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Original Article

Influence of Industrialisation on Sustainable Development: Evidence from Asian and European Developing Countries

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Abstract

The purpose of this study is to examine the impact of industrialisation on sustainable development in developing Asian and European nations between 1990 and 2022. To accomplish this, the study employed a panel dataset and a variety of econometric models, including panel unit root, cointegration, and an autoregressive distributed lag (ARDL) model, to estimate the short-run and long-run dynamics between the variables. Moreover, the dynamic least squares (DOLS) model is used for confirming the robustness of the study's findings. The cointegration result verifies that there is one-way cointegration between the concerned variables. The Panel ARDL's findings reveal that industrialisation has a long-run positive influence on sustainable development (as expressed by SDI) in developing nations in both Asia and Europe. However, compared to developing nations in Europe, industrialisation has a greater influence on sustainable development in Asian developing nations. However, industrialisation has a short-term detrimental impact on sustainable development in developing nations in both Asia and Europe. Therefore, the present study's statistical findings support the incidence of the Environmental Kuznets Curve (EKC) hypothesis in developing Asian and European nations, highlighting the idea that industrialisation initially undermines sustainability (especially environmental sustainability) but eventually promotes sustainable development. These results offer compelling evidence that, on the long-term horizon, one of the major driving forces ensuring sustainable development in developing Asian and European countries is industrialisation.

Keywords: *Industrialisation; Sustainable Development; Asian and European Developing Countries; Panel ARDL*

JEL Classification: *F18; Q50; Q53; Q56*

Introduction

Economic progress and advancement have long been recognised as being significantly influenced by industrialisation by many renowned researchers, such as Cherniwchan (2012), Alley, Egbetunde and Oligbi (2016), and Ndiaya and LV (2018). Economies that have mainly depended on agriculture become more multifaceted and diversified as a result of industrialisation, which also improves living standards, productivity, and advances technology. But typically, this transition from an agri-based economy to an industry-based, multifaceted economy comes with a price, especially when it comes to resource depletion, environmental damage, and widening a range of socioeconomic disparities. The contradiction that developing nations, especially those in Asia and Europe, must carefully negotiate is the idea that industrialisation could both be a driver of prosperity and a possible threat to sustainable development (SD). Securing synergy between economic advancement, environmental preservation, equality, and social fairness has become a critical agenda for governments, researchers, and international bodies alike as the world community grows more and more focused on sustainable development. The 2030 Agenda, or Global Agenda offered by the United Nations, enshrined the

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significance of sustainable development and set forth the Sustainable Development Goals (SDGs) as an inclusive framework for resolving several issues worldwide. The understanding that economic expansion must coexist harmoniously with ecological conservation and social inclusion is fundamental to the SDGs. In light of these objectives, industrialisation frequently offers developing nations both advantages and challenges. Industrialisation has the ability to substantially boost production, reduce poverty, and create jobs (Opoku & Yan, 2019). However, there are significant threats to attaining long-term sustainability due to the environmental and social consequences of unrestrained industrial growth, including increasing carbon emissions, biodiversity loss, and spreading inequality.

Here, especially countries belonging to the Asian and European regions are rapidly industrialising, with differing effects on their social, environmental, and economic contexts. Here it is noteworthy to mention that one of the main aspects of the recent decades-long global economic transition has been the industrialisation of developing Asian nations. Emerging as important industrial central points, nations like China, India, and other countries belonging to Southeast Asia have drawn substantial foreign direct investment (FDI) and have become essential components of global supply networks. Government-led industrial policies of these countries, a focus on exports, the availability of a young labour force, the skilling of human resources, fostering entrepreneurship, etc., have all contributed to this fast industrial expansion. With a sizable portion of the world's industrial production, China especially has appeared as the world's foremost manufacturing powerhouse. China's economy has grown to become the second biggest in the world, and its masses have been lifted out of poverty, due in large part to the country's industrial expansion. But China's industrialisation has also brought about serious environmental damage, with soil pollution, water shortages, and air pollution emerging as major issues. Acknowledging these problems, the Chinese government has implemented measures to encourage more environmentally friendly industrial practices, such as increased investments in environmental protection, renewable energy, and more stringent environmental laws and fostering a sustainable finance ecosystem (Wang & Su, 2019; Aslam *et al.,* 2021). India, an important nation in the Asia region, adopted a distinct route for industrialisation. Even though India's industrial base has grown significantly, especially in areas like steel, pharmaceuticals, and information technology, it is still less diverse than China's. India has experienced ongoing problems with poverty, inequality, and environmental destruction along with its industrialisation. The nation's rapid urbanisation has increased demand for its natural resources and infrastructure, casting doubt on the viability of its growth strategy. Vietnam, Indonesia, Malaysia, the Philippines, and Thailand are among the Southeast Asian nations that have experienced fast industrialisation in recent years. These nations have embraced industrialisation methods focused on exports, drawing direct foreign investment into industries including electronics, textiles, and automobile production. Nonetheless, there have been substantial negative effects of industrialisation on the environment in these nations, with pollution, deforestation, and biodiversity loss emerging as the main issues *(*Elfaki *et al., 2022;* Raihan, *2023).* Asian emerging nations have made significant strides toward incorporating green practices into their industrialisation plans in spite of these obstacles. The necessity of striking a balance between social inclusion, environmental sustainability, and economic progress is becoming more and more apparent to the region's governments. As a result, initiatives fostering green businesses, funding clean energy technology, and strengthening social safety nets for disadvantaged groups have been implemented.

