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Effect of CO_2 Emissions, Human Capital, Foreign Direct Investment, and Trade Openness on Economic Growth in Pakistan

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Abstract

Human capital and environmental degradation are critical factors influencing economic growth. This study analyses the relationship between these factors, foreign direct investment, and trade openness in shaping Pakistan's economic trajectory from 1990 to 2020. The findings of ARDL model and ADF test demonstrate that trade openness, foreign direct investment, and human capital positively impact economic growth. However, the interplay of CO2 emissions with human capital negatively impacts growth. The findings underscore the dual function of human capital in enhancing economic success and environmental standards. Policymakers must mitigate the adverse externalities of environmental degradation to optimize the advantages of human capital and foster sustainable economic development.

Keywords**:** ARDL, CO_2 emissions, economic growth, **e**nvironmental degradation, foreign direct investment, human capital, Pakistan

Introduction

Investments in human capital (HC) are essential to attain sustainable development and enhance economic growth. According to Todaro and Smith (2012), health and well-being cover a person's health, education, and abilities, all of which directly contribute to the individual's productivity and success. The neoclassical economic growth model, established by Solow (1956), asserts that social capital and technological advancement are the principal catalysts of economic expansion. Notwithstanding the importance

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of the matter, Pakistan's healthcare metrics remain subpar, positioning the nation below its South Asian counterparts.

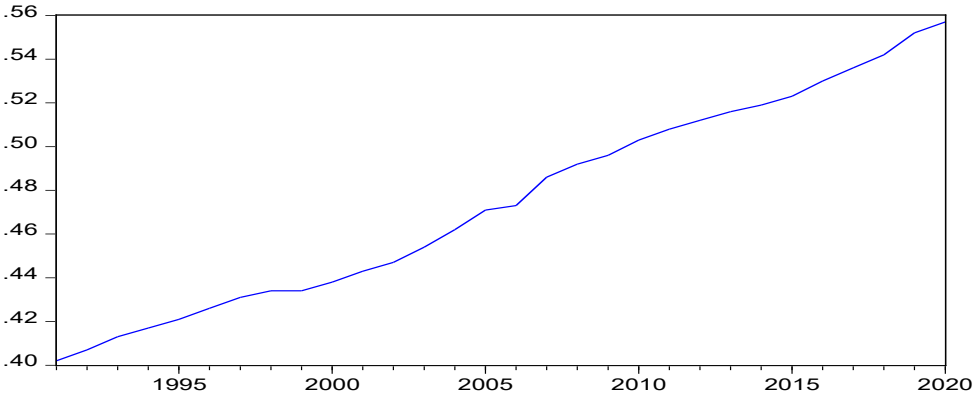
According to Solow's (1956) model advancing human capital, including skills and knowledge, remains a crucial driver of economic progress. Investment in human capital and technological innovation is vital for success in advanced countries. More investments are needed to ensure Pakistan's economic growth in specific industries across Pakistan. In addition to stimulating innovation and contributing considerably to labour productivity, human capital also has the potential to increase prospective earnings. Policy changes that improve education and healthcare have the potential to boost total economic production as well as the productivity of the workforce (Lekhi, 2005).

It is also noteworthy that human capital is a key component of economic growth (EG). It raises the potential wages and productivity of the labor force (Robeyns, 2006). Skills, qualifications, the capacity to develop new goods, and labor experience are factors used to measure human capital (De Oliveira et al., 2000). Specialism and employment separation, enhanced basic education, vocational training, promoting self-employment, and fostering entrepreneurial prospects are ways an economy might increase its human capital (Shutt & Sutherland, 2003). The latter is also regarded as a critical component of an economy, contributing to the supply of a highly trained and creative workforce capable of efficiently using scarce resources, raising per capita income (Brown, 2003). Effective human capital also draws foreign direct investment (FDI), which boosts economic growth (Cleeve et al., 2015).

Furthermore, human capital plays a crucial part in economic development by increasing labor force participation and fostering social and economic equality (Lekhi, 2005). Additionally, it supports economic growth. In addition to promoting economic development, an increase in the level of education and expertise of the labour force also contributes to advancing social justice. Due to problems and issues in literacy rates, school enrolment, access to healthcare, and the availability of clean water, the utilization of healthcare technology in Pakistan needs to be improved. Even though the country's Human Development Index (HDI) showed consistent growth from 1991 to 2020, the rate at which advancements have occurred is somewhat moderate as compared to those of its South Asian rivals.

