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The Role of Financial Development and Technological Innovation for Sustainable Economic Development in Asian Countries

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ABSTRACT:
The purpose of this study is to evaluate the impact that financial development has on sustainable development, together with the interaction of technical innovation, in 31 Asian economies throughout the period from 2003 to 2022. In the current study, sophisticated statistical models like Driscoll-Kraay (D-K) were utilised to make data analysis decisions. Based on the data, it is evident that sustainable development is negatively impacted by any financial progress. The data also suggests that technological innovation acts as a moderator in the relationship between financial development and sustainable development, which is another way in which it contributes to maintaining the relationship.

KEY WORDS:
Financial Development, Technological Innovation, Sustainable Development, Asian Countries

Introduction

In order to study the relationship between technical innovation (TI), financial growth and sustainable economic development (SED) in Asian nations, firstly, we have to understand how financial systems development, specifically tranquil access to credit, supports economic growth while maintaining environmental sustainability. Secondly, the use of digital transformation, smart infrastructure, and renewable energy technologies are being studied to inspect the TI impacts on SD. The prime and foremost objective is to ascertain the difficulties encountered by the Asian countries while incorporating financial and TI into their economic structures. The major obstacles faced by these countries are limitations imposed by regulations, variations in technology, and lack of skilled human capital.

There are serious social, environmental, and economic problems affecting the globe right now. In order to deal with natural calamities, climate change, poverty, elevation, economic inequality and technological advancement, a huge number of financial resources are required. In addition to endangering sustainability, the COVID-19 pandemic has made financial limitations worse for economies all over the world. Tactics like lockdowns have raised various doubts about economic and production outcomes, and the serious lack of long-term financial strategies remains a major obstacle. Therefore, assessment of various socio-economic development elements, including FD, is essential (Hunjra et al., 2022).

Considering the importance of FD and technological advancement in fostering SED, the Endogenous Growth Theory provides valuable insights. This theory provides a thorough framework for comprehending how financial systems and technical developments are both essential for long-term sustainability goals and important drivers of economic growth. Our research aims to identify the mechanisms through which FD, TI, and SED interact and support inclusive and environmentally resilient economies by applying this theory to the analysis of their interactions (Yu et al., 2023).

Sustainable and FD are interrelated ideas that have drawn a lot of attention in the policy discourse and scholarly literature. The enhancement of financial systems and institutions that permits better resource allocation, enhanced financial stability, and broader access to financial services is referred to as FD (Umar et al., 2020). Recent studies have investigated the positive impact of FD on economic growth(GDP) (Ahmed et al., 2022; Ali & Ramakrishnan, 2022).

However, there is currently a lack of available data in the literature about the impact of financial development (FD) on sustainable economic development SED, especially in countries which have been considered as low to middle-income nations. Due to lower savings rates, the latter enjoy limited capital, which creates a variety of capital allocation issues across businesses. Even many industries need funding, despite calls for a move regarding cleaner processes of production processes in support of SED. Owing to outdated technology, these economies primarily trust the agriculture sector, which improves air and water pollution(Ali et al., 2022). With its goal of doubling its GDP in the next ten years, the UAE must priorities the development of its banking sector. The promotion of comprehensive sustainable economic growth (GDP) is negatively affected by environmental degradation in the UAE (Samour et al., 2022).

Private and green investment along with financing should be promoted for achieving justifiable economic development (ED) in OECD countries. FD and finances also play a part in this process. It is clear from OECD studies and data that there is an environmental, financial, and economic connection in OECD countries, and it is something that has to be looked into (Ziolo, et al., 2020).

There are substantial challenges faced by TI during adoption and innovation of new technologies (Omri, 2020). TI has the ability to increase FD and promote sustainable development (Abbasi et al., 2022). Technological innovations in financial services, such as fintech, can increase financial inclusion and significantly impact sustainable development (Falaiye et al., 2024).

Jiao, et al., 2021 think that innovative financial technologies could be useful weapons for continuous battle to mitigate global warming. This would be accomplished by carbon emission trading, clean renewable energy trading, and climate finance flows. But financial technology is now being criticized for their role in accelerating climate change(Ozturk, & Usman, 2023).

