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Natural Resource Efficiency, Financial Development, and Digital Finance: A Pathway to Sustainable Natural Resource Utilization in Thailand and China

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Sustainable utilization of natural resources would remain a basic prerequisite for the achieving long-term economic growth while ensuring environmental preservation specifically within emerging economies such as Thailand and China. This research determines the dynamic relationship between financial development, resource efficiency, and digital finance in promotion of sustainable natural resource utilization within the manufacturing sectors of these two nations. Grounded with Resource-Based View, Knowledge-Based View Dynamic Capabilities Theory, and Ecosystem Theory, the study has developed an integrative framework for explaining how digital maturity and intelligent innovation would facilitate the transition towards circular economy practices and resource sustainability. Aligned with framework of United Nations Sustainable Development Goals specifically SDG-9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) this research has addresses a crucial gap for existing literature by exploring combined impact of digital transformation and entrepreneurial eco-systems on sustainable resource management. With utilization of secondary data from 2000 to 2024 and employing Driscoll-Kraay Standard Error (DKSE) estimation technique, the empirical analysis of study shows that both financial development and resource efficiency strengthens sustainable resource utilization, whereas the role of digital finance remains comparatively limited. The outcomes further reveal that Knowledge Integration Capability (KIC) serves as the most impactful predictor and serves as the key mediating mechanism which links the core constructs to Circular Economy Adoption (CEA), while Digital Circular Economy Maturity (DCEM) acts as a moderator which strengthens positive relationship between KIC and CEA to enhance the overall impact of core drivers. Study also offers theoretical contributions by advancement of integrated perspective on digital and financial drivers of sustainability, while providing practical implications for policy-makers and industry-leaders who seek to enhance digital capabilities, fostering innovation and aligning national industrial strategies with global sustainability objectives.

Keywords: *Digital Finance; Financial Development; China; Thailand; Sustainable Development Goals; Dynamic Capabilities; Sustainable Natural Resource Utilization.*

Introduction

The era of globalization and increased industrialization, sustainable utilization of natural resources has become a crucial concern for nations striving to achieve economic growth by maintaining environmental balance. Emerging economies such as China and Thailand are on forefront on this challenge, where the acceleration of industrial expansion and increasing demand of energy continue to intensify pressure on natural ecosystems (Tian *et al.*, 2023; Raihan *et al.*, 2023). China is alone nearly contributing one-third of world's total CO_2 emissions, mainly due to its resilience on fossil fuels for industrial output (Tian *et al.*, 2023). In the same way, Thailand, industrial and manufacturing sectors consuming energy at a rate which exceeds the nation's GDP growth with oil, natural gas, biomass, and coal accounting for nearly 41 %, 25 %, 19 %, and 12 % of total primary energy consumption (Thailand Environment Institute [TEI], 2021). With recognition of these challenges, Thailand has committed Paris Agreement for reducing its greenhouse gas emissions by 20-25 % by 2030 aligning with global sustainability gaols (Raihan *et al.*, 2023). By underscoring these environmental pressures there is an urgent need for innovative approaches towards resource efficiency, financial development, and digital transformation for transformation towards circular economy (CE) model.

United Nations Sustainable Development Goals (SDGs) has essentially provided a framework for alignment of policy, specifically SD-9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) to focus on necessity of sustainable industrialization, resource-efficient production and resilience of climate. The prominence of goals empirical research remains limited for explaining how financial development, digital finance, and intelligent innovation could jointly promote sustainable natural resource utilization within manufacturing sectors (Zhang,

Wang, & Liu, 2022; Guo *et al.*, 2023; Mosnja-Skare, 2024). However, financial development has long been associated with economic growth and capital efficiency (Durusu-Ciftci *et al.*, 2017), currently suggest that its relationship with digital transformation and innovation in eco-systems could serve as catalyst for sustainable resource management (Xu & Tan, 2020; Chen *et al.*, 2021).