Figure 1

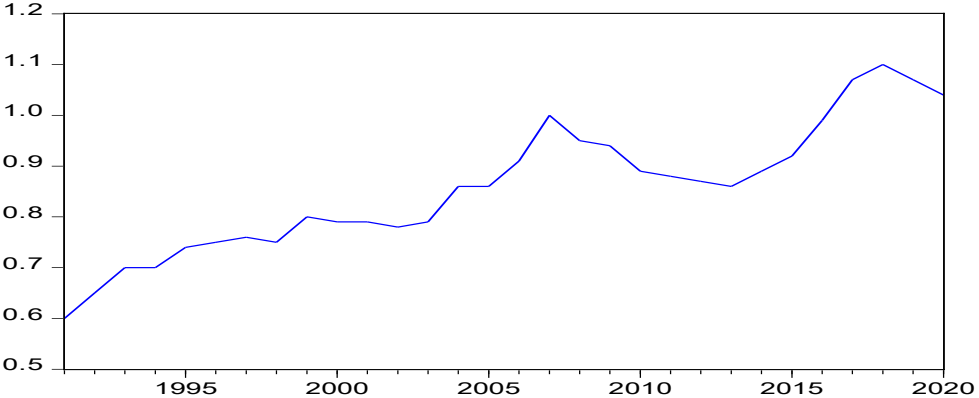
Rising HDI Trend of Pakistan



Note. Source: United Nations

Figure 2

Trend of CO_2 Emissions (metric tons per capita) in Pakistan



Note. Source: World Development Indicators

Pakistan is not an exception to the widespread pattern of environmental degradation (ED). The economy of Pakistan is shifting from agriculture to industry. The need for energy increases along with the country's population, contributing to increased air pollution. Moreover, the increasing use of oil and gas contributes to the rising air pollution. Economic success cannot be further strengthened without a clean environment, regardless of how far a nation grows, since environmental degradation severely influences human health (Hafeez et al., 2018; Rehman et al., 2014). CO_2 emissions are stored in the environment and released into the atmosphere (Hafeez et al., 2018).

The argument that rising economic growth and energy consumption are to blame for environmental issues caused by carbon emissions has been strengthening. Pakistan's GDP per capita is increasing, which raises consumer demand for industrial goods and resultantly contributes to air pollution. As a result, the country's carbon emissions are constantly on the rise. Figure 1 shows the increasing trends and patterns of CO_2 emissions in Pakistan (metric tons).

In a developing nation like Pakistan, a large number of individuals live below the national poverty level. Although economic progress is commonly believed to reduce poverty and unemployment but Pakistan's reality is different. Economic growth alone would not suffice to reduce poverty. Consequently, investing in human capital can advance the abilities of people and help them to overcome poverty. The rise in economic activities causing environmental damage calls for improving the healthcare and educational institutions. According to Ali et al. (2017) in Pakistan, industry has expanded rapidly; resultantly, industrialization and the subsequent urbanization has worsened the environment's quality. Additionally, people in the country's urban areas prefer to use private vehicles due to the inadequate public transportation system, which results in significant vehicle emissions that worsen the environment. Thus, over time, urbanization has deteriorated population health and contributed to pollution (Ali et al., 2019; Faridi et al., 2018). It demonstrates that the country's human capital is also impacted by environmental degradation.

Considering the above discussion, this paper investigates the influence of environmental degradation, foreign direct investment, trade openness, and human capital on economic growth of Pakistan. It also considers the interaction between human capital formation and environmental degradation to analyze their link with economic growth.

Even with the progress made, Pakistan's human capital still needs to be developed as compared to the country's potential for economic development. To realize the full potential of human capital development and the resultant economic growth, the government must play a proactive role in increasing educational opportunities, healthcare services, and skill development programs.

Section 1 provides an overview of the study, Section 2 lays out the literature review, Section 3 describes the data and methodologies, Section

4 provides further information about literature review, and Section 5 states the findings and recommendations.

Literature Review

Social skills and financial development are closely related. Additionally, the government needs to provide greater funding for education and healthcare. According to Todaro and Smith (2012), human capital comprises a person's capacity to enhance their production and efficiency by means of education, skill development, and good health. The notion that investing in human capital leads to increased economic growth is an old one and dates back to Smith (1776). A key component of classical economics is the emphasis on investing in human capital. The endogenous growth theory states that internal forces enhance economic growth in the first place. This theory validates the significance of human capital, innovation and knowledge and their role in economic progress. It also focuses on how knowledge has beneficial spillover effects that eventually drive economic progress (Jonathan et al., 2006). Moreover, another growth theory has been developed in response to the shortcomings of the endogenous theory (Galor, 2005). The relationship between human capital and economic growth is also explained by this theory. Its primary aspects include the steps necessary to escape the Malthusian trap, the beginning of falling birth rates, the consequences of the modern era, and the discovery of human capital as a crucial growth factor.

The effects of environmental degradation and human capital on economic growth have been the subject of several empirical investigations. Aghaei et al. (2023) used data from 2000 to 2008 to examine the relationship between economic growth and human capital. The results showed that provincial groups' economic development benefited from the human capital index. However, in developed regions, human capital was found to have a stronger effect on economic growth than other categories. Mabrouki (2023) examined the relationship among human capital, economic development, education, and patents in Scandinavian nations from 1990 to 2019. The findings demonstrated a long-term cointegrating link among life expectancy at birth, population, economic growth, capital, and education. The findings also indicated a robust link with economic growth regarding the number of patents. Mengesha and Singh (2023) examined the influence of human capital accumulation before 1980 on Ethiopia's economic development trajectories from 1980 to 2020. The

findings indicated that child mortality rates and elementary education attainment had little adverse effects on economic growth. Still, life expectancy at birth and educational attainment in secondary and tertiary labor forces positively influenced it. Uddin et al. (2021) analyzed the correlation among institutions, economic growth, and human capital using a panel of 120 emerging nations from 1996 to 2014. The results indicated that institutions and human capital significantly influenced economic development. It was remarkable to see the detrimental interaction between institutions and human development, considerably hindering the economic progress of emerging nations. Rahim et al. (2021) examined the progress of the Next Eleven countries concerning natural resources, human capital, financial development, industrialization, technical innovation, and international commerce from 1990 to 2019. The results indicated that industrialization, monetary advancement, technological innovation, human capital, and participation in global commerce influenced economic growth.

