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Human Capital and Carbon Emissions: The Way forward Reducing Environmental Degradation

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Abstract: Many environmental problems are human induced, one of which is the change in atmospheric composition, a hot research topic in recent decades. This study aims to investigate the impact of human capital (HC) on carbon dioxide (CO_2) emissions in Sri Lanka using time series annual data from 1978 to 2019. The time series data were examined for a unit root problem and an unknown structural break. An autoregressive distributed lag (ARDL) approach was employed to identify the long-run relationship between HC and CO_2. The results confirm the long-term relationship between carbon emissions and human capital. As a unique finding of this research, the estimated coefficient of human capital to carbon emission is negative and statically significant, suggesting that a 1 percent increase in HC decreases carbon emissions by 1.627789 percent. The significance of this finding is that it can help achieve Sustainable Development Goal "13", which focuses on combating climate change and its effects. The study indicated that building in HC by investing more in education helps to reduce carbon emissions in the long term. It reflects that human capital accumulation is linked to reduced environmental degradation due to lower CO_2 emissions.

Keywords: ARDL approach; carbon dioxide; human capital; sustainable development goals; environmental degradation

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1. Introduction

The balance between economic growth and the environment has become a worldwide challenge. Environmental issues are a major source of concern around the world, and they have been studied from various perspectives [1,2]. According to the EKC hypothesis, economic activity and environmental degradation have an inverted U-shaped relationship. Pollution and degradation are high in the early stages of economic growth; however, the trend reverses when a specific per capita income level is reached. Economic growth leads to environmental improvement in high-income groups [3]. Various factors in the economic growth and environment nexus were taken into account in various studies, such as energy consumption [4–9], technological innovation [10–13], trade openness [14–16], urbanization [17–19], financial development [20–24], and economic growth [25–28]. It is necessary to educate the general community about the significance of climate change to connect shifting lifestyles and economic practices with preserving the environment, expanding the economy, and sustainable development (SD). The population's influence on the environment will increase as it grows. Because of this rise in population, there will be a corresponding rise in the level of urbanization, an increase in the demand for water and other precious resources, and an increase in the need for land, infrastructure, industry, and energy. As a result, the destruction of the environment is mainly attributable to human activity [28,29].

Environmental issues are human induced. It is evident that human capital (HC) can play a positive role in environmental quality based on the relationship between human capital and energy consumption in the existing literature [29–32]. Devotion to advanced HC has an opportunity to address environmental sustainability without challenging economic growth [30]. HC is effective in improving a country's environmental performance. Previous research indicates that greater HC correlates with improved environmental awareness and compliance, leading to reduced ecological pollution [33–36]. Additionally, HC is a strong determinant of a country's economic development. The human capital framework recognizes the value of educated, innovative, knowledgeable, and skilled labor as an input component in the manufacturing process [37–39]. HC can increase humans' ability to handle their working conditions efficiently by providing the possibility to understand energy security and environmental pollution issues. HC is important in reducing carbon emissions by improving energy efficiency [40]. Because of advances in HC, energy consumption can vary across sectors and households. For example, employing skilled personnel in the automotive industry can produce fuel-efficient vehicles, decreasing overall oil consumption. Increased HC may result in increased spending on electronic appliances, which may increase electricity consumption [6]. The role of HC can be explained from the demand side and production side [21]. Higher educational attainment positively impacts environmental quality from the demand side. More educated consumers demand more environmentally friendly products and are more likely to press businesses to reduce pollution levels [41]. Due to a strong substitution relationship between human capital and energy, more worker training may reduce the energy required in the production process [39].