Contrasting to their Asian counterparts, the industrialisation trajectory of European developing countries, especially those in Eastern and Southeastern Europe, varies. The industrialisation of the developing European nations has been more gradual than that of Asia, largely due to historical legacies and their inclusion into the European Union (EU) structure. These nations' industrialisation plans have been significantly impacted by the environmental and social regulations of the EU. Many developing European nations have been compelled to enact stronger environmental restrictions and harmonise their industrial policies with EU directives as part of the EU accession process. This has helped to advance a more environmentally conscious industrialisation strategy that places a focus on minimising carbon emissions, increasing energy efficiency, and limiting adverse ecological consequences. However, despite all this, these European developing countries continue to face challenges related to inequality, unemployment, income disparities and the environment.

Given this context, it is critical to comprehend how industrialisation affects sustainability results in different regions. Hence, this study intends to explore how industrialisation influences sustainable development and emphasise the regional differences in striking a balance between economic advancement, environmental sustainability, and social equality by concentrating on developing nations in both Asia and Europe during 1990 to 2022. This study is especially pertinent in light of the ongoing discussions around global climate change, which place rising demands on emerging nations to lower their carbon footprints while still industrialising to meet domestic demand for employment and economic growth. The present study contributes in a number of ways to the corpus of literature previously published in the domains of social science research and economics. First of all, it takes into account not just the economic but also the environmental and social aspects of sustainable development. Second, in order to quantify sustainable development, the current study developed a sustainable development index, which is further taken into account as a dependent variable. Finally, given the significance of developing nations in Asia and Europe and their struggles to maintain economic growth while protecting the environment and promoting societal advancement, this study intends to investigate the ways in which industrialisation affects sustainable development in these regions.