Bawono (2021) analyzed data from 1984 to 2019 to investigate the impact of technology and human capital on Indonesia's economic development. The results indicated that enhancements in human capital via education influenced economic growth. Further, the study showed that technology positively influences economic growth. Moreover, enhancing human capital and technology is crucial to achieve Indonesia's economic development objectives. The efficacy of programs designed to improve technology and human capital is contingent upon educational advancement since it elevates the quality of human resources. Intisar et al. (2020) analyzed 19 Asian countries from 1985 to 2017, focusing on the impact of technological openness and human capital on economic development. Although the labor force participation rate positively influences economic development in West Asia and negatively affects South Asia, the findings indicated a significant and direct correlation between trade openness and human capital. Foreign direct investment adversely affects the economies of West Asia. While, the increase in GDP per capita has notably benefited South Asia. Wang et al. (2020) analyzed data from 1995 to 2017 to investigate the non-linear correlations among GDP, healthcare expenditure, and CO_2 emissions in Pakistan. The results indicated a robust causal association among Pakistan's economic progress, CO_2 emissions, and healthcare expenditure in both short- and long-term.

Likewise, Ali (2020) examined the correlation between Pakistan's economic growth, human capital development, and infrastructure investment. The results indicated that government spending significantly influenced economic growth. Shah et al. (2020) aimed to analyze several macroeconomic variables that facilitated accelerated economic growth from 1970 to 2019. The findings indicated that while trade openness hindered economic advancement, industrial output, financial innovation, and human capital are the primary catalysts of Pakistan's economic success. They advised the government to adopt policies that invest in human capital and fixed assets to stimulate economic development and generate employment.

Khan and Chaudhry (2019) analyzed the relationship between GDP growth, employment, and human capital in emerging countries using data from 1996 to 2018. The findings demonstrate that the elements of human capital proved to be essential in stimulating economic development and employment creation in developing nations. Afridi (2016) analyzed the data from 2014 to 2015 to investigate the correlation between human capital and Pakistan's economic progress. The results indicated that economic growth was profoundly influenced by population expansion and the development of human capital. The results suggested that emphasizing the health and education sectors promotes the development of HC. Reevaluating financial allocation is essential to emphasize the fundamental elements of a robust economic framework, such as health and education.

Cooray et al. (2016) examined the influence of women's human capital development on economic growth and remittance efficiency. The data used in this research spanned from 1970 to 2012. The data indicated variations in the correlation between remittances and women higher education throughout basic, secondary, and tertiary levels. As shown by the data, increased human capital diminished the marginal impact of remittances on the per capita income of low-skilled workers. Alatas and Cakir (2016) investigated the relationship between economic growth and human capital across 65 nations from 1967 to 2011. GDP per capita indicates economic advancement, whereas the human capital index is based on years of education, educational returns, and infant mortality rates, used as human capital metrics in various studies. The education and health coefficients revealed that, in emerging nations, human capital has a direct and substantial influence on economic development.

Shahzad (2015) examined the data from 1990 to 2013 to assess the influence of human capital accumulation on economic development in Pakistan. The findings demonstrated that physical and human capital significantly and positively influence GDP. The results highlighted the importance of education and Health for Pakistan's economic development. Borojo and Yushi (2015) examined the impact of human capital on Ethiopia's economic progress from 1980 to 2013. They found that public spending on health education and attendance in elementary and secondary schools proved to be beneficial and essential for economic growth in both short and long term.

Furthermore, physical capital positively impacts economic growth, but inflation adversely affects it. Rehman et al. (2014) analyzed the influence of self-employment and human capital development on Pakistan's economic growth from 1995 to 2010. The findings indicated that self-employment significantly influenced economic growth in Pakistan.

Furthermore, it was found that a short-term unidirectional causality exists between economic growth and education, as well as long-term linear causation between self-employment and economic growth. Khilji et al. (2013) analyzed the data from 1951 to 2011 to examine the importance of human resources for Pakistan's economic development. The study found that Pakistan's gross domestic product is intimately correlated with its human resource base. Simultaneously, it was found that Pakistan's economic development has a favorable correlation with its literacy rate.

Arabi and Abdalla (2013) analyzed how Sudan's economic growth was impacted by human capital between 1982 and 2009. The results indicated that health quality and total factor productivity have favorable and adverse effects on economic growth and human development, respectively. The results also suggested that educational quality plays a substantial role in economic growth. Asghar et al. (2012) explored how economic growth of Pakistan from 1974 to 2009 was impacted by human capital. The results showed that even though Pakistan has been allocating a smaller portion of its GDP to healthcare and education, human capital still has a significant direct influence on the economic growth of the country. The study concluded that to make the most of human capital, economic policies that effectively fund public health and education systems must be developed and put into place. The influence of human capital formation on Pakistan's economic growth was also examined by Ali et al. (2012). Their research

revealed that GFCF, education, and inequality significantly and favorably influence GDP while domestic investment, CPI inflation, and infant mortality have a negative and substantial influence on economic growth. Similarly, Amir et al. (2012) explored the association between economic growth and human capital. The former was discovered to be significantly impacted by human resources. The study suggested that vocational training facilities need special consideration because they contribute to economic expansion. Mahmood (2012) used data from 1971 to 2009 to explore the association between human capital and economic growth in Pakistan. The outcomes validate the hypothesis that the country's economic development is positively impacted by human capital. Thus, to improve economic development, authorities need to concentrate on creating human capital. Finally, using data from 1960 to 1987, Agiomirgianakis et al. (2002) explored the long-term influence of schooling on economic growth. The findings demonstrated that GDP is significantly impacted by schooling. A nation's economic growth corresponds with the gains in primary, secondary, and university education.