Various developed countries, along with a few developing countries, are leading in TI, whereby the majority of developing and specifically least developed nations are lagging, landlocked and facing notable challenges during the adoption of new technologies. This means that there is still a methodological gap in the research which can determine the impact of TI on the achievement of sustainable development (SD), which diverges among different stages of income levels or economic development. (Omri, 2020).

Keeping in view inconsistency, Hunjra et al. (2022) have conducted research on low and middle-income countries. Now, I have chosen Asian countries (AC). The interdependence of technical innovation (TI), sustainable economic development (SED), and financial development (FD) highlights how urgent it is to address global issues. Although FD's beneficial effects on GDP have been well researched, less is known about how it affects SED, especially in low- and middle-income countries where advancement is hampered by a lack of capital and antiquated technology. Furthermore, there are advantages and disadvantages to technology's involvement in advancing SED.

TI is explored for its possible implications for climate change, even while it shows promise in tackling environmental concerns through mechanisms like carbon emission trading.

Key borderline contributions of current research are imitated in two aspects: First, TI, FD and SED were put in the same research framework initially, followed by an in-depth econometric analysis to figure out the effect of FD along with innovation in technology (TI) on SED was carried out to improve the quantitative research, especially in FD field, technological innovation (TI), and sustainable economic development (SED). Various statistical techniques are employed to address problems like indigeneity, cross-sectional dependence, and heteroscedasticity. In order to investigate the relationship between TI, FD and SED, various techniques, including Principal component analysis (PCA) along with Driscoll–Kraay standard errors (D-K) and regression, were intended for reliable results.

The contribution of the current study will be vital for the exploration of the role played by TI and FD on SED in Asian nations. The findings will highlight how financial institutions and technological advancements propel GDP and sustainability by utilizing the Endogenous Growth Theory. The study revealed that in Asian countries (AC) lying in the low- and middle-income range, there is a considerable gap in the research by analyzing how FD affects SED, especially wherein technology is antiquated and capital is poor. Critical potentials, including technological innovations like digital transformation, smart infrastructure, and renewable energy technologies for the promotion of SED along various constraints of these factors, are studied in this study.

Literature Review

Financial Development and Sustainable Economic Development

In the literature review section, we will discuss about empirical and theoretical reinforcements of FD to establish the association between financial inclusion (FI) and SED as both of them are closely related. The literature study dowries various theoretical stances regarding correlation between climate change (CC), carbon emissions (CE), and inclusive financial growth (IFG).

Amjad et al. (2021) conducted a study to examine how FD can be used for environmental pollution reduction and promote sustainable GDP throughout the years 1980–2020. According to the findings, financial development's positive shocks spur economic expansion and lower pollution levels in the environment. Adams and Klobodu (2018) investigate how financial advancement (FA) affects environmental quality and find a favorable correlation between the two. Because FA permits investors to employ environmentally friendly technologies, Boutabba (2014) examines the impact of FD on the ingestion of energy, GDP, and environmental deprivation in India and a statistically significant negative relationship was recognized between carbon emissions and FD. Ozturk and Acaravci (2013) studied the fact that environmental performance can be improved by FD by providing firms access to cutting-edge green technologies.

In a similar vein, Ahmed, (2017) find out the effects of FD on generation of renewable energy (RE) and discovers a favorable correlation between the two. According to the study's conclusion, producing RE is very expensive; therefore, a nation's ability to generate RE sources that contribute less significantly to environmental degradation is facilitated by its FA. (Hunjra et al., 2022)

For the G7 countries between 1990 and 2017, Shoaib et al. (2020) discovered a positive association between FD growth and SED. According to Zaidi et al. (2019), the correlation between FD and natural resources is positive in the OECD countries between 1990 and 2016 (Omri, 2020).