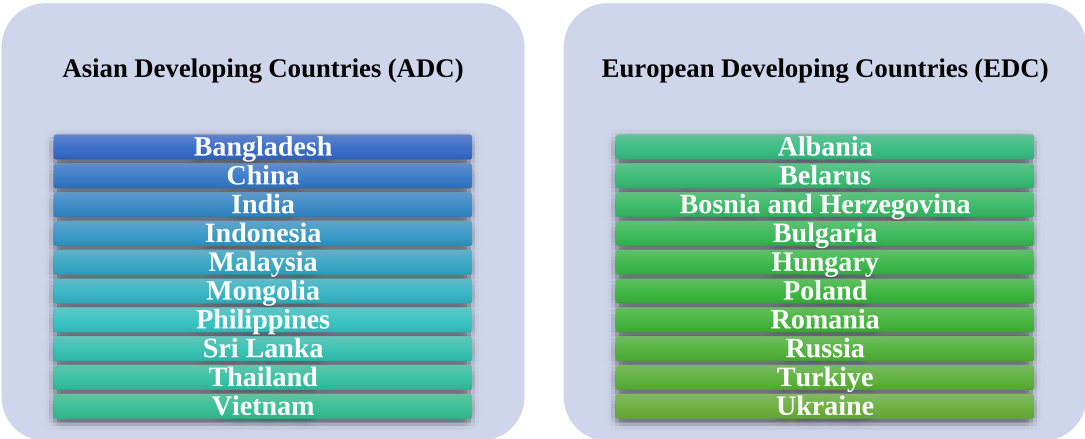
Literature Review

Over the past couple of decades, a sequence of academic research has been steered to investigate how industrialisation interacts with various macroeconomic developmental aspects in different nations and regions. Below is a summary of those selected earlier studies. According to Merican *et al. (2007),* one of the main causes of the global rise in pollutant emissions is industrialisation. Regarding the empirical aspect of industrialisation, Akbostancı, Tunç & Türüt-Aşık (2011) examined 57 Turkish companies between 1995 and 2001 and discovered that the foremost factor influencing the rise of carbon emissions is variations in overall industrial activity. Cherniwchan (2012) considered emissions data from 157 nations between 1970 and 2000 to analyse how industrialisation impacts the environment as economies grow and economies follow the structural shift from agriculture to industry. Researchers discovered that as economies grow over time, changes in environmental quality are largely determined by the level of industrialisation. The findings demonstrated how industrialisation worsens environmental quality by increasing emissions. Researchers discovered that there is an 11.8 percent upsurge in the emissions for every 1 percent raise in industry's proportion of overall output. Similarly, according to a study by Hassaballa (2013), industrialisation and FDI are two of the main root causes of emissions that exacerbate climate change by causing global warming. Lin, Moubarak and Ouyang (2014) investigated the relationship between China's carbon dioxide emissions from 1980 to 2012 and the growth of its industries. An autoregressive distributed lag (ARDL) multivariate model's results showed that industrial growth might eventually have an impact on energy consumption, which could then have an impact on carbon dioxide emissions. Shahbaz *et al.* (2014) looked into the interlinkages between Bangladesh's industrialisation, energy use, and carbon emissions. They made use of quarterly data from 1975 to 2010. In the case of Bangladesh, the results of an autoregressive distributed lag (ARDL) bounds test showed the existence of an EKC between industrial development and carbon emissions. Keeping in mind the recent upsurges in GHG emissions and their consequent adverse impact on Mother Nature Opoku and Boachie (2020) investigated the environmental impact of industrialisation and FDI in the context of 36 selected economies from the African region during 1980 to 2014 by using the PMG estimation technique. They reported that mostly industrialisation has an insignificant effect on the environment, and in contrast, FDI has a significant effect on the environment. Sikder *et al.* (2022) revealed the detrimental effect of the industrial development environment through the exacerbation of CO_2 discharge. Here, researchers considered a panel data set of 23 developing countries from 1995 to 2018 and utilised the Panel ARDL model. Using the CS-ARDL model, Voumik and Sultana (2022) reported how industrialisation deteriorates environmental quality in BRICS countries. Ahmed *et al.* (2022) investigated the impact of industrialisation and FDI on the environment in the context of 55 selected countries from the Asia Pacific region during the period from 1995 to 2020 by employing the Panel ARDL estimation technique. They found that industrialisation has a constructive and significant effect on the environment, and in contrast, foreign direct investment has a significant adverse effect on the environment. Tackie *et al. (2022)* also reported the linkages between industrialisation and economic development in West African countries. Afriyie *et al. (2023)* used the PMG approach to determine the nexus between industrialisation and CO_2 emissions and reported a statistically negative relationship between industrialisation and CO_2 emissions in 37 sub-Saharan African countries. Ghosh and Paul (2024) investigated the effects of industrialisation and energy usage on environmental sustainability from 1990 to 2022 using annual data from seven chosen Asian emerging economies. Using the Panel ARDL estimating model, they discovered that industrialisation pumps carbon emissions that ultimately deteriorate environmental sustainability. On the other hand, studies by Ndiaya and LV (2018), Opoku and Yan (2019), Elfaki, Handoyo and Ibrahim (2021), Fagboyo and Ajisafe (2022), and Saba and Ngepah (2022) reported industrialisation as a driver of the economic growth of countries.

Upon reviewing the aforementioned literature, it is evident that the majority of earlier research either examined the interaction between industrialisation and economic development or investigated the impact of industrialisation on environmental sustainability. Since the three collective aspects of sustainable development are economic, social, and environmental, it is necessary to conduct a study that takes into account all three dimensions simultaneously, not just the economic or environmental ones. Furthermore, a study that aims to explore how industrialisation influences sustainable development in Asian and European developing countries is much desired, given the significance of developing economies in Asia and Europe and their ongoing struggle to ensure economic development without impairing the environment and fostering societal development.

Methodology

The present study is quantitative in nature and relied on multiple reliable databases to obtain secondary data to explore the dynamic interaction between industrialisation and sustainable development over time from 1990 to 2022 across several developing countries belonging to, especially the Asian and European regions.



Source: Authors' own presentation

Figure 1: List of Selected Countries Asian and European Region

Figure 1 presents a list of sample countries that include Bangladesh, China, India, and 7 other countries from the Asian continent, and Bulgaria, Hungary, Poland, and 7 other countries from the European continent. The IMF's country groupings and standard classifications identify these countries.