Theoretical Framework

This research analyses the correlation between human resources, destruction of the environment, foreign direct investment, trade accessibility, and economic development using information collected from 1992 to 2021. Data from secondary sources, including the World Bank Indicators and the Economic Survey of Pakistan, was used. The ARDL model was chosen because of its flexibility in accommodating mixed-order integration variables. Bounds test was used to assess the long-term cointegration of variables, while the error correction model (ECM) was utilized to capture the short-term dynamics. Diagnostic assessments, including the Breusch-Godfrey and Ramsey RESET tests, were conducted to ensure the model's robustness and stability.

$$EG_t = \beta_o + \beta_1 CO_{2t} + \beta_2 HC_t + \beta_3 (CO_2 * HC)_t + \beta_4 FDI_t + \beta_5 TO_t + u_t$$

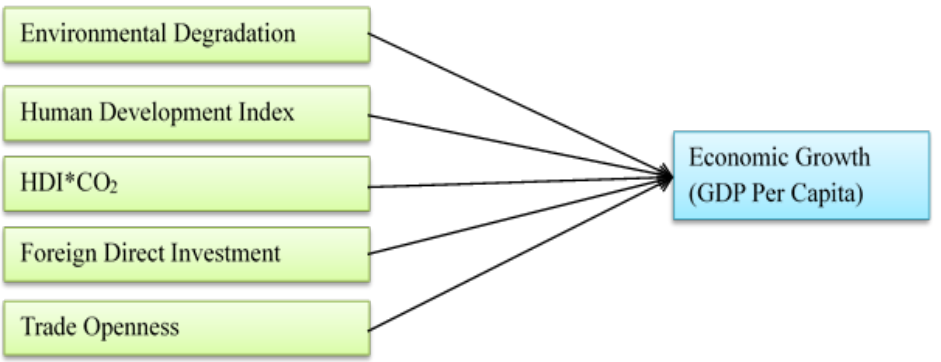
In the above equation, CO_2 stands for carbon dioxide emissions, EG for economic growth as measured by GDP per capita, and FDI for foreign direct investment. HC represents human capital (measured using HDI index), CO_2*HDI represents interaction term, TO indicates trade openness and u_t illustrates the error term.

This study applied Pesaran and Shin's (1995) ARDL technique to inspect the long-term association between human capital, economic growth, and environmental deterioration in Pakistan. The main benefit of this model is that it can be utilized for mixed-order integration of variables at both the I(0) and I(1) orders. To determine if the variables cointegrate over the long run, the study used a bounds test. The Wald test, often known as the F-test, establishes if variables have a long-term association or cointegration. This approach has various advantages over other cointegration techniques. When certain variables in a model are at first difference and some are stationary at level, the ARDL model is employed. The following equation represents the ARDL model of environmental deterioration, economic growth and human capital:

$$EG_t = \beta_0 + \sum_{i=1}^{k}\beta_1 \Delta CO_{2t-i} + \sum_{i=1}^{k}\beta_2 \Delta HC_{t-i} + \sum_{i=1}^{k}\beta_3 CO_2 * HC_{t-i} + \sum_{i=1}^{k}\beta_4 \Delta FDI_{t-i} + \sum_{i=1}^{k}\beta_5 \Delta TO_{t-i} + \mu_t$$

Figure 3

Conceptual Framework



The first step in ARDL estimation is to determine the long-term association between variables. The next step is to evaluate the short-term dynamics. The following equation deals with error correction as it relates to human beings, environmental harm, and economic progress:

$$EG_t = \alpha_0 + \sum_{i=1}^{k}\alpha_1 \Delta EG_{t-i} + \sum_{i=1}^{k}\alpha_2 \Delta CO_{2t-i} + \sum_{i=1}^{k}\alpha_3 \Delta HC_{t-i} + \sum_{i=1}^{k}\alpha_4 CO_2 * HC_{t-i} + \sum_{i=1}^{k}\alpha_5 \Delta FDI_{t-i}$$

$$+ \sum_{i=1}^{k}\alpha_6 \Delta TO_{t-i} + \partial ECM_{t-1} + \mu_t$$

where ∂ represents the coefficient of ECM which indicates the speed of adjustment, while α_i are the short-run coefficients of variables. The following conceptual framework has been employed to analyze the influence of CO_2 emissions, human capital, trade openness and FDI on the economic growth of Pakistan.

Data Analysis

The ARDL model results demonstrate the positive impact of economic growth on trade openness, foreign direct investment, and human capital in Pakistan, relative to other nations. The interaction term (CO_2*HC) indicates a negative correlation, emphasizing the dual challenge of mitigating environmental degradation while concurrently enhancing human capital. As confirmed by diagnostic tests, the proposed model exhibited stability and robustness, with no evidence for heteroskedasticity or serial correlation.

While the results indicate that human capital does make a beneficial contribution to economic growth, the findings also show that the present level of human capital development restricts its potential to offset environmental concerns. The enhancement of human capital should be the primary emphasis of policymakers. This should be accomplished by focused expenditures in education and healthcare sectors, in conjunction with steps to minimize carbon emissions.

Table 1 presents the descriptive statistics of the variables. Regarding economic growth, the GDP per capita has a mean value of 4.5221 and a standard deviation of 1.9737. The potential range of EG values is from 0.1240 to 8.0952. The kurtosis value indicates a platykurtic distribution, whereas the skewness value of -0.2182 denotes a negatively skewed distribution. The descriptive statistics of other variables may be inferred similarly from Table 1.