Literature on digital finance focus on transformative potential for extending financial inclusion, improving capital allocation and fostering innovation (Li *et al.*, 2022; Ozili, 2018). Huang and Huang (2018), digital finance leverages digital technologies such as artificial intelligence (AI), block-chain and big data to facilitate financing, payment and investment services. Blakstad and Allen (2018) has further extended this concept defining sustainable digital finance as integration of technological ecosystems which include mobile payments, peer-to-peer lending, and IoT for supporting inclusive and sustainable economic growth aligned with SDGs. Thailand Moenjak et al. (2020) has increased expansion of digital payment systems driven by collaboration between public and private sectors, improves transparency and allocation of resources. In China Xu and Tan (2020) observed that 1% increase in financial development could enhance utilization efficiency reinforcing the relationship between financial innovation and sustainability.

The research fills a crucial gap by developing an integrated analytical framework which draws on Resource-Based View (RBV), Knowledge-Based View (KBV), Dynamic Capabilities Theory, and Ecosystem Theory. The perspectives provide a comprehensive understanding of how firms and national systems develop capabilities to reconfiguring resources, integrating digital knowledge, and leveraging innovation for enhancing sustainability performance (Teece, 2018; Lin *et al.*, 2023; Zeng *et al.*, 2025). RBV focus on firm's level of resources such as financial capital and technological infrastructure could provide a competitive advantage when there is an effectively deployed towards sustainable goals. However, Dynamic Capability Theory has explained how organizations adapt, innovate and transform in response to environmental and technological disruptions.

Emphasizing on Thailand and China, this study determines the dynamic relationships between financial development, resource efficiency and digital finance in driving the sustainable natural utilization from 2000 to 2024. With the use of Driscoll–Kraay Standard Error (DKSE) estimation approach, the research has contributed to both theoretical advancements and practical policy-making. The outcomes of this study is expected to inform policy-makers, industry leaders and financial regulators on strategies for integration of digital maturity, innovation eco-systems, and circular economy principles to achieve SDGs and ensure long-term sustainability. The subsequent sections of this study include a review of relevant literature, an explanation of methodological design which includes the integration of NARDL technique followed by empirical outcomes and a discussion of outcomes which link financial innovation and digital transformation with sustainable industrial development.

Literature Review

Financial Development

Financial development refers to the process in which the institutions and market in a specific region use certain financial systems in order to improve the finance working in a region. Financial development is liked with the efficiency and depth of the financial instruments and the stability of finance in a country (Comin & Nanda, 2019). Financial development of any region is measured through the size of financial sector, provision of financial services and the liquidity of assets. Financial development also promotes economic growth by reducing information asymmetries for improving investment efficiency, and channelling savings into productive sectors (Durusu-Ciftci *et al.*, 2017; Taghizadeh-Hesary & Yoshino, 2020; Zemlickiene *et al.*, 2025). Within the framework of Resource-Based View (RBV), financial systems are considered to be valuable and rare organizational resources that enable firms to develop sustainable advantages from better capital deployment. Within the context, of sustainability, robust financial systems facilitate green financing and environmentally responsible investments, aligning with SD 9 and SD 12.

H1: *Financial development has a positive and significant impact on sustainable natural resource utilization.*

Resource Efficiency

Resource efficiency refers to the process of production of goods and services using limited resources but there is no impact on the output of the organization. There is maximum utilization of human and natural resources that work for the reduction of pollution and also plays part in environmental sustainability (Domenech & Bahn-Walkowiak, 2019). This involves the adoption of technological innovations, cleaner production techniques and circular production models which enhances competitiveness and reduction production costs (Zhang & Dilanchiev, 2022; Nicoletti & Appolloni, 2024). Within the context of Dynamic Capabilities Theory, firms with strong innovation and adaptive capacities could continuously enhancing resource utilization processes. Improvement in resource efficiency contributes to SD-12 with promotion of recycling, reuse and sustainable production systems,

H2: *Resource efficiency positively influences sustainable natural resource utilization through improved productivity and reduced environmental degradation.*

Digital Finance

Digital finance referred to the use of digital technology in daily matters including mobile phones, internet, AI etc. Digital finance is also known as FINTECH. Digital finance provides solutions for different financial problems including online payment, mobile banking etc. It has provided ease to people as they can operate their accounts while sitting at home and they do not need to go to financial institutions and wait in lines. Digital finance has many benefits for the countries like it increases financial inclusion and it is accessible by the public for any kind of credit and also there

is efficiency in transactions and the transactions can be made in no time through internet (Pazarbasioglu et al., 2020; Du & Wang, 2025; Liu et al., 2025). This enhances financial inclusion, transaction efficiency, and transparency in economic systems. This enhances financial inclusion, transaction efficiency, and transparency in economic systems. Beyond the operational benefits, digital finance also contributes towards sustainability by enabling access for green investments, supporting financial inclusion for small firms, and fostering innovative financing models such as peer-to-peer lending and green crowd-funding (Guo et al., 2023).