Table 1: Description of Selected Variables in this Study

Code	Brief Description of Variable	Proxy Parameter
SDI	Sustainable Development Index (SDI). It is calculated based on the methodology provided by Jin *et al*. (2020). It takes into account twelve different parameters of sustainable development, which covers all the three core areas, i.e., economic, Social and environmental (presented in table 2). All those parameters are converted into Natural Log.	Sustainable Development
INDUS	Natural Log of industry value added (constant 2015- in USD $)	Industrialisation
FDI	Natural Log of percentage of net inflow of FDI to GDP	Foreign Direct Investment-

Source: Authors' own compilation

- **Developing SDI using Principal Component Analysis (PCA)**

Principal Component Analysis (PCA) is an approach for reducing the dimensions of multivariate datasets. PCA condenses the information scattered across multiple dimensions into a fewer number of dimensions. A widely accepted, suitable method for creating an index based on several parameters is PCA. Researchers used this PCA to construct the SDI, which then serves as a dependent variable in the econometric model.

Table 2: Results of Principal Concept Analysis (PCA) to Develop SDI

Components	Eigenvalue	Difference	Proportion	Cumulative
1	5.1452	2.2575	0.4288	0.4288
2	2.8876	1.5954	0.2406	0.6694
3	1.2921	0.3880	0.1077	0.7771
4	0.9041	0.2296	0.0753	0.8524
5	0.6744	0.2928	0.0562	0.9086
6	0.3815	0.1168	0.0318	0.9404
7	0.2647	0.1158	0.0221	0.9625
8	0.1488	0.0195	0.0124	0.9749
9	0.1292	0.0299	0.0108	0.9857
10	0.0993	0.0509	0.0083	0.9940
11	0.0484	0.0243	0.0040	0.9980
12	0.0240	---	0.0020	1.0000

SDI	Eigenvectors (factor loadings)
Variable	**Component 1**
GDP_GROWTH	-0.0537
GNI_PC	0.4238
EMPLOYMENT	0.4121
CO_2 _ EMISSIONS	0.2489
PM_2.5	0.1747
FOREST_AREA	0.0464
ARABLE_LAND	0.0089
RENEWABLE _ENERGY	-0.0926
MEAN_SCHOOLING	0.3869
LIFE_EXPECTANCY	0.3667
PEOPLE_USING_WATER	0.3606
PEOPLE_USING_SANITATION	0.3605

Source: Authors' own estimation

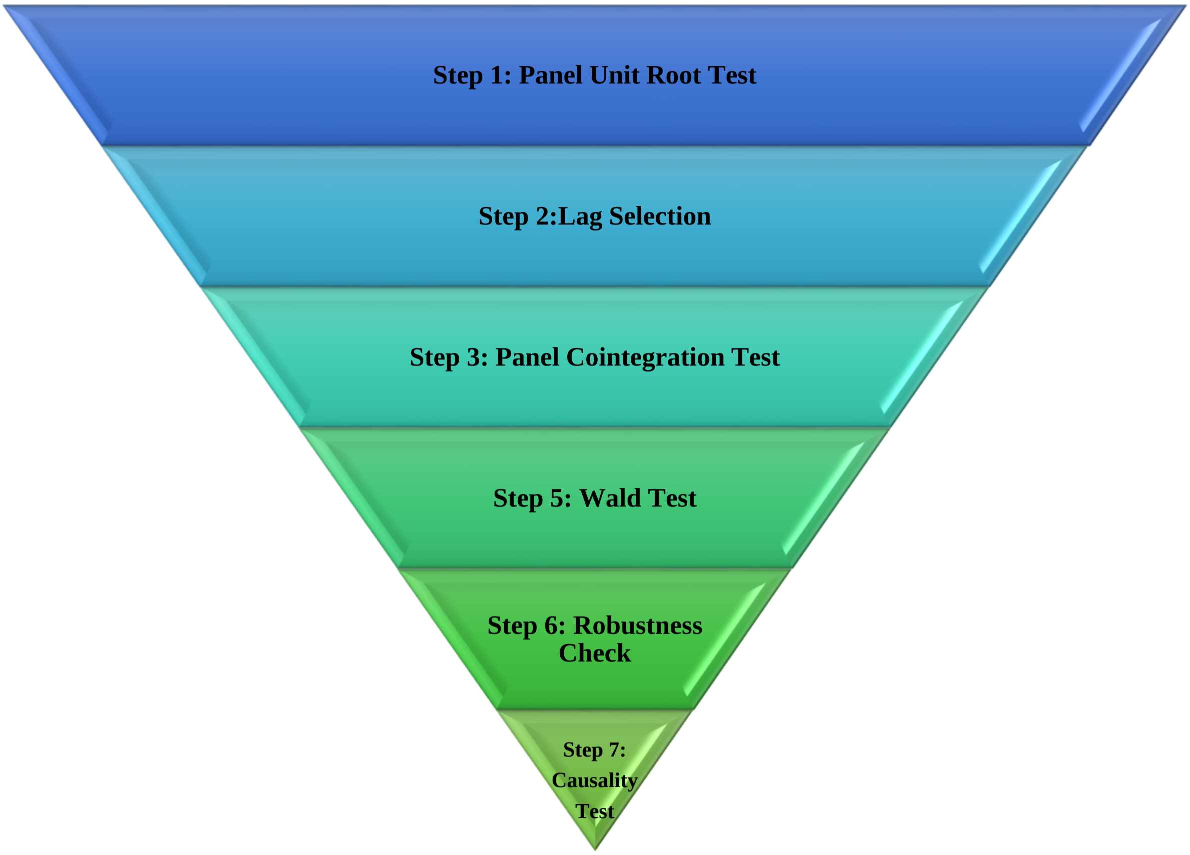
The summary results of PCA are displayed in Table 2 and include details on the eigenvalues, corresponding factor loadings, and difference. Component 1, itself solely accounts for 42 per cent of variations, but the following 11 components together explain 58 per cent of variances, according to the cumulative proportion. Thus, Component 1 is elected as the cornerstone of the SDI.