Many researchers investigated the effect of HC on energy consumption. However, very little research has been conducted on the role of HC in carbon emissions. Therefore, it is vital to explore the impact of human capital on carbon emissions. As a result, this paper aims to investigate the effect of HC on CO_2 emissions in Sri Lanka. Sri Lanka is an emerging economy in the South Asian region, experiencing an average annual growth of 4% for the last few years. Carbon emissions in the country are steadily increasing, which is one of the indicators of environmental degradation. Sri Lanka ratified the Kyoto Protocol, an international agreement under the United Nations Framework Convention on Climate Change (UNFCC), in 2002, with the ultimate goal: "stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous human interference with the climate system". In addition, Sri Lanka was one of the 171 countries that signed the Paris Agreement in 2016. The agreement was a watershed moment in the multilateral climate change process. It was the first time a binding agreement brought all nations together in a common cause to take ambitious steps to combat climate change and adapt to its effects [42]. According to the World Resources Institute Climate Analysis Indicators Tool (WRICAIT), GHG emissions increased by 14 $MtCO_2$ between 1990 and 2011, averaging 2% per year, while GDP grew by 198 percent, averaging 5% per year in Sri Lanka. With the carbon intensity of Sri Lanka's economy approximately 1.5 times the global average, there is potential to reduce GHG emissions relative to GDP in Sri Lanka. Sri Lanka declared to reduce GHG emissions by 7% by 2030, with 4% coming from energy and 3% from other sectors (using 2010 as a baseline year) through Intended Nationally Determined Contribution (INDC) intention [43].

Sri Lanka is selected for this study for various reasons, and it also indicates this study's novelty. Demographic structure factors are the primary determinants of carbon emissions. HC has proven essential in boosting green production through energy conservation and emission reduction. Environmental regulation is a crucial source of knowledge accumulation and technological innovation [44]. Hence, a country-specific level study is believed to be necessary for an individual country to recognize the impact of human capital on CO_2 emissions. Second, our research findings contribute to the plan for achieving Sustainable Development Goal 13, which focuses on combating climate change and its effects. Initially, most studies were based on the relationship between energy usage and environmental degradation, with only a few investigating human capital's roles in combating climate change and fostering economic sustainable development.

Third, no study has examined the relationship between carbon emissions and human capital in Sri Lanka to the best of our knowledge. Only a few studies [19,45,46] have investigated the relationship between carbon emissions and economic development, energy demand, urbanization, tourism receipts, and trade intensity in Sri Lanka. Furthermore, the current study contributes to the debate over what factors can assist Sri Lanka in meeting its climate change and sustainable development goals. Therefore, in this study, we have attempted to analyze the effect of HC on carbon emission in Sri Lanka for the first time as a macro-level analysis. Figures 1 and 2 display the trends of CO_2 emissions and human capital index in the study period.

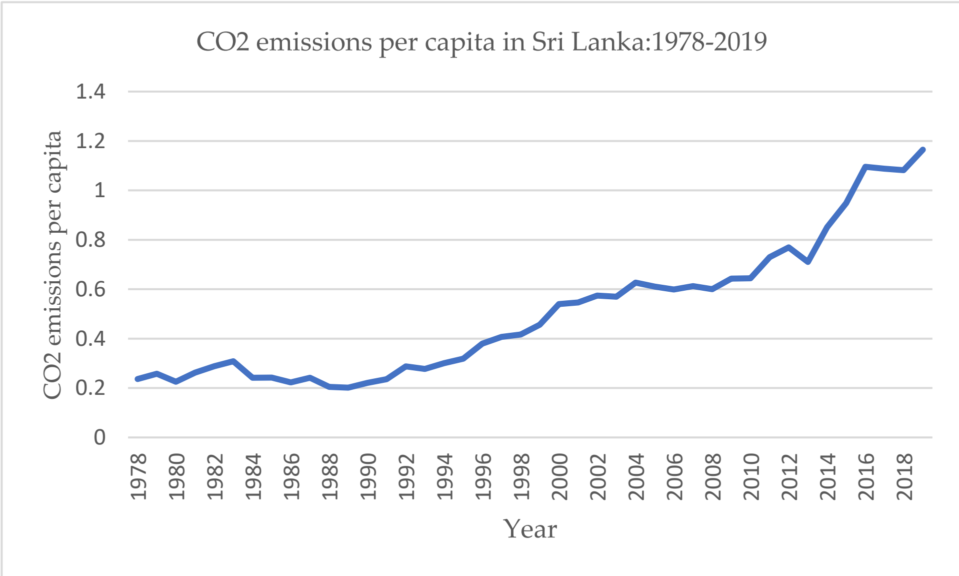

Figure 1. CO_2 emissions per capita in Sri Lanka.