Table 1

Descriptive Statistics

Variables	Mean	Maximum	Minimum	*SD*	Skew	Kurt
EG	4.522	8.095	0.124	1.974	-0.218	2.406
CO_2	0.857	1.100	0.601	0.128	0.123	2.365
HC	0.475	0.557	0.402	0.048	0.121	1.699
CO_2*HC	0.412	0.596	0.241	0.100	0.262	2.143
FDI	1.097	3.700	0.400	0.826	2.087	6.368
TO	5.770	10.600	0.960	2.552	-0.084	1.979

The correlation coefficient is a method to quantify the proximity of the link between two variables. It assesses the strength and direction of the association between them, indicating whether it is strong or weak, positive or negative. The correlation matrix is shown in Table 2. The results indicate that all four variables— CO_2 emissions, HC, FDI, and TO—exhibit a positive correlation with EG. However, the interaction term demonstrates a negative relationship (CO_2*HC).

Table 2
Correlation Matrix

Correlation	EG	CO_2	HC	CO_2*HC	FDI	TO
EG	1.0000					
CO_2	0.0231	1.0000				
HC	00432	0.9195	1.0000			
CO_2*HC	-0.0257	0.9854	0.9686	1.0000		
FDI	0.0585	0.2450	0.0161	0.1377	1.0000	
TO	0.2829	-0.0350	-0.0794	-0.0501	0.2068	1.0000

The stationarity of the data was assessed using the Augmented Dickey-Fuller (ADF) test for unit root analysis. The variables EG, FDI, CO_2 emissions, and TO are integrated at level, as shown in Table 3. However, HC is integrated at the first difference. According to the results, the ARDL model is a good fit for making long-term prediction parameters.

Table 3
Unit Root Analysis

Variables	Level		1st Difference		Outcomes
	t-Test	Prob.	*t*-Test	Prob.	
EG	-2.9975	0.0475	--	--	I(0)
CO_2	-4.1632	0.0155	--	--	I(0)
HC	--	--	-4.8886	0.0005	I(1)
FDI	-3.0171	0.0455	--	--	I(0)
TO	-5.3707	0.0010	--	--	I(0)

Table 4
Bounds Test Estimates

Test	Value	K
F	8.1412	5

Critical Value Bounds		
Significance	I(0)	I(1)
10%	2.25	3.36
5%	2.61	3.78
2.5%	2.95	4.17
1%	3.40	4.67

The analysis used a bound test to determine the long-term cointegration of variables. Table 4 demonstrates that the F-test result is above the critical values; thus, long-run cointegration is present among the variables in the model. We may now proceed to the long-term approximation of the parameters using the ARDL classic.

Table 5 displays the long-run estimations for the ARDL model. It shows that CO_2 emissions have adversely and considerably impacted Pakistan's economic growth. According to the coefficient value of environmental degradation (CO_2), EG decreases by 0.344 units for every unit rise in CO_2 emissions. Alam et al. (2007) also found similar results. The findings also indicate that HC has a considerable positive effect on EG. The HC coefficient demonstrates that Pakistan's EG increases by 1.645 units for each unit rise in HC. According to Gheraia et al. (2021) and Shah et al. (2020), robust educational institutions may enhance economic production and development by rendering a country more competitive, cultivating a specialized workforce, and fostering economic progress. Shah et al. (2020) and Shahzad (2015) documented similar findings. The findings of the CO_2-HC interaction term demonstrate that HC is adversely affected. The coefficient of the interaction term (CO_2*HC) indicates that for each unit increase in the interaction term, Pakistan's EG decreases by -2.352 units. Similar results were documented by Bano et al. (2018) and Hao et al. (2021). CO_2 emissions adversely affect human capital, impeding economic growth. This research also indicates a significant association between EG and FDI. The coefficient of FDI signifies that Pakistan's EG increases by 0.974 units for each unit increase in FDI. Previous research indicates that FDI substantially enhances economic development in the host country by increasing investment capital and facilitating technical spillovers (Herzer & Klasen, 2008). Pegkas (2015) and Dinh et al. (2019) recorded these observations.

Trade openness or TO substantially and positively impacts Pakistan's EG. The TO coefficient indicates that a 1% rise in TO results in a 0.284%

increase in EG. This illustrates how trade liberalization enhances domestic expenditure and wages, fostering economic prosperity in a country. Fetahi-Vehapi et al. (2015) and Nasreen and Anwar (2014) also acknowledged these findings.

Table 5
Long-term Estimates from ARDL

DV: Economic Growth (GDPPC)				
Variables	B	S.E.	T	Prob.
CO_2	-0.344	0.121	-2.837	0.0013
HC	1.645	0.432	3.805	0.0004
CO_2*HC	-2.352	0.563	-4.177	0.0007
FDI	0.974	0.354	2.749	0.0165
TO	0.284	0.120	2.361	0.0157

The ARDL model's short-run estimations are shown below in Table 6. A statistically significant and negative ECM(-1) is required for examination in the short-run ECM model. A statistically significant ECM (-1) term of -0.4310 indicates a correction rate of 43.10 for short-run disruptions during the transition from the short-run to the long-run equilibrium.