- **Model Specification**

In order to meet the prime aim of this study i.e., to examine the effects of industrialisation on sustainable development in developing Asian and European nations, present study used the following fundamental mathematical model.

$$SDI = f\ (INDUS, FDI)$$

- **Testing Procedures**



Source: Authors' own presentation

Figure 2: Layout of Estimation Procedure

Figure 2 presents layout of the empirical estimation procedure which explained as follows:

Step 1: Panel Unit Root Test
In the first step, researchers used the Levin-Lin-Chu (LLC) method to conduct a panel unit root test, which confirms the stationary nature of the selected variables. If all of them are stationary, either purely at level or at first difference, i.e., if they are purely integrated, either order 0, i.e., I (0), or order 1, i.e., I (1), then it allows us to further conduct the Panel ARDL test (Befikadu & Tafa, 2022; Hussain, Rehman & Bashir, 2023). Earlier studies of Chikezie Ekwueme, Lasisi and Eluwole (2023) and Ghosh and Paul (2024) also relied on the LLC method to confirm that the selected variables are stationary or not.

Step 2: Lag Selection
Now, researchers use one of the prominent information criteria, i.e., the Akaike Information Criterion (AIC), to determine optimal lags for the selected variables. The studies of Rehman, Noman and Ding (2020) and Banday and Aneja (2024) also relied on this criterion to determine optimal lags for their studies.

Step 3: Panel Cointegration Test
In the next step, researchers apply Kao Cointegration Tests to check for a long-term relationship between industrialisation and sustainable development. This test also aids in enhancing the accuracy of estimations. Previous research conducted by Yiew, Lee, and Lau (2021) and Ghosh and Paul (2024) also utilized the Kao method to examine the presence of cointegrating relationships between variables.

Step 4: Panel Autoregressive Distributive Lag (ARDL) Estimation
Then, the Panel ARDL estimation approach is performed to capture the long-run as well as short-run dynamics of interactions between select variables. Etensa, Taye and Bersisa (2022), Ale & Islam (2022), and Iziga and Takagi (2023) also utilised this approach to capture the long-run as well as short-run dynamics of different macroeconomic factors in their studies.

$$\text{SDI it} = \alpha i + \sum_{j=1}^{p} \beta 1j\ \text{SDIi}, t-j + \sum_{k=0}^{q} \beta 2k\ \text{INDUSi}, t-k + \sum_{m=0}^{q} \beta 3m\ \text{FDIi}, t-m + \varepsilon\ \text{it}$$

SDI it = SDI i.e., dependent variable for country i at time t
INDUS it = INDUS i.e., independent variable for country i at time t
FDI it = FDI i.e., control variable for country i at time t
α i = fixed country-wise effects
β1j, β2k, β3m = coefficients of the SDI, INDUS and FDI.
ε it = error term
p and q represent the lag lengths of the SDI and INDUS, FDI respectively.