H3: *Digital finance positively moderates the relationship between financial development and sustainable natural resource utilization by improving financial accessibility and innovation diffusion.*

Sustainable Natural Resource Utilization

Sustainable natural resource utilization often refers to as responsible and balanced management of natural resources for meeting the requirements without comprising the ability of future generations to meet their own (Raihan et al., 2023; Khatami et al., 2024). This integration of social, economic and environmental dimensions from renewable energy use, conservation practices and circular production systems. From lens of Dynamic Capability Theory sustainability involves continuous reconfiguration resource and processes for adaption of ecological and technological changes (Teece, 2018). Sustainable natural resource utilization is directly aligned with SDG-13 and also aligned with core objective of this research framework.

Economic Growth Theory

Economic growth theory explains the mechanism through which the maximum output of goods and services is obtained at a time. One of the basic model for economic growth is the Solo-Swan growth model which is the long run model for economic growth and this model focuses on the capital accumulation, growth of labour force, and technological progress in economic growth (Cayssials & Picasso, 2020; Ahmed *et al.*, 2025; Halicka, 2024; Skare *et al.*, 2024; Wu *et al.*, 2025). According to this model capital accumulation in the form of infrastructure, machinery and other physical capital contributes towards the economic growth. The increase in financial development helps in the capital accumulation through efficient investments and mobilization of resources (Swan, 2023b). Similarly, another determinant of economic growth is labour force and its expansion due to increase in population and the population is also participating in labour practices. Resource efficiency can help in optimizing labour participation and increase their efficiency that results in the long term economic growth (Cayssials & Picasso, 2020; Hsu, 2024). Moreover, the technological innovation is also critical for economic growth as it enhances productivity and efficiency. Digital finance promotes technological innovation by providing financial solutions and allocating investments for research and development (Swan, 2023a). This model explains how the growth of out-put is driven by capital accumulation, expansion of labour and technological progress. In this research financial development act as a catalyst for capital accumulation by promoting efficient investment and mobilization of resources.

H4: *Financial development, resource efficiency, and digital finance collectively stimulate sustainable economic growth through enhanced capital accumulation and innovation.*

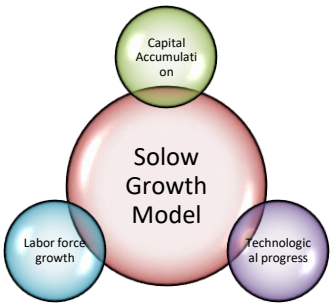

Figure 1. Solow Growth Model

Financial Development and Natural Resource Utilization

Financial institutions play crucial role in allocating capital for natural resources and the institutions include banks, investment firms and other financial bodies that generate investments. Financial institutions provide various types of investment including loans and project finance in order to support projects that are linked with natural resource utilization like mining and renewable energy resource (Taghizadeh-Hesary & Yoshino, 2020). The institution conduct risk assessments and design measures to mitigate risk and these institutions provide insurance to the investors in order to protect them from any kind of risk and other uncertainties (Saunders, Cornett, & Erhemjamts, 2021). A major portion of investment is directed towards exploring and extraction of natural resources like scanning the area for mineral deposits and drill areas for oil and gas extraction. The investment in these activities require high capital expenditures and there are certain risks attached with the resource discovery (Dwumfour & Ntow-Gyamfi, 2018). RBV supports the concept towards the access for capital and financial intelligence are strategic resources which enhances organizational competitiveness in sustainability transitions.