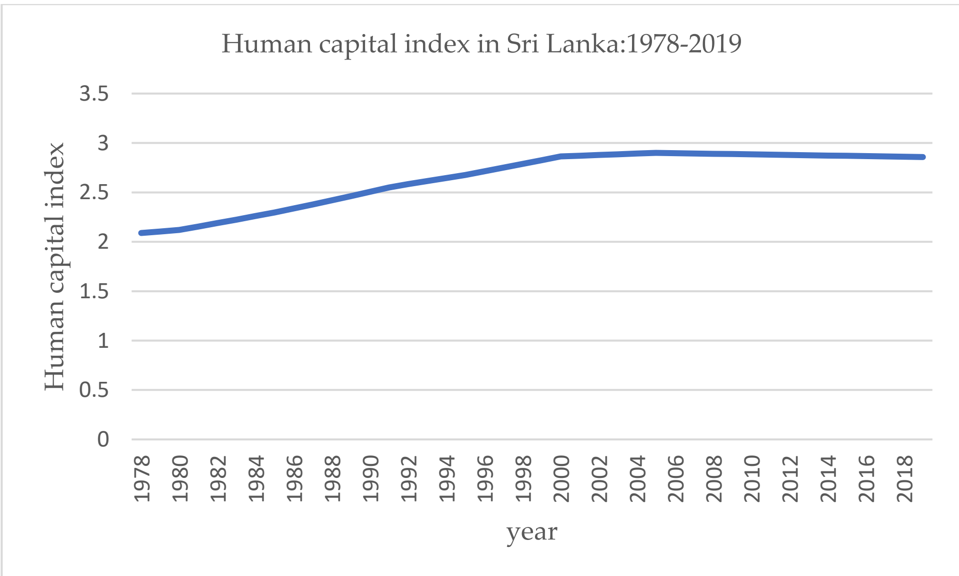

Figure 2. Human capital index in Sri Lanka.

The remaining sections of this paper are as follows: the second section provides a brief literature review and the third section describes the methodology and data sources. The fourth section presents the results of empirical findings and the discussion is in the fifth section. Finally, the conclusions and policy implications are discussed.

2. Literature Review

Many studies have described the significance of HC from various perspectives. The productive aspect of HC plays a critical role in achieving economic development, which impacts the environment [47]. At present, the importance of HC for environmental protection has sparked policy debate in national and international frameworks. The increase in human demands, such as food, water, energy, infrastructure, and others, exerts ecological pressure, resulting in resource depletion, waste emissions, land-use changes, and pollution [28]. Kwon (2009) explained human capital in three levels: general, firm, and task-related human capital [40]. Generally, human capital refers to education and experience.

In contrast, firm-related HC relates to education, skills, and knowledge, and task-related human capital refers to knowledge, education, training, and skills associated with performing a job. Yao et al. (2020) viewed HC through macro- and micro-level channels. From a macro-level perspective, the relationship between human capital and CO_2 appears to be negative, whereas human capital is a critical driver of CO_2 reduction from a micro-level perspective [48]. CO_2 is a chemical compound of two oxygen atoms fused to a carbon atom. It is produced by the consumption and waste of animals, plants, and microorganisms and the burning of fossil fuels [49,50]. Hence, many human economic activities are associated with carbon emissions [32,51]. Khan et al. (2021) pointed out human capital accumulation is critical in reducing CO_2 emissions [52]. Reduced investment in education can seriously threaten CO_2 emission targets [53].

The micro-level channels examine the effect of HC levels in the firm on whether the firm complies with environmental regulations. According to these studies, firms with higher levels of HC are more likely to adopt cleaner production and demonstrate better environmental compliance [36,54–56]. HC can help reduce energy consumption by improving energy efficiency in the manufacturing sector, and it can also help reduce carbon emissions [39,40]. Better-educated workers in the production sector facilitate innovation and technology diffusion [54,57]. Not only at the production level but also at the household level, educated people place a higher value on environmentally friendly activities such as greater use of recycling and selecting energy-saving appliances [28,41,58,59]. Environmentally friendly production methods and lifestyles are more likely to be chosen by advanced HC [60]. HC leads to fewer environmental concerns, affecting ecological quality [61].