Step 5: Wald Test
The Wald test is then used to figure out the extent to which the variables that are conceived of as independent are adding value and strengthening the model.

Step 6: Robustness Check
In addition, this study uses the Panel DOLS Model to validate the robustness of the Panel ARDL estimation results (Sikder *et al*., 2022). This DOLS explicitly includes leads and lags to adjust for endogeneity, making it more flexible and successful in non-large samples (yearly data of only 33 years). It tends to be more efficient when dealing with smaller datasets (Majekodunmi *et al*., 2023).

Step 7: Causality Test
Lastly, the validity and direction of causation between several selected variables are examined using the causality test. In this study, a Granger causality test is used to observe and report the causal connection between different selected variables. Earlier studies by Alam *et al.* (2021) and Pradhan *et al.* (2022) also utilised this approach to capture the causal linkages among different variables.

Results and Discussion

This section presents and discusses the results of different estimations in a lucid way.

Table 3: Overview of Specific Variables' Descriptive Statistics

Variables	SDI		INDUS		FDI	
	ADC	EDC	ADC	EDC	ADC	EDC
Mean	7.2015	2.0019	3.5236	3.1585	0.5674	0.6258
Median	-0.0040	0.9052	3.5548	3.2824	0.6927	0.8597
Maximum	4.7680	1.8556	3.8821	4.0004	3.7821	3.4413
Minimum	-5.8129	-7.8149	3.0029	1.5895	-5.4055	-10.551
Std. Dev.	2.1972	2.5492	0.2115	0.5459	1.2394	1.2314
Skewness	-0.2852	-2.3664	-0.2901	-1.8906	-1.4901	-2.7850
Kurtosis	3.2000	4.1232	2.2002	5.8496	5.8663	2.2336
Observations	330	330	330	330	330	330

Source: Authors' own estimation. ADC represents Asian Developing Countries and EDC represents European Developing Countries

The summary statistics of selected variables for Asian developing countries and European developing countries are reported in Table 3. In the case of Asian developing countries, it shows that the mean values of SDI, INDUS, and FDI are 7.2015, 3.5236, and 0.5674, respectively. The values of the standard deviation (Std. Dev.) of SDI, INDUS, and FDI are 2.1972, 0.2115, and 1.2394 for Asian developing countries. Hence, in terms of standard deviation, the highest deviation is reported for SDI, which denotes there exists great disparity in terms of SDI for different developing countries in Asia. In terms of skewness, all the selected variables for Asian developing countries report negatively skewed values. Where, in the case of European developing countries, the mean values of SDI, INDUS, and FDI are 2.0019, 3.185, and 0.6258, respectively. The values of the standard deviation of SDI, INDUS, and FDI are 2.5492, 0.5459, and 1.2314 for European developing countries. Hence, in terms of standard deviation, the highest deviation is reported for SDI, which denotes there exists great disparity in terms of SDI for different developing countries in Europe. In terms of skewness, all the selected variables for European developing countries report negatively skewed values.

Table 4: Panel Unit Root Test Results

Variable	Stat.	Probability Value	Order of Integration
(a) Levin, Lin and Chu Test for ADC			
SDI	- 3.2771	0.0005	At level [i.e., I (0)]
INDUS	- 7.3974	0.0000	At 1st difference [i.e., I (1)]
FDI	- 6.4796	0.0000	At level [i.e., I (0)]
(b) Levin, Lin and Chu Test for EDC			

SDI	-8.5554	0.0000	At 1st difference [i.e., I (1)]
INDUS	-3.1953	0.0007	At level [i.e., I (0)]
FDI	-5.9013	0.0000	At 1st difference [i.e., I (1)]

Source: Authors' own estimation

Tables 4(a) and 4(b) display the outcomes of the panel unit root test using the LLC approach for Asian developing countries and European developing countries, respectively. Table 4(a) demonstrates that SDI and FDI are stationary at level, i.e., I (0). But INDUS is not stationary at the level; after taking the first difference, it becomes stationary, i.e., I (1). In contrast, for European developing countries, results of the LLC test demonstrate that INDUS is stationary at level, i.e., I (0), whereas the outstanding two variables are stationary at first difference, i.e., I (Researchers can apply the Panel ARDL model (Attiaoui *et al*., 2017; Ghosh & Paul, 2024) since the selected variables integrate I (0) and I (1).24).