H5: *Financial development enhances sustainable natural resource utilization by improving capital allocation, reducing investment risk, and promoting green financing.*

Resource Efficiency and Sustainable Development

Resource efficiency refers to the generation of maximum output while using limited resources and ultimately reducing the waste and pollution. It involves optimized use of resources for getting maximum output. There is a concept of circular economy in which the waste material is recycled and is reused for future and it has been shift from traditional method of make use and dispose (Domenech & Bahn-Walkowiak, 2019). Resource efficiency is of significant importance for achieving sustainable development. Resource efficiency reduces the economic activities like extraction of natural resources and waste generation rather it protects the environment and

contribute to biodiversity preservation. According to (Zhang & Dilanchiev, 2022), resource efficiency increases the competitiveness and productivity by reducing production cost and maximizing use of resources accompanied by innovation and technology development. The industries can increase their return on investments by utilizing resource efficiently and through resource productivity. Resource efficiency also promotes social equity as it makes resources accessible by everyone and improve the livelihoods of people as well as developing resilience in the society through economic development and reduction of poverty that collectively contributes to social cohesion (Padilla-Rivera, Russo-Garrido, & Merveille, 2020). Hence resource efficiency is fundamental concept for economic development by reducing resource depletion and promoting economic prosperity. Knowledge-Based View also depends on firm's Knowledge Acquisition Mechanism (KAM) and Knowledge Integration Capability (KIC) where KAM also refers to the process through which organizations acquire sustainability knowledge from external and internal sources, and KIC could refers to their ability to synthesize and apply knowledge effectively in production systems (Lin et al., 2023). The relationship between these two capabilities enables the firms to adopt Circular principles into product design and operational models.

H6: *Knowledge acquisition and integration capabilities positively influence resource efficiency by facilitating circular business design and technological innovation.*

Digital Finance and Sustainability

Digital finance uses various technologies to deliver financial services like mobile banking that enables people to access banking applications and perform transactions by using their smart phones and internet. The banking applications help in checking their balance and transfer money to anyone as well as pay bills while sitting at home as it provides convenience to people (Durai & Stella, 2019). Digital finance is of significant importance for sustainability as it expands its services to all population and provide them opportunities for economic growth hence reducing poverty and inequality among people (Lee, Lou, & Wang, 2023). Moreover, the digital circular economy maturity is the extent to which a firms or economy has integrated as digital technologies into circular economy practices which serves as a moderator to enhance the relationship between innovation knowledge integration, and sustainability outcomes (Lin et al., 2023).

H7: *Digital Circular Economy Maturity (DCEM) positively moderates the relationship between knowledge integration capability and circular economy adoption, strengthening sustainable resource utilization outcomes.*

Sustainable Natural Resource Utilization in Thailand and China

Thailand and China both face significant pressure of environmental challenges and economic development. Thailand is rich in natural resources and it has diverse ecosystem like marine life, forests etc. but due to the rapid increase in population and industrialization, there is great pressure on natural resources which can lead to deforestation and water pollution. According to Apipoonyanon, Kuwornu, Szabo, and Shrestha (2020), Thailand has started certain forest management initiatives to manage its forest resources as well as expanding the area for forests to start reforestation. Similarly, Thailand also faces water pollution issues due to contaminated water and inefficient water management practices. The sustainable practices focus on the conservation of water ensure water efficiency for water security (Deb, Babel, & Denis, 2018). China faces air and water pollution due to the emission of industries and this is causing health issues as well. In order to cope this the government has implemented strategies regarding emission control standards and taxes have been imposed on pollution in order to prevent it for future (K. Liu & Lin, 2019). The measures of policy of China reflects the growing commitment towards SDGs and circular economy implementation.

H8: *The impact of financial development, resource efficiency, and digital finance on sustainable resource utilization differs between Thailand and China due to variations in digital circular economy maturity and policy implementation.*

Methodology

This research study considers how sustainable natural resource utilization is impacted by financial development, resource efficiency and digital finance in two countries: Thailand and China. Through the use of secondary data from popular online databases, the study employed an asymmetric technique known as DKSE to scrutinize the model proposed. Data for this study is taken for a time period of over two decades, i.e., 2000 to 2024. We present the model as follows:

$$SRU_{it} = FD_{it} + RE_{it} + DF_{it} + INF_{it} + URB_{it} + e_{it} \quad (1)$$

where, SD= sustainable resource use, FD= Financial development, RE= Resource efficiency, DF=Digital finance, INF= Inflation, URB= urban population, e= residual or error term.