The macro level shows that the relationship between HC and pollution emissions is more complex and heterogeneous because human capital influences CO_2 emissions in multiple ways [30]. The studies examining the relationship between human capital and energy consumption concluded that fossil fuel consumption is the key source of CO_2 emissions [6,7,62]. Much international agreement has been reached on reducing CO_2 emissions and promoting low-carbon economies. Hence, examining the relationship between human capital and environmental outcomes, including CO_2 emissions, has become popular among researchers. Gnangoin et al. (2022) investigated the moderating influence of HC on the link between economic growth, renewable energy, non-renewable energy, and CO_2 emissions in 20 emerging economies over the 1990–2021 time period. The estimators generalized least squares (GLS) and two-stage least squares (TSLS) are used in the investigation. They discovered that HC helps to minimize the negative impact of non-renewable energy usage on environmental quality [29].

In a country-specific study, Zhang et al. (2021) investigated how natural resources, human capital, and economic growth affected environmental degradation in Pakistan from 1985 to 2018 using the autoregressive distributed lag method (ARDL) approach [63]. The analysis results show that HC and natural resources negatively impact CO_2 in the long run. They concluded that adopting new production processes via using new technology by human intellectual capital plays a critical role in resource utilization, resulting in the mitigation of environmental degradation. These findings were similar to the study of

Bano et al. (2018), Mahmood et al. (2019), and Pata and Caglar (2021) [32,64,65]. Anthropogenic production and consumption activities pollute the air, soil, and water, endangering human health and long-term development. Hence, countries have implemented various measures and technologies to reduce and control GHG emissions, especially CO_2 emissions. Pata and Caglar (2021) revealed that HC is crucial in reducing environmental degradation in China using annual time series data from 1980 to 2016.

In the parallel view, using a set of HC proxies that differed in age and qualification, Yao et al. (2020) investigated whether investing in HC can help with carbon reduction without causing economic growth to be distorted. The study found a negative and significant association between HC and CO_2 emissions from 1997 to 2016 in China [48]. Li and Ouyang (2019) found an inverted N-shaped relationship between human capital and CO_2 emission intensity from 1978 to 2015 in China. The study's findings emphasized the role of net foreign direct investment (FDI) and HC in reducing CO_2 emissions [21]. With greater openness, a higher level of financial development supports technological innovation by bringing low-carbon technologies aboard or increasing spending on energy conservation research and development. This improves energy efficiency and, as a result, reduces the intensity of CO_2 emissions. Another example of the role of HC in environmental degradation in China demonstrates that the Chinese economy is sustained through pollution-enhanced trade. In contrast, HC is conducive to emissions and environmental degradation [66]. Contrary to these studies, Hassan et al. (2019) and Danish et al. (2019) argued that human capital does not affect the ecological footprint (EF) in Pakistan [67,68].

In a panel study, Rahman et al. (2021) investigated the effects of economic growth, energy consumption, human capital, and exports on ten newly industrialized countries (NICs) from 1979 to 2017. They discovered that GDP per capita and HC hurt CO_2 emissions [1]. Yao et al. (2019) examined how human capital accumulation is associated with improvements in environmental quality via CO_2 emission reductions using a historical dataset for 20 organizations for economic cooperation and development economies (OECD) from 1870 to 2014. They discovered that the relationship between human capital and CO_2 emissions changes over time, shifting from positive to negative in the 1950s and becoming more strongly negative after that [69]. Nathaniel et al. (2021) examined the relationship between urbanization, natural resources, human capital, and CO_2 emissions in eighteen Latin American and Caribbean countries (LACCs). According to the findings, natural resource depletion, urbanization, and economic growth increase emissions, whereas HC reduces them [70]. Li and Ullah (2022) found that good changes in education have lowered CO_2 emissions, and an adverse change in education has increased CO_2 emissions in Brazil, Russia, India, China, and South Africa (BRICS) countries. They applied the non-linear panel ARDL method for this study, and it covered the panel data from 1991 to 2019 [71].

Furthermore, research reveals that HC plays a moderating role in promoting the sustainability of urbanization. Lin et al. (2021) assessed the impact of innovative HC on CO_2 emissions in China, using panel data from 30 Chinese provinces from 2003 to 2017 [72]. The number of patents per one million R&D staff full-time equivalent is used as a variable for innovative HC. The results based on ordinary least squares (OLS) and the system generalized method of moments (SYS-GMM) reveal that innovative human capital helps to reduce environmental degradation in China. Khan et al. (2021) explored the roles of institutions and human capital in the impact of fiscal decentralization on CO_2 emissions using a balanced panel dataset of seven OECD countries between 1990 and 2018 [52]. The empirical findings show that fiscal decentralization improves environmental quality. The institutional quality and HC development improvements strengthen the relationship between fiscal decentralization and environmental quality.