Table 5: Panel Cointegration Test Results

Kao Test				
	ADC		**EDC**	
	***T*-stat.**	**Probability Value**	***T*-stat.**	**Probability Value**
Augmented Dickey Fuller (ADF)	1.9520	0.0255	1.5483	0.0408
Residual Variance	0.0292		0.0036	
HAC variance	0.0292		0.0036	

Source: Authors' own estimation

Now, a panel cointegration test using the Kao approach is performed to examine the survival of cointegrating relationships among the variables for each panel data series. The outcomes of these cointegration analyses are shown in Table 5. Since the probability values are less than 0.05, it can be inferred that there is a cointegrating assembly between the select variables for both regions.

Table 6: Panel ARDL Long-run Estimation Results - Effect of Industrialisation on Sustainable Development (indicated by SDI)

Variable	**ADC**		**EDC**	
	Coefficient Value	**Probability Value**	**Coefficient Value**	**Probability Value**
INDUS	0.6429	0.0532	0.2410	0.0017
FDI	0.4291	0.0000	0.0411	0.0000

Source: Authors' own estimation

Table 6 displays the estimation results of the Panel ARDL method for the long-run association of selected variables. The table demonstrates that, for Asian developing nations, industrialisation has a considerable long-term positive impact on sustainable development. In Asian developing countries, a 1 percent increase in industrialisation (measured by INDUS) would result in a 0.64 percent improvement in sustainable development. Besides being statistically significant at the 1 percent level, FDI also has a favourable impact on sustainable development when it comes to Asian developing nations. Similarly, industrialisation has a positive impact on sustainable development in European developing countries. In the case of European developing nations, a 1 percent increase in industrialisation (measured by INDUS) would result in a 0.24 percent improvement in sustainable development. Thus, it can be observed that industrialisation has a greater influence on sustainable development in Asian developing countries than it does in developing countries in Europe. In addition to being statistically significant at the 1 percent level, foreign direct investment (FDI) has a positive effect on sustainable development in developing countries in Europe.

This occurs as a result of several facts, including the fact that, in comparison to developing nations in Europe, Asian countries frequently have a higher percentage of younger inhabitants, which can serve as a steady supply of labour and propel economic expansion in the Asian region. Therefore, the establishment and growth of industries enable developing Asian nations to reap greater socio-economic dividends from them. Furthermore, European developing countries may compete harder with surrounding developed nations (like the UK, Germany, etc.) for foreign direct investment (FDI), which restricts the socioeconomic benefits for industrial development. In contrast, developing Asian countries frequently obtain significant FDI from overseas, which helps them reap better socioeconomic benefits for industrial development.

Table 7: Panel ARDL Short-run Estimation Results - Effect of Industrialisation on Sustainable Development (indicated by SDI)

	ADC		EDC	
Variable	**Coefficient**	**Probability Value**	**Coefficient**	**Probability Value**
ECT	-0.1607	0.0000	-0.4483	0.0000
D (INDUS)	0.1460	0.3794	-0.0705	0.5089
D (INDUS (-1))	-0.0755	0.0075	-0.2181	0.0044
D (FDI)	0.2638	0.0000	-0.0090	0.2383
D (FDI (-1))	-0.1021	0.7144	-0.0028	0.7200
C	3.6772	0.0000	-0.6052	0.0047

Source: Authors' own estimation

The estimation of the short-run ECM model conducted using the Panel ARDL method and its results are summarised in Table 7. It demonstrates that for developing nations in Asia and Europe, the error correction term (ECT) is both negative and statistically significant at the 1 percent level. This illustrates the rate of shifts leading to the long-term equilibrium. Further, it reveals that since the coefficient value of INDUS is negative and statistically significant, it implies that short-run industrialisation hampers sustainable development in Asian Developing countries at lag 1 period. Whereas, FDI has a constructive effect on sustainable development in Asian developing countries in short-run. Similarly, in the case of European developing countries, short-run industrialisation hampers sustainable development in Asian developing countries at lag 1 period. In the case of European developing countries, a 1 percent increase in industrialisation impairs sustainable development by 21 percent. Here, FDI does not impose a statistically significant effect on sustainable development.

Table 8: Wald Test Results

	ADC		EDC	
Test Stat.	**Value**	**Probability Value**	**Value**	**Probability Value**
F-stat.	16.4215	0.0000	4.3942	0.0132
Chi-square	32.8430	0.0000	8.7884	0.0123

Source: Authors' own estimation

Table 8 exhibits the findings of the Wald Test for Asian Developing Countries and European Developing Countries, highlighting a significant F statistic at the one percent level, confirming that independent variables continue to add values to the estimation model for both the panel groups.