Data for SD is operationalized using the indicator total natural resource rents (as a fraction of the GDP). Domestic credit to private sector (% of GDP) is used to measure FD. Resource efficiency is measured using the indicator for energy efficiency, which is the energy intensity level of primary energy. This indicator provides information of the amount of energy expended to generate one unit of economic yield. Digital finance is measured through automated teller machines (ATMs) per 100,000 clients is extracted from WDI. The study controls for inflation and urban population. Inflation accounts for consumer prices, measured in annual percentage. Urban population represents the proportion of urban population in total population.

Estimation Procedure

To analyse the collected data, the research performed a variety of tests. These tests are described as follows:

Cross Sectional Dependence Test

First of all, the CSD among variables is evaluated using Pesaran (2004) test because this is the main issue in the panel data analysis. It shows how common factors like interdependency in error term, stock market movements, volatility of some economic factors and economic shocks can affect the observable factors. The null hypothesis of this test indicates that CSD is not present in panel data and the alternative hypothesis shows that CSD is present in our data (Adebayo, Ağa, Agyekum, Kamel, & El-Naggar, 2022).

Slope Heterogeneity Test

In addition to CSD analysis, the slope heterogeneity issue is also crucial to check as there is a possibility that slope coefficients may vary across the cross-sections. Therefore, ignoring the problem of the slope heterogeneity also provide biased estimation. Two selected countries China and Thailand are connected in multiple aspects, but still they have many differences among these nations. Thus, the issue of slope heterogeneity is expected to exist (Xue, Haseeb, Mahmood, Alkhateeb, & Murshed, 2021). Therefore, the slope heterogeneity test proposed by Pesaran and Yamagata (2008) is used in the present study.

Unit Root Tests

The first-generation unit root methods such as the Im Pesaran and Shin panel unit root test, does not take into account the CSD and slope heterogeneity issues. Therefore, the use of first-generation tests is not suitable in the case of CSD and slope heterogeneity issues (Xue et al., 2021). Therefore, the cross-sectionally augmented Im–Pesaran–Shin (CIPS) and cross sectional autoregressive distributed lag model (CADF) tests proposed by Pesaran (2007) are used in the present research. These methods are believed to provide reliable and consistent unit root properties in the case of CSD and heterogeneity problems. The basic CADF test statistic is expressed as follows:

$$\Delta y_{it} = \partial_{it} + \delta_i y_{i,t-1} + c_i \bar{y}_{t-1} + \sum_{j=0}^{s} d_{ij} \overline{\Delta y}_{t-j} + \sum_{j=1}^{s} \delta_{ij} \overline{\Delta y}_{i,t-j} + e_{it} \quad (2)$$

Where, the first difference operator is denoted by Δ, $\bar{y}$ and Δy indicates the cross-sectional average values of the lagged and the first difference values, respectively. The basic CIPS test statistic can be estimated from the above equation as follows:

$$\text{CIPS} = \frac{1}{N} \sum_{i=1}^{N} CADF_i \quad (3)$$

Driscoll-Kraay Standard Error Method

As the present study aims to analyse the relationship between SD, RE, DF and FD, the DKSE method proposed by Driscoll and Kraay (1998) is appropriate one on the basis of several justifications. This approach addresses the problem of serial correlation- a situation in which there is correlation among observations of time series data at different time periods. The presence of this issue can lead to biased standard errors and inefficient estimates if this is not properly addressed. Second, DKSE also provides efficient estimates when the issue of autocorrelation and heteroscedasticity exists (Driscoll & Kraay, 1998). The issue of heteroscedasticity results in biased standard errors which can lead to misleading statistical inferences and DKSE approach ensures the validity of hypotheses and reliable coefficient estimation (Shah, Hussain, Nawaz, & Iqbal, 2021). Also, the DKSE approach is particularly appropriate when we have limited cross sections and small time period as in the present study. Moreover, this approach is applicable regardless of the data distribution. This approach is applicable to all types of empirical analyses either linear or non-linear models (Afolabi, Amosun, Agbor, & Okunade, 2024).