Table 6
ECM Model Estimates

DV: Economic Growth (GDPPC)				
Variables	B	S.E.	T	Prob.
C	-64.239	16.7301	-3.840	0.0000
D(CO_2)	28.8429	13.5018	2.136	0.0000
D(FDI)	-0.6477	0.4059	-1.5958	0.1432
D(TO)	0.2870	0.0609	4.7152	0.0003
ECM(-1)	-0.4310	0.1798	-2.3958	0.0000

This study evaluated serial correlation, heteroskedasticity, and model misspecification using an A series of diagnostic assessments for different models. ECM model exhibits neither serial correlation nor heteroscedasticity. The outcomes of the Jarque-Bera test and the Ramsey RESET test indicate that the model is well-specified, and the residuals conform to a normal distribution test.

Table 7

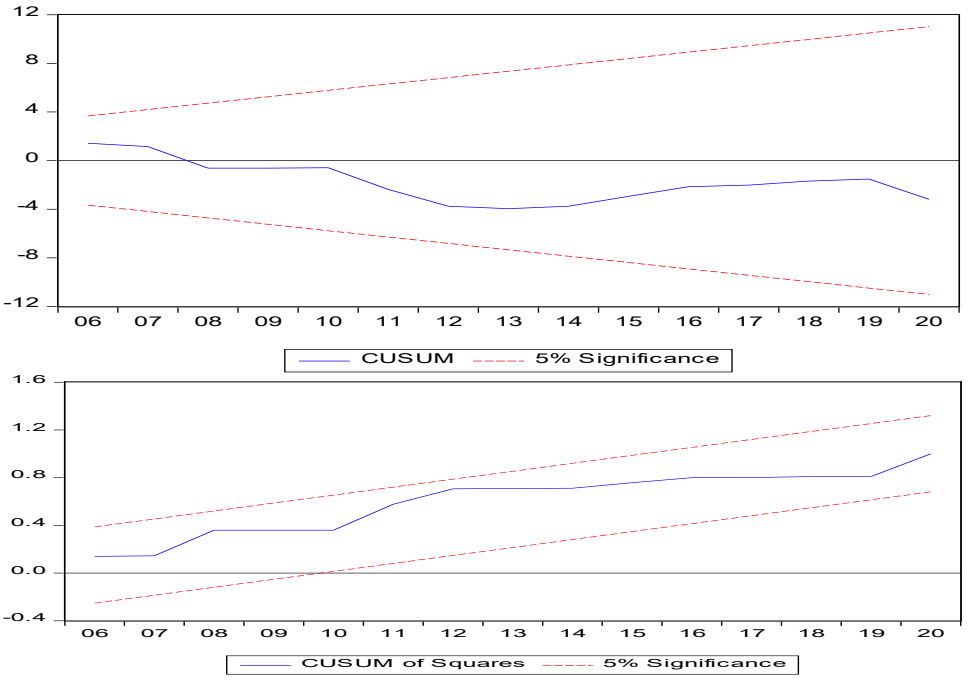
Model Diagnostic Tests

Issue	Test	Statistic	Prob.	Conclusions
Heteroscedasticity	Breusch-Godfrey	1.1005	0.1667	Not Found
Autocorrelation	Breusch-Pagan-Godfrey	1.7734	0.1454	Not Found
Normality of Residuals Model Mis-specification	Jarque-Bera	0.8944	0.6393	Normally Distributed
Heteroskedasticity	Ramsey RESET Test	0.4099	0.5311	Correctly Specified

Figure 4 illustrates that the model exhibits dynamic stability; the projected line remains under the critical zones at 5% significance level, which indicates that the recursive residuals are stable.

Figure 4

Model Stability



Conclusion and Suggestions

The ARDL model results demonstrate the positive impact of economic growth on trade openness, foreign direct investment, and human capital in Pakistan, relative to other nations. The interaction term (CO_2*HC) indicates a negative link, highlighting the twin difficulty of regulating environmental deterioration and simultaneously growing human capital. The model was stable and robust, with no indication of heteroskedasticity or serial correlation, as determined by diagnostic tests.

While the results indicate that human capital does make a beneficial contribution to economic growth, the findings also show that the present level of human capital development in the country restricts its potential to offset environmental concerns. The enhancement of human capital should be the primary emphasis of policymakers in Pakistan. This should be accomplished by focused expenditures in education and healthcare sectors, in conjunction with steps to minimize carbon emissions. The ARDL findings indicate that Pakistan's economic development is significantly and favorably correlated with CO_2 emissions, foreign direct investment, trade openness, and human capital; nevertheless, the interaction between CO_2 and human capital adversely affects country's economic growth. It also suggests that when human capital and CO_2 emissions are combined, the outcomes reveal that environmental degradation and the HDI together have a negative influence on Pakistan's EG.

The results indicate that human capital remains ineffective in improving environmental quality, despite its potential. This implies higher household wealth and better human capital in terms of environmental preservation and awareness. Nations prioritizing the development of human capital cannot escape the environmental effects of economic growth. These results also imply that policymakers should consider the negative externalities of environmental degradation when promoting economic growth to reap the benefits of human capital. Spending more on education guarantees quick economic growth and prevents environmental deterioration in developing countries, where education is now the least prioritized problem. Additionally, the study suggests using print and electronic media to spread environmental awareness. Promoting resource sustainability at all levels should involve integrating environmental sustainability subjects into higher education. Lastly, suitable channels must also be developed to encourage

trade openness and FDI inflows. However, measures are required to prevent investments that harm the environment of the country.

Conflict of Interest

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

Data Availability Statement

The data associated with this study will be provided by the corresponding author upon request.

