doi.org/10.1007/s11356-021-16949-x.

Macchiavello, E. & Siri, M. (2020). Sustainable Finance and Fintech: Can Technology Contribute to Achieving Environmental Goals? A Preliminary Assessment of. Green FinTech'. *European Banking Institute Working Paper Series*, 71. Available at: https://doi.org/10.2139/ssrn.3672989.

Mendonça, A.K. de S. et al. (2020). Hierarchical modeling of the 50 largest economies to verify the impact of GDP, population and renewable energy generation in CO2 emissions. *Sustainable Production and Consumption*, *22*, 58–67. Available at: https://doi.org/10.1016/j.spc.2020.02.001.

Menegaki, A. N. (2019). The ARDL Method in the Energy-Growth Nexus Field; Best Implementation Strategies. *Economies*, *7*(4), 105. Available at: https://doi.org/10.3390/economies7040105.

Muganyi, T., Yan, L. & Sun, H. (2021). Green finance, fintech and environmental protection: Evidence from China. *Environmental Science and Ecotechnology*, 7, 100107. Available at: https://doi.org/10.1016/j.ese.2021.100107.

Nassiry, D. (2018). The role of fintech in unlocking green finance: Policy insights for developing countries. in *ADBI Working Paper*. Asian Development Bank Institute.

Neupane, D. (2023). Biofuels from Renewable Sources, a Potential Option for Biodiesel Production. *Bioengineering*, *10*(1), 29. Available at: https://doi.org/10.3390/bioengineering10010029.

Ozturk, I. (2010). A literature survey on energy–growth nexus. *Energy Policy*, *38*(1), 340–349. Available at: https://doi.org/10.1016/j.enpol.2009.09.024.

Pavlyk, V. (2020). Assessment of green investment impact on the energy efficiency gap of the national economy. *Financial Markets, Institutions and Risks*, *4*(1), 117–123. Available at: https://doi.org/10.21272/fmir.4(1).117-123.2020.

Peixoto, P., Martinho, V. J. P. D. & Mourao, (2022). Corruption and Inflation in Agricultural Production: The Problem of the Chicken and the Egg. *Economies*, *10*(11), 268. Available at: https://doi.org/10.3390/economies10110268.

Pesaran, M. H., Shin, Y. & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326. Available at: https://doi.org/10.1002/jae.616.

Puschmann, T., Hoffmann, C. H. & Khmarskyi, V. (2020). How Green FinTech Can Alleviate the Impact of Climate Change—The Case of Switzerland. *Sustainability*, *12*(24), 10691. Available at: https://doi.org/10.3390/su122410691.

Raberto, M. et al. (2019). From financial instability to green finance: the role of banking and credit market regulation in the Eurace model. *Journal of Evolutionary Economics*, *29*(1), 429–465. Available at: https://doi.org/10.1007/s00191-018-0568-2.

Ren, Y., Li, B. & Liang, D. (2023). Impact of digital transformation on renewable energy companies' performance: Evidence from China. *Frontiers in Environmental Science*, 10. Available at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.1105686 (Accessed: 16 September 2023).

Sahara et al. (2022). Economic impacts of biodiesel policy in Indonesia: a computable general equilibrium approach. *Journal of Economic Structures*, *11*(1), 22. Available at: https://doi.org/10.1186/s40008-022-00281-9.

Schletz, M., Franke, L. A. and Salomo, S. (2020). Blockchain Application for the Paris Agreement Carbon Market Mechanism—A Decision Framework and Architecture. *Sustainability*, *12*(12), 5069. Available at: https://doi.org/10.3390/su12125069.

Schumacher, K., Chenet, H. & Volz, U. (2020). Sustainable finance in Japan. *Journal of Sustainable Finance & Investment*, *10*(2), 213–246. Available at: https://doi.org/10.1080/20430795.2020.1735219.

Soytas, U. & Sari, R. (2007). The relationship between energy and production: Evidence from Turkish manufacturing industry. *Energy Economics*, *29*(6), 1151–1165. Available at: https://doi.org/10.1016/j.eneco.2006.05.019.

Tan, Q. et al. (2023). Fintech development, renewable energy consumption, government effectiveness and management of natural resources along the belt and road countries. *Resources Policy*, *80*, 103251. Available at: https://doi.org/10.1016/j.resourpol.2022.103251.

Thompson, B. S. (2017). Can Financial Technology Innovate Benefit Distribution in Payments for Ecosystem Services and REDD+?. *Ecological Economics*, *139*, 150–

157. Available at: https://doi.org/10.1016/j.ecolecon.2017.04.008.

Tolliver, C. et al. (2021). Green Innovation and Finance in Asia. *Asian Economic Policy Review*, *16*(1), 67–87. Available at: https://doi.org/10.1111/aepr.12320.

Tu, C. A. & Rasoulinezhad, E. (2021). Energy efficiency financing and the role of green bond: policies for post-Covid period. *China Finance Review International*, *12*(2), 203–218. Available at: https://doi.org/10.1108/CFRI-03-2021-0052.

Ünlü, U. et al. (2022). Nexus between Renewable Energy, Credit Gap Risk, Financial Development and R&D Expenditure: Panel ARDL Approach. *Sustainability*, *14*(23), 16232. Available at: https://doi.org/10.3390/su142316232.

Vergara, C. C. & Agudo, L. F. (2021). Fintech and Sustainability: Do They Affect Each Other?. *Sustainability*, *13*(13), 7012. Available at: https://doi.org/10.3390/su13137012.

Vo, D. H. et al. (2022). Revisiting the energy-growth-environment nexus in the OECD countries: An application of the CS-ARDL approach. *Energy, Sustainability and Society*, 12(1), 47. Available at: https://doi.org/10.1186/s13705-022-00375-z.

Wang, L. et al. (2022). How big data drives green economic development: Evidence from China. *Frontiers in Environmental Science*, *10*(1055162). Available at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.1055162/full (Accessed: 26 January 2023).

Wen, H., Lee, C.-C. & Song, Z. (2021). Digitalization and environment: how does ICT affect enterprise environmental performance?. *Environmental Science and Pollution Research*, *28* (39), 54826–54841. Available at: https://doi.org/10.1007/s11356-021-14474-5.

World Bank. (2018). *Annual Report 2018*.

World Bank. (2022). *Fintech and the Digital Transformation of Financial Services Fintech and the Future of Finance Flagship Technical Note*. World Bank (Other Financial Sector Study). Available at: https://doi.org/10.1596/37340.

Xing, L., Sizov, G. & Gundersen, O. E. (2022). Digital Transformation in Renewable Energy: Use Cases and Experiences from a Nordic Power Producer. in Mikalef and E. Parmiggiani (eds) *Digital Transformation in Norwegian Enterprises*. Cham: Springer International Publishing, 63–89. Available at: https://doi.org/10.1007/978-3-031-05276-7_5.

Yu, M. et al. (2022). Digital finance and renewable energy consumption: evidence from China. *Financial Innovation*, 8(1), 58. Available at: https://doi.org/10.1186/s40854-022-00362-5.