Few research studies have investigated the relationship between FD and SED by utilizing FD's moderator variable, which alters FD's environmental impact. Ojeyinka and Osinubi (2022) investigated the relationship between FD and SED in 22 sub-Saharan nations. The study's findings indicate that the relationship between FDI and sustainable development (SD) is negative; nevertheless, when globalization is taken into account, CO2 emissions

rise. Globalization was also employed by Sheraz et al. (2021)as a modulator of the FD on SED in G20 nations. Findings demonstrated that, throughout the sample, the financial sector increases SED; nevertheless, this effect turns negative when the moderator is involved (Rani et al., 2023).

H1: The impact of Financial development (FD) is significantly positive on sustainable economic development (SED).

Sustainable Economic Development and Technology Innovation

The study emphasizes the relationship between population growth, economic development, innovation, and technology and carbon emissions. By using data spanning over a period of 40 years regarding the impact of technology on SD, the avenues through which TI promotes SD are pinpointed. The demonstration of empirical results shows that, by promoting GDP without adversely harming the environment, TI's role is pivotal in fostering SD. Results also demonstrate that FD significantly aids in a nation's SD by reducing emissions of CO2(carbon dioxide), and the growth of the economy further kick-starts the sustainability process through the lowering of CO2 emissions (Ahmad et al., 2023).

According to the first line of research, the correlation between carbon emissions, technological innovation, and sustainable economic growth is negative. According to their empirical research, rising nations' environmental damage is pointed as the financial sector grows. According to Kirikkaleli et al. (2022), financial expansion lowers Chile's consumption-based carbon emissions. Similarly, TI and FD across 27 nations. The authorizing impact of FD on TI in China and Malaysia was highlighted by (Destek & Sarkodie, 2019). According to a number of studies examining the beneficial ecological effects of financial sector advancement, this industry supports technological advancements as well as green and cleaner energy initiatives, hence approving natural prominence (Saqib et al., 2023).

Model build by this paper is moderated mediation as TI and environmental regulation enforcement were used as mediator and moderator respectively. This research, on other hand, conducts an empirical test using a panel of 30 provincial industries of China between 2006 and 2015 using sys-GMM approach. An analysis of the regional heterogeneity effect is also conducted. First, China's industrial sustainable growth benefits from flexible environmental policies, as demonstrated by the results(Yuan & Zhang, 2020).

According to Yang et al. (2022), China has made rapid advancements in digitization and related technological developments in recent years, becoming a leader in several industries (Couture et al., 2021). Furthermore, there is a progressive transition occurring in the world of the internet from an information-centric to a value-centric perspective, and the notion of digitization is becoming increasingly significant. In addition to fostering TI, digitization gives the social economy and businesses new platforms and forms, expanding their market reach and improving their financial efficiency (Chen, 2020).

H2: The impact of Technological innovation (TI) on sustainable economic development (SED) is significantly positive.

Generally, research continually comes to the conclusion that TI and FD are key factors influencing Asia's sustained GDP. Improved financial systems make it easier to spend more in technology, increasing output and promoting environmental sustainability. Thus, in order to ensure long-term sustainable growth, policymakers are encouraged to support technical breakthroughs and financial sector reforms.

To sum up, prior studies confirmed the significant impact of TI on FD and TI on sustainable GDP. But there is lesser understanding on this topic available. By investigating the combined impact of FD and TI on sustainable GDP in developing nations, this study seeks to close that gap.

Methodology

Data and Variables

Our sample comprised of thirty-one (31) Asian countries (AC) during the 2003 to 2022; which are delineated in Table 1. In order to assess the largest individual impact from the selected indicators on this index for whole Asia and specific countries in the study sample Principal component analysis (PCA) was applied. Annual data of world development indicators from data bank of World bank was collected.

The choice of our sample and variables two composite financial indicators is based on classification by World Bank's Global Financial Development Database which is dependent on accessibility data regarding study sample for a significant investigation period. and subject to data availability of our study sample for a significant investigation period. The statistical descriptions of variables in Table 2.

Current research explores whether financial Development is related with sustainable economic development for thirty-one (31) Asian countries (AC). The selected variables used for constructing two composite financial indicators i.e. FD, SED and TI are prescribed in Table 2.

$$SED=\beta_o+\beta_1 FDindex+\beta_2 Techindex+\beta_3 GDP+\beta_4 TR+\beta_5 ADR+\beta_6 IT+\varepsilon_0$$

Operationalization of Variables

Sustainable economic development (SED)

The SED can be defined as the process through which present and future prospective regarding fulfillment of human requirements vis a vis usage of natural resources wisely, direction of technical development coupled with institutional change.