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References

Afridi, A. H. (2016). Human capital and economic growth of Pakistan. *Business & Economic Review*, *8*(1), 77–86.

Aghaei, M., Rezagholizadeh, M., & Bagheri, F. (2023). The effect of human capital on economic growth: The case of Iranâs provinces. *Quarterly Journal of Research and Planning in Higher Education*, *19*(1), 21–44.

Agiomirgianakis, G., Asteriou, D., & Monastiriotis, V. (2002). Human capital and economic growth revisited: A dynamic panel data study. *International Advances in Economic Research*, *8*(3), 177–187. https://doi.org/10.1007/BF02297955

Alam, S., Fatima, A., & Butt, M. S. (2007). Sustainable development in Pakistan in the context of energy consumption demand and environmental degradation. *Journal of Asian Economics*, *18*(5), 825–837. https://doi.org/10.1016/j.asieco.2007.07.005

Alatas, S., & Cakir, M. (2016). The effect of human capital on economic growth: A panel data analysis. *Journal of Management Sciences*, *14*(27), 539–555.

Ali, H. S., Law, S. H., Yusop, Z., & Chin, L. (2017). Dynamic implication of biomass energy consumption on economic growth in Sub-Saharan Africa: Evidence from panel data analysis. *GeoJournal*, *82*, 493–502. https://doi.org/10.1007/s10708-016-9698-y

Ali, L. (2020). Human capital, equipment investment and the economic growth of Pakistan. *International Journal of Business and Management Sciences*, *1*(2), 78–88.

Ali, R., Bakhsh, K., & Yasin, M. A. (2019). Impact of urbanization on CO2 emissions in emerging economy: Evidence from Pakistan. *Sustainable Cities and Society*, *48*, Article e101553. https://doi.org/10.1016/j.scs.2019.101553

Ali, S., Chaudhry, I. S., & Farooq, F. (2012). Human capital formation and economic growth in Pakistan. *Pakistan Journal of Social Sciences*, *32*(1), 229–240.

Amir, M., Mehmood, B., & Shahid, M. (2012). Impact of human capital on economic growth with emphasis on intermediary role of technology: Time series evidence from Pakistan. *African Journal of Business Management*, *6*(1), 280–285. http://doi.org/10.5897/AJBM11.2104

Arabi, K. A. M., & Abdalla, S. Z. S. (2013). The impact of human capital on economic growth: Empirical evidence from Sudan. *Research in World Economy*, *4*(2), 43–53. http://dx.doi.org/10.5430/rwe.v4n2p43

Asghar, N., Awan, A., & Rehman, H. U. (2012). Human capital and economic growth in Pakistan: A cointegration and causality analysis. *International Journal of Economics and Finance*, *4*(4), 135–147.

Bano, S., Zhao, Y., Ahmad, A., Wang, S., & Liu, Y. (2018). Identifying the impacts of human capital on carbon emissions in Pakistan. *Journal of Cleaner Production*, *183*, 1082–1092. https://doi.org/10.1016/j.jclepro.2018.02.008

Bawono, S. (2021). Human capital, technology, and economic growth: A case study of Indonesia. *Journal of Asian Finance, Economics and Business*, *8*(5), 29–35.

Borojo, D. G., & Yushi, J. (2015). The impact of human capital on economic growth in Ethiopia. *Journal of Economics and Sustainable Development*, *6*(16), 109–118.

Brown, P. (2003). The opportunity trap: Education and employment in a global economy. *European Educational Research Journal*, *2*(1), 141–179. https://doi.org/10.2304/eerj.2003.2.1.4

Cleeve, E. A., Debrah, Y., & Yiheyis, Z. (2015). Human capital and FDI inflow: An assessment of the African case. *World Development*, *74*, 1–14. https://doi.org/10.1016/j.worlddev.2015.04.003

Cooray, A., Dutta, N., & Mallick, S. (2016). Does female human capital formation matter for the income effect of remittances? Evidence from developing countries. *Oxford Development Studies*, *44*(4), 458–478. https://doi.org/10.1080/13600818.2016.1194970

De Oliveira, M. M., Santos, M. C., & Kiker, B. F. (2000). The role of human capital and technological change in overeducation. *Economics of Education Review*, *19*(2), 199–206. https://doi.org/10.1016/S0272-7757(99)00020-5

Dinh, T. T. H., Vo, D. H., Vo, A. T., & Nguyen, T. C. (2019). Foreign direct investment and economic growth in the short run and long run: Empirical evidence from developing countries. *Journal of Risk and Financial Management*, *12*(4), Article e176. https://doi.org/10.3390/jrfm12040176

Faridi, M. Z., Chaudhry, M. O., & Azam, A. (2018). Do economic development, urbanization and poverty matter for environmental degradation? Evidence from Pakistan. *Pakistan Journal of Social Sciences*, *38*(1), 262–287.