Although a growing body of studies has investigated the role of HC on environmental degradation, insufficient attention has been given to Sri Lanka in the literature. Only a few studies [19,45,46] can be found in the literature in line with the study area. According to data in the expanding literature, HC is recognized as having a critical role in environmental degradation. A summary of studies related to HC and CO_2 is presented in Table 1.

Table 1. Chronological summary of the recent literature.

Researcher(s)	Sample	Number of Countries	Method
Li X et al. (2022) [71]	1991–2019	BRICS countries	Non-linear panel ARDL
Gnangoin et al. (2022) [29]	1990–2021	20 emerging economies	Generalized least squares (GLS) and two-stage least squares (TSLS)
Pata and Caglor (2021) [65]	1980–2016	China	ARDL
Zhang et al. (2021) [63]	1985–2018	Pakistan	ARDL
Rahman (2021) [1]	1979–2017	Newly industrialized countries (NICs)	FMOLS, DOLS, pooled mean group (PMG)
Lin et al. (2021) [72]	2003–2017	30 Chinese provinces	OLS, system generalized method of moments (SYS-GMM)
Nathaniel et al. (2021) [70]	1990–2017	Latin American and Caribbean countries	Augmented mean group (AMG)
Khan et al. (2021) [52]	1990–2018	7 OECD countries	Cross-sectional ARDL (CS-ARDL)
Yao Y et al. (2020) [69]	1870–2014	OECD countries	OLS
Li ouyang (2019) [21]	1978–2015	China	ARDL
Yao et al. (2019)	1965–2014	OECD countries	Cross-sectional dependence (CD)
Mahmood et al. (2019) [64]	1980–2014	Pakistan	Three-stage least squares (3 SLS)
Bano et al. (2018) [32]	1971–2014	Pakistan	ARDL and vector error correction (VECM)
Sapkota and Bastola (2017) [73]	1980–2010	14 Latin American countries	Panel-fixed and random-effects methods

To sum up, we hypothesize that human capital can reduce environmental degradation by synthesizing the evidence presented above. As a result, we propose the following hypothesis:

H1: Human capital poses a positive impact on environmental quality.

3. Methodology

The relationship between CO_2 emission and HC is examined in our study based on the "Stochastic Impact by Regression on Population, Affluence, and Technology" (STIRPAT) model developed by Dietz and Rosa (1997) [74]. Prior studies commonly used this model by adding additional factors to capture the effect of human actions on environmental degradation [29,75,76]. Hence, we sequentially added several control variables, possibly related to variation in CO_2 emissions as shown in the previous literature, to alleviate omitted variable bias [30,32,77]. The flow chart of the methodological approach adopted in the study is shown in Figure 3.

In line with the study's objective, we adopt CO_2 per capita as a variable to describe environmental degradation. We estimate the following functional form: the explanatory and control variables.

$$CO_2 = f\,(HC, GDP, EC, URB, FDI)$$

where;

CO_2 = CO_2 emissions per capita
HC = Human capital index
GDP = Per capita GDP
URB = Urban population growth rate
FDI = FDI net Inflows as a percentage of GDP.