Dumitrescu and Hurlin (D-H) Causality Test

Lastly, the panel causality test proposed by Dumitrescu and Hurlin (2012) is applied to evaluate the causal relationship among dependent and independent variables. The DH panel causality test is advantageous over Granger causality test as this test efficiently analyses CSD issue and unbalanced panel data (Adalı & Yüksel, 2017).

Findings and Discussions

Firstly, Table 1 represents descriptive statistics of variables of study. The values of mean, standard deviation, minimum values and maximum values are reported. Also, the findings of Jarque-Bera (J-B) test are given which show that some of the data series are not normally distributed.

Table 1

Descriptive Statistics Analysis

Variables	Mean	Standard deviation	Minimum value	Maximum value	J-B statistics
SRU	2.714	1.798	0.863	9.648	62.472***
DF	56.58	43.812	-22.340	114.27	4.418
FD	130.06	31.439	60.757	194.16	0.575
RE	6.613	2.158	4.232	10.910	6.831**
INF	2.634	2.252	-1.298	8.016	5.504*
URB	47.809	8.899	31.386	65.544	1.353

****, ** and * show significance at 1, 5 and 10%, respectively.*

Before parameter estimation, different preliminary tests are performed to assess the presence or absence of certain issues such as CSD and slope heterogeneity. The results of CSD test given in Table 3 show that all variables except DF, exhibit CSD problem. The highly significant test statistics lead us to reject the null hypothesis of cross-sectional independence for all variables except DF.

Table 3

CSD Estimation

Variables	CD-Test	P-value
SD	4.419***	0.000
DF	-0.171	0.864
RE	3.513***	0.000
FD	4.029***	0.000
INF	3.265**	0.001
URB	4.978***	0.000

*Where, ** and *** reveal significance at 5 and 1%, respectively.*

Table 4 represents the findings of the slope heterogeneity test. The results indicate that our data. Suffer from the problem of slope heterogeneity. The statistically significant delta tilde and adjusted delta tilde statistics reject the null hypothesis of slope homogeneity and support the alternative hypothesis suggesting that the problem of slope heterogeneity is present in our data.

Table 4

Slope Heterogeneity Test

	Statistics	P-value
Delta Tilde	2.692**	0.007
Adjusted delta tilde	3.173**	0.002

*Where, ** and *** reveal significance at 5 and 1%, respectively.*

Table 5 shows findings of unit root test for all variables. The findings indicate that some variables exhibit non stationarity at level and other show the stationarity at the first difference. In other words, the study variables show mixed order of integration.

Table 5

Results of Unit Root Test

Variables	**CIPS**		**CADF**	
	I(0)	**I(1)**	**I(0)**	**I(1)**
SD	-3.013***	----------	-2.141	-3.830**
DF	-1.566	-4.547***	-1.365	-2.744*
RE	-0.766	-3.677***	-0.869	-2.753*
FD	-0.409	-2.926***	-0.771	-5.218***
INF	-4.333***	----------	-3.575**	---------
URB	-5.376	----------	-2.661*	---------

*Where, *, ** and *** reveal significance at 10, 5 and 1%, respectively.*

After these tests, the results of DKSE approach are given in Table 6. Based on these results, an increase in RE contributes significantly and negatively to SRU as we observe that there is a positive and significant relationship between energy intensity (used to measure RE) and SRU. A unit increase in RE is found to reduce SRU by 1.36 percent. This negative relationship between RE and SRU is due to the fact that with more intensive use of the energy resources, there will be more unsustainable use of the resources and accelerated environmental degradation. Therefore, stringent rules for energy efficiency and energy-efficient production technologies and processes are essential in these countries. The outcomes are in line with Nur, Topaloglu, Yilmaz-Ozekenci, and Koycu (2025) and (Sun & Yao, 2023).

Secondly, FD has significant and negative impact on SRU in China and Thailand. Regarding the magnitude of the concerned coefficient, for every percent increase in FD, SRU reduces by 0.074 percent. This indicates that FD enhances economic expansion that raises carbon emissions (Kirikkaleli & Adebayo, 2021). The negative impact of FD on SRU is in-line with Lv et al. (2022) who found that FD increases energy intensity in China. Likewise, Wang, Wang, Dong, and Zhang (2023) found that FD reduces SRU due to inefficient resource use. Thus, the finding implies that availability of funds pollute sectors and enterprises, as the mismatch of the resources provides more financing for highly polluting enterprises, which further enhance wastage of resources (Wang *et al.*, 2023).