Fetahi-Vehapi, M., Sadiku, L., & Petkovski, M. (2015). Empirical analysis of the effects of trade openness on economic growth: An evidence for South East European countries. *Procedia Economics and Finance*, *19*, 17–26. https://doi.org/10.1016/S2212-5671(15)00004-0

Galor, O. (2005). From stagnation to growth: Unified growth theory. In P. Aghion & S. Durlauf (Eds.), *Handbook of economic growth* (pp. 171–293). Newness

Gheraia, Z., Benmeriem, M., Abdelli, H. A., & Saadaoui, S. (2021). The effect of education expenditure on economic growth: The case of the Kingdom of Saudi Arabia. *Humanities and Social Sciences Letters*, *9*(1), 14–23. https://doi.org/10.18488/journal.73.2021.91.14.23

Hafeez, M., Chunhui, Y., Strohmaier, D., Ahmed, M., & Jie, L. (2018). Does finance affect environmental degradation: Evidence from one belt and one road initiative region? *Environmental Science and Pollution Research*, *25*, 9579–9592. https://doi.org/10.1007/s11356-018-1317-7

Hao, L. N., Umar, M., Khan, Z., & Ali, W. (2021). Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? *Science of the Total Environment*, *752*, Article e141853. https://doi.org/10.1016/j.scitotenv.2020.141853

Herzer, D., & Klasen, S. (2008). In search of FDI-led growth in developing countries: The way forward. *Economic Modelling*, *25*(5), 793–810.

Intisar, A. R., Yaseen, M. R., Kousar, R., Usman, M., & Makhdum, M. S. A. (2020). Impact of trade openness and human capital on economic growth: A comparative investigation of Asian countries. *Sustainability*, *12*(7), Article e2930. https://doi.org/10.3390/su12072930

Jonathan, K., Grubb, M., Popp, D., & Edenhofer, O. (2006). The transition to endogenous technical change in climate-economy models: A technical overview to the innovation modeling comparison project. *The Energy Journal*, *27*(1), 17–56.

Khan, R., & Chaudhry, I. S. (2019). Impact of human capital on employment and economic growth in developing countries. *Review of Economics and Development Studies*, *5*(3), 487–496. https://doi.org/10.26710/reads.v5i3.701

Khilji, B. A. (2005). Education as a factor of human capital formation in Pakistan (1951-1998). *Journal of Agriculture and Social Sciences*, *1*(4), 370–373.

Lekhi, R. K. (2005). The *economics of development and planning*. Kalyani Publishers.

Mabrouki, M. (2023). Patent, education, human capital, and economic growth in Scandinavian countries: A dynamic panel CS-ARDL analysis. *Journal of the Knowledge Economy*, *14*(3), 3028–3043. https://doi.org/10.1007/s13132-022-01001-1

Mahmood, M. T. (2012). Does human capital expedite economic development? The case of Pakistan. *Journal of Economics and Behavioral Studies*, *4*(3), 163–171. https://doi.org/10.22610/jebs.v4i3.313

Mengesha, Z. D., & Singh, L. (2023). Human capital accumulation and economic growth of Ethiopian economy. *African Journal of Science, Technology, Innovation and Development*, *15*(2), 211–226.

Nasreen, S., & Anwar, S. (2014). Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries. *Energy Policy*, *69*, 82–91. https://doi.org/10.1016/j.enpol.2014.02.009

Pegkas, P. (2015). The impact of FDI on economic growth in Eurozone countries. *The Journal of Economic Asymmetries*, *12*(2), 124–132. https://doi.org/10.1016/j.jeca.2015.05.001

Pesaran, M. H., & Shin, Y. (1995). *An autoregressive distributed lag modeling approach to cointegration analysis*. Cambridge University Press.

Rahim, S., Murshed, M., Umarbeyli, S., Kirikkaleli, D., Ahmad, M., Tufail, M., & Wahab, S. (2021). Do natural resources abundance and human capital development promote economic growth? A study on the resource curse hypothesis in next eleven countries. *Resources, Environment and Sustainability*, *4*, Article e100018. https://doi.org/10.1016/j.resenv.2021.100018

Rehman, I. U., Mahdzan, N. S. A., Trifu, A., & Bilal, M. (2014). A cointegration approach to modeling human capital formation, self-employment, and economic growth: Evidence from Pakistan. *Quality & Quantity*, *48*, 1439–1453. https://doi.org/10.1007/s11135-013-9845-1

Robeyns, I. (2006). Three models of education: Rights, capabilities and human capital. *Theory and Research in Education*, *4*(1), 69–84. https://doi.org/10.1177/1477878506060683

Shah, S. Z. A., Asghar, M. M., & Riaz, U. (2020). Exploring the factors affecting economic growth in Pakistan. *Global Social Sciences Review*, *5*(3), 400–409. http://dx.doi.org/10.31703/gssr.2020(V-III).43

Shahzad, F. (2015). Role of human capital on economic growth: A case study of Pakistan. *International Journal of Accounting and Economics Studies*, *3*(1), 20–24. https://doi.org/10.14419/rwjt2n26

Shutt, J., & Sutherland, J. (2003). Encouraging the transition into self-employment. *Regional Studies*, *37*(1), 97–103. https://doi.org/10.1080/0034340022000033427

Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations: Volume One*. Edinburgh Research Achieve. https://era.ed.ac.uk/handle/1842/1455

Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, *70*(1), 65–94. https://doi.org/10.2307/1884513

Todaro, M. P., & Smith, S. C. (2012). *Economic development* (11th ed). Prentice Hall.

Uddin, M. A., Ali, M. H., & Masih, M. (2021). Institutions, human capital and economic growth in developing countries. *Studies in Economics and Finance*, *38*(2), 361–383. https://doi.org/10.1108/SEF-10-2019-0407

Wang, Z., Bui, Q., Zhang, B., & Pham, T. L. H. (2020). Biomass energy production and its impacts on the ecological footprint: An investigation of the G7 countries. *Science of the Total Environment*, *743*, Article e140741. https://doi.org/10.1016/j.scitotenv.2020.140741