By adopting (Hunjra et al., 2022), the study utilized changed net investment funds (% of GNI) as an intermediary for the reasonable monetary turn of events. In any case, past examinations involved Gross domestic product as the maintainable improvement intermediary for the connection between environmentally friendly power and economic turn of events. Numerous observational examinations in this field utilize genuine Gross domestic product per capita to gauge improvement.

Financial Development (FD) and Technological Innovation (TI)

In order to develop a composite measure of financial inclusion, FD and TI are used as variables of interest in this study by adopting Chatterjee (2020) and Renzhi and Baek (2020). We consider two potential proxies: (FD1) Broad money (% of GDP) and FD2) domestic credit to the private sector (% of GDP). The Technology index was developed based on four components: no of patent total residents, Mobile (subscription per 100)., High-technology exports (% of manufacturing exports), Internet (% of the population) and Z-score are distinct normalization strategies for normalizing inclusive FD and TI factors (Hussain et al., 2023). As per(Hunjra et al., 2022), adjusted net savings are used as indicators for SED. The variables have been divided into dependent variables (sustainable economic development), independent variables (financial development and technology innovation), and control variables (GDP, TR, ADR, IT) for empirical research.

Data Analysis

Table 1

List of countries in the study sample (31 countries)

S. No	Names	S. No	Names	S. No	Names
1	Brunei	12	Jordan	23	Cambodia
2	Israel	13	Kazakhstan	24	India
3	Japan	14	Lebanon	25	Indonesia

S. No	Names	S. No	Names	S. No	Names
4	South Korea	15	Malaysia	26	Kyrgyz Republic
5	Kuwait	16	Maldives	27	Mongolia
6	Macao	17	Thailand	28	Pakistan
7	Qatar	18	Afghanistan	29	Philippines
8	Saudi Arabia	19	Tajikistan	30	Sri Lanka
9	Singapore	20	Yemen	31	Vietnam
10	United Arab Emirates	21	Bangladesh		
11	Iraq	22	Bhutan		

Table 2

Asia's financial indicators considered in the study (2003-2022)

Variable	Description	Source
ANS	Adjusted net savings, excluding particular emission damage (% GNI)	WDI
FDI	i) Broad money (% of GDP)	WDI
FD2	ii) Domestic credit to private sector (% of GDP)	WDI
Tech1	No. of Patent total residents	WDI
Tech2	High-technology exports (% of manufacturing exports)	WDI
Tech3	Internet (% of Population)	WDI
Tech4	Mobile (subscription per 100)	WDI
GDP	GDP per capita (constant 2010 US$)	WDI
TR	Trade (% of GDP)	WDI
ADR	The Age dependency ratio (% of working-age population)	WDI
IT	International tourism, receipts (% of total exports)	WDI

Table 3

Summary of Statistical Description of Selected Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Ans	620	14.934	10.614	-34.849	45.479
Fd1	620	81.858	53.874	9.663	370.133
Fd2	620	61.387	43.897	1.267	297.962
Patent	620	20991.099	55161.156	1	368416
Technology	620	14.984	12.748	0	67.045
Internet	620	42.431	31.062	0.065	100
Mobile	620	100.018	56.691	0.296	420.853
GDP	620	15529.449	19768.788	338.739	98752.229
Tr	620	98.579	60.817	21.326	437.327
Adr	620	52.539	17.907	16.172	109.448
It	620	13.865	17.7	0.359	93.652

Descriptive statistics are shown in Table 3. The mean values of fd1 and fd2 (two proxies of financial development) are lower than the maximum value. Liu, Hong, and Sohail (2022) suggest the lower FD in Asian countries. Furthermore, the mean value of TI-related proxies such as the patent (M = 20991.099), technology (M = 14.984), internet (M = 42.431) and mobile (M = 100.018) are lower than the expected value, which shows that Asian countries may face challenges in accessibility to TI. From the control variables, the GDP mean and standard deviation are greater than those of the remaining control variables. This implies that GDP variation is more prominent than that of other control variables (Mhlanga, 2022).