Table 6

Findings of DKSE Approach

Variables	Coefficient	DKSE Approach	P-Value
DF	-0.012	0.011	0.277
RE	1.360***	0.215	0.000
FD	-0.074***	0.020	0.001
INF	0.306***	0.776	0.001
URB	0.382***	0.087	0.000

*** *shows P=0.000.*

In contrast, DF impacts the SRU negatively and insignificantly. DF which blends traditional financial services with information technology and the internet comprising internet banking, mobile payment, financial service outsourcing, online lending, online insurance, online funds, and other financial services including online payment, often results in increase in energy consumption and internet technologies and digital infrastructure, which may lead to more and unsustainable use of resources (Wu, Liu, & Zhang, 2023). As a result, the doubling of energy utilization efficiency is greatly accelerated by the sustainable growth of all facets of finance (Yang & Masron, 2022). The finding of the study is consistent with the study conducted by Wu et al. (2023). As we added two control variables in our model, the findings reveal that INF has significant and positive impact on SRU. The concerned coefficient reveals that for one percent increase in INF, SRU increases by 0.306 percent. Inflation contributes positively and significantly to the sustainable development. This outcome is consistent with Sadiq, Ou, Duong, Van, and Xuan Bui (2023) who argued that INF has positive relationship with sustainable energy consumption. This is also consistent with the outcome of Hidayatno, Destyanto, and Hulu (2019) and (Rafindadi & Mika'Ilu, 2019).

Finally, URB significantly and positively impacts SRU in selected countries. The magnitude of the concerned coefficient reveals that SRU increases by 0.38 percent for every percent increase in URB. This finding is supported by Y. Liu, Lu, Xian, and Ouyang (2023) who found that urban development in China is associated with rising efficiency in natural resource use. Similarly, Lu et al. (2022) found that urban development leads to increase in efficiency in agricultural water use.

In the last step of analysis, we performed D-H Causality test and its findings are given in Table 7. The findings show that uni-directional causal relationship is present from FD and URB to SRU, and SRU to DF and INF. This unidirectional causal association shows that FD and URB impact SRU whereas other variables do not cause SRU in selected countries.

Table 7

Findings of D-H Causality Test

Null hypothesis	Z-bar Stat	P-value
DF has no causal association with SRU	1.46	0.142
SRU has no causal association with DF	2.522	0.011
RE has no causal association with SRU	1.592	0.111
SRU has no causal association with RE	0.574	0.565
FD has no causal association with SRU	2.535	0.011
SRU has no causal association with FD	-0.764	0.444
INF has no causal association with SRU	1.325	0.185
SRU has no causal association with INF	2.721	0.006
URB has no causal association with SRU	1.836	0.066
SRU has no causal association with URB	-0.131	0.895

Conclusion and Policy Recommendations

Sustainable use of natural resources is crucial for economic growth and environmental protection, with Thailand and China facing challenges due to rising CO2 emissions from non-renewable resources. Financial development is essential for tackling these issues, as it encourages physical capital accumulation and improves capital allocation efficiency. Digital finance, which uses digital technology for financing, payment, and investment services, provides potential for growth in developing nations. Investment patterns vary, with a major portion directed towards exploring and extracting natural resources. Sustainable investment practices are increasingly being adopted to promote biodiversity. Digital finance, which uses various technologies to deliver financial services, is of significant importance for sustainability, providing investment for clean and green environmental projects, supporting innovation and technology adoption, and promoting sustainable consumption through transparent supply chains and renewable energy use.

In this regard, the study examines the impact of financial development, resource efficiency, and digital finance on sustainable natural resource utilization in two East Asian countries namely Thailand and China over 2000 to 2024 period. The presence of the issues of CSD and slope heterogeneity led us to select DKSE approach. The findings of this approach postulates a negative and insignificant association between digital finance and sustainable resource utilization, and negative and significant relationship between financial development and sustainable resource utilization. However, resource efficiency is found to have significant and positive impact on sustainable resource utilization. The outcomes of DH causality test indicate that only urbanization and financial development cause sustainable natural resource utilization.