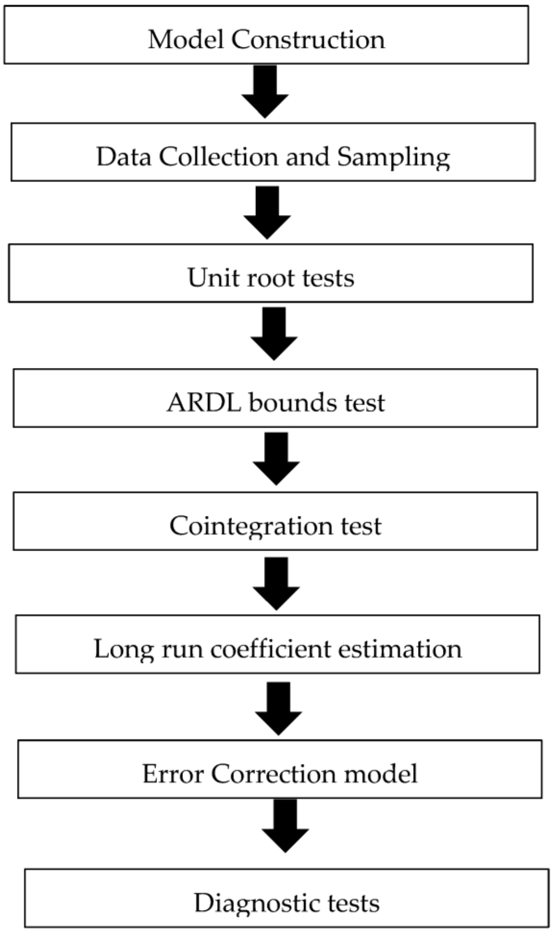

Figure 3. Flow chart of the methodological approach.

The current study uses annual data for Sri Lanka, spanning the years 1978 to 2019, and the study's timeframe is limited to the availability of the selected data. Table 2 gives more information about the description of the variables used for the analysis.

Table 2. Description of the variables.

Variable	Symbol	Description	Data source
CO_2 Emissions	CO_2	CO_2 emissions (tons per capita)	Our World in data [78]
Human Capital	HC	Human capital index based on years of schooling and assumed rate return to education	Feenstra et al. (2015) [79]
Gross Domestic Product	GDP	Per capita GDP (constant 2010 USD)	World Development Indicators [80]
Energy Consumption	EC	Per capita gigajoule of oil equivalent	BP Statistical Review of World Energy [81]
Urbanization	URB	Urban population growth rate	World Development Indicators [80]
Foreign Direct Investment	FDI	Net inflows as a percentage of GDP	World Development Indicators [80]

As normality issues in the variables are detected before conversion to logarithm form, the variables in the study are converted into natural logarithms according to the literature [61,65,68,82].

The functional form of carbon emission is rewritten in logarithmic form as follows:

$$lnCO_2 = \beta_0 + \beta_1\, ln\mathrm{HC}_t + \beta_2\, ln\mathrm{GDP}_t + \beta_3\, ln\mathrm{EC}_t + \beta_4\, ln\mathrm{URB}_t + \beta_5 ln\mathrm{FDI}_t + e_t \quad (1)$$

where t is the time series operator; β_1 , β_2 , β_3 , β_4, and β_5 are the coefficients of HC, GDP, EC, URB, and FDI, respectively; and e_t is the error term.

We used the ARDL method to discover long-run and short-run dynamic relationships between the variables. This method, pioneered by Pesaran et al. (2001), was created to examine the cointegration of variables [74]. Many researchers have used various cointegration techniques [83,84] in their research. Some of these techniques have drawbacks, such as not incorporating structural breaks and ignoring the integration sequence among variables. The ARDL model has the following advantages over existing econometric techniques [10,65,85,86]. (i) Even if the variables are stationary at the I (0), the first difference (i), or mixed integration levels, is applicable. (ii) Regardless of sample size or endogeneity, estimates based on the ARDL approach are reliable. (iii) When lag orders can be changed to produce more robust results, the ARDL bounding test is the best technique for time series data. (iv) The ARDL method can assist researchers in developing a dynamic unrestricted error correction model (UECM) using a simple linear transformation. (v) The ARDL method deals with endogeneity and serial correlation in time series data. Equation 1 is transformed into the ARDL model, as shown in Equation (2).