Table 4

Result of Bartlett test of sphericity and Kaiser-Mayer Olkin Measure of Sampling Adequacy

	Bartlett test of sphericity			Kaiser-Mayer Olkin Measure of Sampling Adequacy
	Chi-square	Degrees of freedom	P-Value	
Financial development				
Z-score normalization	714.899	1	0.0000	0.50
Technology Innovation				
Z-score normalization	509.712	6	0.0000	0.469

Source: Authors' calculations. Note: Bartlett test of sphericity H0: Variables are not intercorrelated. *** indicates statistical significance at a 1% level.

The z-score is a typical normalization technique to standardize the pointers where scaling depends on deviation from the mean. Through this technique, utilization empowers cross-country examinations. Be that as it may, two matters should be focused on, i.e., the size of the sample should be large, and recalibration is required when new information focuses are added.

z-score normalization is used to construct the standardization as delineated below: -

$$Zee = \frac{Xi - \bar{X}}{\sigma}$$

where,

$\bar{x}$ = group average

$\sigma =$ standard deviation

For the inspection of suitability of this data for factor analysis Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) test were performed in beginning of PCA. In order to examine whether the correlation matrix used in the PCA is an identity matrix, Bartlett's test of sphericity is used. It should be significant ($p < 0.05$) for factor analysis to be suitable(Le et al., 2019).

Meanwhile, the Kaiser-Meyer-Olkin (KMO) test was conducted to measure the sampling adequacy. It indicates the proportion of common variance that might be caused by underlying factors. The KMO index ranges from 0 to 1, with > 0.5 generally indicating that the factor analysis is suitable (Hussain et al., 2023). The results of performing these two tests are reported in Table 4. In this case, one KMO value is equal to 0.5, and the other value is 0.469, which is approximately equal to 0.5. For Bartlett's test of sphericity, the computed p values in both cases are lower than the significance level alpha = 0.01. This means that the result of the null hypothesis, H0, is rejected, confirming that the variables used in the PCA are correlated. As such, the results of both tests support the use of PCA in this study.

Table 5

Total variance explained

	Component	Eigenvalues	% of Variance	Cumulative Variance %
Financial Development Index				
Normalized variables using standardized Z-score	1	1.82813	0.9141	0.9141
	2	0.171868	0.0859	1.0000

Technology Innovation Index				
	1	1.83478	0.4587	0.4587
Normalized variables using	2	0.998865	0.2497	0.7084
standardized Z-score	3	0.901445	0.2254	0.9338
	4	0.264909	0.0662	1.0000

Table 5 indicates the estimated factors and their eigenvalues. Based on this, we selected to employ the first two factors for PCA on the FD index and TI index. Since they were taken together, they explain more than 80% of the total variance of the FD indicators. For TI indicators, they explain approximately 93% of the total variance; all four factors are retained. Then, in the second phase, we estimate that the eigenvalues are larger than one and suggest that both indicators have significant variability. This indicates their ability to explain the changes within the original variables.

Table 6

	Ans	FDindex	techindex	Gdp	Tr	adr	it
Ans	1.00						
FDindex	-0.14***	1.00					
techindex	0.08	0.59***	1.00				
Gdp	0.26***	0.35***	0.61***	1.00			
Tr	0.23***	0.21***	0.24***	0.33***	1.00		
Adr	-0.20***	-0.32***	-0.55***	-0.62***	-0.36**	1.00	
It	-0.21***	0.11**	0.15***	0.24***	0.06	-0.20***	1.00

The correlation represented in Table 6 shows strong negative correlations between the FD index (FDindex) and the technology innovation index (tech index), suggesting that countries with higher FD tend to have lower technological accessibility. Moreover, GDP shows positive correlations with both FDindex and techindex, indicating that economic growth is associated with advancements in both financial development and technology. Additionally, there are significant negative correlations between the FDindex and ans and weak positive correlations between the tech index and ans, suggesting that they are not particularly strong.