Table 9: Panel DOLS Test Results

	ADC		EDC	
Variable	**Coefficient**	**Probability Value**	**Coefficient**	**Probability Value**
INDUS	0.7880	0.0040	0.6015	0.0332
FDI	0.1057	0.0000	0.1369	0.0018
***R*-squared**	0.9826		0.9880	
Adjusted *R*-squared	0.9796		0.9864	

Source: Authors' own estimation

Table 9 lists the results of robustness tests using the DOLS method. The findings of the DOLS test are unswerving with the empirical insights of Panel ARDL long-run estimation, which highlights the positive contribution of industrialisation to sustainable development. As per table, for both the groups of countries, the coefficient value of INDUS is positive and statistically significant at the 1 percent level and per cent level, respectively. Hence, it is observed that industrialisation contributes to sustainable development in Asian Developing Countries and European Developing Countries.

Table 10: Summary of Pairwise Granger Causality Tests

		ADC		EDC	
Null Hypothesises (NHs) are:	**Observation**	**F-Stat.**	**Probability**	**F-Stat.**	**Probability**
INDUS does not Granger Cause SDI	310	6.1042	0.0025	3.2340	0.0227
SDI does not Granger Cause INDUS		0.1436	0.8663	12.607	9.E-08
FDI does not Granger Cause SDI	310	5.2271	0.0059	2.7155	0.0450
SDI does not Granger Cause FDI		0.5054	0.6037	3.3801	0.0187
FDI does not Granger Cause INDUS	310	4.4629	0.0123	4.7417	0.0030
INDUS does not Granger Cause FDI		2.1148	0.1224	1.4930	0.2166

Source: Authors' own estimation

The results of the Granger causality tests are shown in Table 10. It can be observed that there is a long-run unidirectional causality running from INDUS to SDI, FDI to SDI and FDI to INDUS for Asian Developing Countries. Whereas, the same table shows a significant strong unidirectional causality relationship running from INDUS to SDI and FDI to INDUS and bidirectional causality running between FDI to SDI for European developing countries. Thus, this causality result also validates the results of the panel ARDL model.

Conclusion

In the social sciences, industrialisation and its impact on economic development are always among the most extensively studied academic research. On the other hand, in recent years, social science research has placed increasing emphasis on environmental deterioration, a variety of societal concerns, and the achievement of sustainable development. Especially researchers in the fields of economics and social science are interested in investigating how industrialisation influences environmental sustainability in various groupings of nations. This study intends to empirically contribute to the ongoing worldwide issue by exploring the influence of industrialisation on sustainable development in Asian and European developing countries. More specifically, this study uses annual data from 20 developing countries in the Asia and Europe region over the period from 1990 to 2022. The present study employs different panel econometric estimators as adopted by a number of the prior studies in the fields of social science and economic research. Empirical results show that in the short run, industrialisation impairs sustainable development in both Asian and European developing countries. In contrast, industrialisation improves sustainable development in Asian as well as European developing countries in long-run. But in the case of Asian developing countries, industrialisation has a greater influence on sustainable development than it does in developing countries in Europe. Further, the results of the present study statistically confirm the survival of the EKC hypothesis in both Asian as well as European developing countries, which highlights that in the short run, industrialisation impairs sustainability (mainly environmental aspects), but later on it fosters sustainable development.

This study urges policymakers to frame and adhere to more sustainable industrial practices and foster green financing. On the one hand, industries should transit towards clean energy solutions, modern technologies, and recycling approaches. On the other hand, industries should follow certain best practices and increase their involvement in community development programs, skill enhancement programs, R&D activities, incubator centers, etc.

Limitations

This study has certain limitations. First, this study focused on the influence of industrialisation on sustainable development, considering FDI as a control variable. Here, apart from FDI, other macro-economic variables like geopolitical risk, political stability, etc. may be taken into account. Second, this study considers only 20 developing countries in the Asia and Europe region; more countries can be considered from other regions also. Thirdly, this study considers the annual data rather than monthly or quarterly data from 1990 to 2022. Thus, there is still room for more research in this area. As a result, there are several spaces that provide opportunities for further research. In order to present the micro-level scenario of the interplay between industrialisation and sustainable development, future research can take into account firm-specific data. As stated, the scope of future research is also made possible by the consideration of various macroeconomic indicators, the inclusion of additional nations, the use of monthly or quarterly data, and the extension of the study period.

Conflict of Interest

The authors declare that they have no conflict of interests.

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