Several worthy policies are recommended on the basis of these findings. As, financial development contributes negatively and significantly to sustainable development, therefore the study suggests that within the global framework, policymakers should further consider the roles of financial development in order to boost sustainable resource use. This can be achieved by adopting reform in financial sector such as the mandatory integration of environmental, social and governance reporting in all financial sectors and institutions. Governments must encourage the development and usage of resource efficiency funds and green bonds which will redirect the flow of capital towards sustainable projects such as water conservation and energy efficient manufacturing. Moreover, tax reliefs should be provided to the projects in which resources are efficiently used in order to encourage sustainability in operations and investments. Furthermore, the government must develop effective rules to coordinate financial and

environmental restrictions. The primary task of the government's administrative divisions is to effectively implement environmental and financial policies, which necessitates an efficient use of natural resource. As a result, the government must set environmental compliance criteria in order to assist businesses in obtaining financial support for implementing environmental regulations. Furthermore, the government should create a framework for disclosing each enterprise's environmental compliance. Secondly, as digital finance is found to have no significant impact on sustainable resource use, governance, environmental and social standards must be built for digital financial institutions which will evaluate their environmental performance and sustainability performances. Furthermore, monitoring systems must be established to check how digital financial inclusion is related to resource sustainability and green funding programs must be established to support green digital innovations.

The study's findings contribute to current standards for developing and optimizing environmental regulations. The current study emphasizes the need of understanding the role of new technologies in improving the resource efficiency, digital finance and financial institutions set up to support sustainable development. Nonetheless, some developing nations, like China and Thailand, lag the world's leading economies in terms of financial technology for promoting sustainable development, exacerbating the problem of resource scarcity. The nation should focus on promoting the implementation of strong environmental compliance regulations in industrial activities. Thus, the current study emphasizes the importance of environmental quality and laws, which should be a primary priority for populous and rising economies such as China and Thailand. Furthermore, the current study emphasizes the need of protecting natural resources for future generations, in accordance with the United Nations' goals for sustainable development. Thus, the study's findings offer policymakers with guidance for ensuring sustainable resource management in nations such as China and Thailand. Environmentally responsible policies may enable long-term and green economic growth. This can assist to eliminate the region's resource shortage and environmental degradation issues.

Implications

The current study is important since it provides a complete examination of sustainable development in China and Thailand. Its findings can be utilized to form broad conclusions and implications for emerging economies. The findings of this study contribute to the existing academic debate on sustainable development while also presenting practical ways to address difficulties linked with the environmental effect of sustainable development.

The theoretical contributions of this work include the literature on environmental compliance and sustainable development. The current study examines the influence of environmental quality within the context of the research framework. The analysis of the importance of sustainable development adds to the theoretical value of this work, since natural resource utilization is a thriving area with the potential to promote sustainability. Furthermore, the current study focuses on the China and Thailand context and adds significantly to existing research on the factors influencing sustainable development. The booming economy of China provides an ideal framework for examining the impact of environmental compliance and quality in improving sustainable development. The rising worry about the scarcity of natural resources throughout the world emphasizes the theoretical contributions of this work. The current study emphasizes the necessity for more research to investigate the factors that might assist protect natural resources and promote sustainable development.

Limitations of the Study

The current study has several limitations, and the robustness and generalizability of the findings can be affected due to these aspects of this study. First of all, the applicability of results across the Thailand and China contexts could be limited due to the differences in their culture, regulatory frameworks, and economic structures. Secondly, the nature of factors such as technological advancements and financial markets are dynamic, and they are rapidly evolving so it will limit the scope of this study. This study may overlook the important factors than can significantly influence this study i.e., sustainable utilization of resources through the governmental influence, social dynamics of countries and dynamic political scenarios. Future research can concentrate on a few significant global economies and make a comparison between China and Thailand's environmental management and those of big economies. This can give a comprehensive overview of the laws put in place globally to protect environmental quality. Future studies may find it helpful to identify directions and suggestions based on the limitations of this study.

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