Table 7

Driscoll-Kraay standard errors

Variables	D.K(OLS) l_sed	D.K(OLS) l_sed	D.K(OLS) l_sed
FD index	-0.119***		-0.0800***
	-0.0265		-0.0241
Tech index		-0.145***	-0.0938***
		-0.0352	-0.0295
l_gdp	0.0626	0.0945**	0.0998***
	-0.039	-0.0362	-0.0333
Tr	0.00156***	0.00133***	0.00150***
	-0.000313	-0.000356	-0.00036
Adr	-0.00448	-0.00619**	-0.00547*
	-0.00313	-0.00342	-0.00336
It	-0.00315***	-0.00238***	-0.00273***

Variables	D.K(OLS) l_sed	D.K(OLS) l_sed	D.K(OLS) l_sed
	-0.000749	-0.00061	-0.00077
Constant	2.246***	2.079***	1.978***
	-0.52	-0.514	-0.489
Observations	575	575	575
R-squared	0.106	0.105	0.121
Stat	48.33	17.36	29.5
P-value	0	0	0
Number of groups	31	31	31

Standard errors in parentheses
***p<0.01, **p<0.05, *p<0.1 *Statistical significance is denoted by ***, *, and * at 1, 5, and 10 per cent, respectively.

This table shows the Driscoll-Kraay regression analysis whereby the impact of the FD index (financial development index) dependent variable l_sed (sustainable economic development) is statistically substantially negative in the first model, along with a coefficient of -0.119. It suggested that an increasing FD index is linked with a decreasing dependent variable, holding other variables constant. This relationship is significant. Similarly, Techindex also reflects a negative effect on the dependent variable, which is statistically significant in both models, with coefficients of -0.145 and -0.0938, indicating that increasing Techindex is associated with a decrease in the dependent variable, holding other variables constant. These relationships are also significant at the 1% level. If we talk about the coefficient for l_gdp (log of economic growth), it is positive in all models, indicating that an increasing l_gdp is linked with an increase in the dependent variable (l_sed). However, this relationship is statistically significant only in the third model. Tr (trade openness) has a positive effect on the dependent variable in all models, with statistically significant coefficients of 0.00156, 0.00133, and 0.00150. This suggests that the increase in Tr is linked with an increase in the dependent variable. These relationships are significant. Adr (ageing population dependency) coefficients are negative in all models, which shows that increasing Adr is linked with a decrease in the dependent variable, but this relationship is statistically significant only in the second model at the 10% level. It (international tourism) has negative coefficients in all models, suggesting that when there is an increase in international tourism, then there will be a decrease in the dependent variable. In all models, these relationships are statistically significant at a 1% level.

Overall, the above-narrated results indicate that FDindex, Techindex, Tr, and It have significant effects on the dependent variable (l_sed).

Conclusion

The research was aimed at measuring and identifying trends regarding FD, TI, and SED by choosing 31 AC as a sample. It also examined whether FD is linked with TI and SED, which could escalate either synergies or conflicts of policies, which will open the direction for further research. For the construction of two financial indicators, PCA was performed on various sets of normalized variables. The overall findings of the study show fluctuating trends among the research sample. The estimation results from Driscoll-Kraay standard errors (D-K) indicate FD has a significant and negative effect on SED and TI, which also indicates the significant and negative effect on SED in a sample of study chosen for investigation from a period spanning 2003 to 2022. GDP also has a significant and positive impact on SED, suggesting a role of economic growth in powerful developments in FD and technology. The results remain the same for the overall sample and subsample countries at various economic levels.

The outcome of the study established a clear connection between GDP, FD, TI, and SED in 31 Asian countries. Findings clearly reflect a significant impact on FD; hence, the government must pay attention to the

development of mechanisms for the enhancement of FD and TI. Furthermore, the approach can ignore the importance of the informal sector in these countries, which has a big influence on advances in technology and finance. Due to the complex interactions between several variables that affect SED, the study also has difficulty separating out the effects of certain policies or innovations. Lastly, the thoroughness of the analysis may be impacted by gaps in the quantity and ability of data on some metrics, such as rates of technological adoption and environmental sustainability.

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