$$\begin{gathered}\Delta ln\mathrm{CO}_2 = \sigma_0 + \textstyle\sum_{i=1}^{p} \beta_{1i}\Delta CO2_{t-i} + \sum_{i=0}^{p} \beta_{2i}\Delta ln\mathrm{HC}_{t-i} + \sum_{i=0}^{p} \beta_{3i}\Delta ln\mathrm{GDP}_{t-i} + \sum_{i=0}^{p} \beta_{4i}\Delta ln\mathrm{EC}_{t-i} + \\ \textstyle\sum_{i=0}^{p} \beta_{5i}\Delta ln\mathrm{URB}_{t-i} + \sum_{i=0}^{p} \beta_{6i}\Delta ln\mathrm{FDI}_{t-i} + \lambda_1 ln\mathrm{CO2}_{t-i} + \lambda_2 ln\mathrm{HC}_{t-i} + \lambda_3 ln\mathrm{GDP}_{t-i} + \lambda_4 ln\mathrm{EC}_{t-i} + \\ \lambda_5 ln\mathrm{URB}_{t-i} + \lambda_6 ln\mathrm{FDI}_{t-i} + \mu_t \ldots\end{gathered} \tag{2}$$

where Δ *is* the 1st difference operator, p is the lag length, and coefficients are shown through β. We construct two hypotheses from Equation (2), which represents long-run relationships. The first of which is the null hypothesis ($H_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0$) of no cointegration and the second of which is the alternative hypothesis ($H_1 = \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \neq 0$).

A prerequisite to ARDL is a review of the data integration levels. This step is critical in determining whether the study's variables are 1(0) or 1(1). To use the ARDL method, the analyzed series should not be I (2) because cointegration occurs when some or all variables are integrated at 1(1). The well-known augmented Dicky–Fuller test (ADF) and Phillip–Perron (PP) test are used to accomplish this. However, if the series contains structural breaks, the ADF test has low power and size distortions [87]. The Zivot–Andrews test, which accounts for structural breaks, addresses this issue.

After examining the order of integration of the series, we employ the ARDL bound testing method. The lag order of the data series is chosen first, and then the long-run relationship between variables is tested (using F-statistics). This study used the SIC lag selection criteria. The ARDL bound testing approach confirms the variables' long-run cointegration.

4. Results

4.1. Pretest Analysis Results

Table 3 shows descriptive statistics of the variables chosen for the study. The mean and median values for all variables are largely consistent. The standard deviation results show that economic growth, urbanization, FDI, and CO_2 emissions are more volatile than economic growth, energy consumption, and human capital.

The unit root test results, shown in Table 4, show that the variables are integrated at the level form and the first difference level. These results consent us to apply ARDL, as all series are integrated at I (0) or I (1). The Zivot–Andrews [88] test (Table 5) identifies structural breaks in the data series. The results show that structural breaks existed in 1986, 1990, 1992, 1993, 1996, 1997, 2001, and 2013, indicating that economic structure and policy changes occurred in those years. The ZA unit root test results show that variables are non-stationary at the level or first difference. These results indicate that none of the variables are integrated to a higher order than one. As a result, it confirms using a bounds test of cointegration with a structural break.

Table 3. Descriptive statistics.

	$LNCO_2$	LNHC	LNGDP	LNEC	LNURB	LNFDI
Mean	−0.827823	0.968352	7.471611	2.052030	−0.106771	−0.045134
Median	−0.829884	1.031918	7.438848	2.145323	0.007533	0.109643
Maximum	0.152668	1.064589	8.296966	2.818720	0.859657	1.047172
Minimum	−1.601980	0.736648	6.727785	1.348979	−3.048122	−2.919806
Std. Dev.	0.546336	0.111118	0.489755	0.458099	0.648859	0.653775

Source: author's calculation using E-Views 10.

Table 4. Unit root test results.

Variable	ADF T -Stat.	PP T -Stat.	Status
$lnCO_2$	−2.050807	−2.022569	I (1)
$\Delta lnCO_2$	−6.945449 ***	−6.931714 ***	
lnHC	1.290634	0.446233	I (1)
ΔlnHC	−3.269384 *	−3.269384 *	
lnGDP	−1.918812	−1.586788	I (1)
ΔlnGDP	−4.330575 ***	−4.330575 ***	
lnEC	−1.944247	−2.168478	I (1)
ΔlnEC	−5.006364 ***	−4.873415 ***	
lnURB	−3.668992 **	−3.612026 **	1 (0)
ΔlnURB	−6.374327 ***	−14.91526 ***	
lnFDI	−1.975037	−7.508564	I (1)
ΔlnFDI	−3.382546 *	−18.41232 ***	

Note: ***, **, and * mean significant at 1%, 5%, and 10%, respectively. Δ denotes the first order difference operator. Source: author's calculation using E-Views 10.

Table 5. Structural break unit root test results.

Variable	ZA t-Stat.	Structural Break	Variable	ZA t-Stat.	Structural Break
$lnCO_2$	−3.812554 **	1996	$\Delta lnCO_2$	−8.066055	1990
lnHC	−2.220063	1986	ΔlnHC	−7.083219 ***	2001
lnGDP	−3.233356 **	2010	ΔlnGDP	−4.699741	2003
lnEC	−3.365144 **	1997	ΔlnEC	−5.604818	2001
lnURB	−6.202557 ***	2013	ΔlnURB	−6.348209	1993
lnFDI	−5.884232 ***	1992	ΔlnFDI	−7.173892	1990

Note: *** and ** mean significant at 1% and 5%, respectively. Δ denotes the first order difference operator. Source: author's calculation using E-Views 10.

Based on the vector autoregression (VAR) lag order selection results (Table 6), we chose lag 1 using Schwarz criterion (SC).

The model with the lowest SC value is ARDL (1,0,0,0,0,1), which is shown in Figure 4. The appropriate lag lengths (p) corresponding to each variable, such as $lnCO_2$, lnHC, lnGDP, lnEC, lnURB, and lnFDI in Equation (2), are 1, 0, 0, 0, 0, and 0, respectively.

Table 6. Lag order selection results.

Lag	Logl	LR	FPE	AIC	SC	HQ
1	80.41439	NA	8.87×10^{-10}	−3.816123	−3.560190	−3.724296
2	368.4023	472.5955	2.22×10^{-15}	−16.73858	−14.94705 *	−16.09579
3	418.2855	66.51092 *	1.25×10^{-15}*	−17.45054 *	−14.12341	−16.25679 *
4	445.0516	27.45243	2.93×10^{-15}	−16.97701	−12.11429	−15.23230

Note:* mean lag order selected by the criterian. author's calculation using E-Views 10.

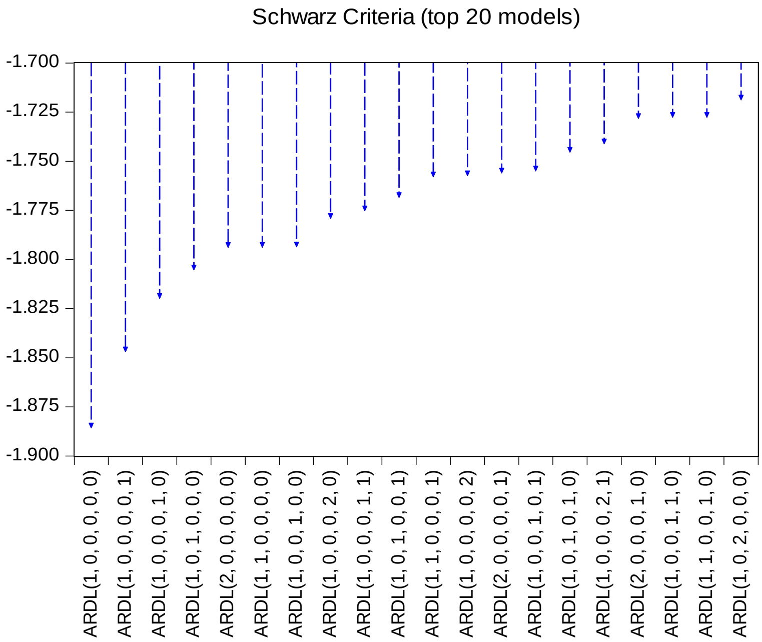

Figure 4. Schwarz Criteria.

The ARDL bound cointegration test results in Table 7 confirm that long-run cointegration exists in the carbon emission model. The value of the bound test F-statistic is 4.305054, which is significant at the 5 percent level when compared against the upper and lower critical bounds.

Table 7. Results of the ARDL bound test.

Model	**$\ln CO_2$ = f (lnHC, lnGDP, lnEC, lnURB, lnFDI)**
Bound test-F-statistics	4.305054
Significance	5%
Lower 1(0) Bound	2.62
Upper 1(1) Bound	3.79

Source: author's calculation using E-Views 10.

4.2. Long-Run and Short-Run Dynamics

We estimated the long-run and short-run dynamics of the carbon emission model after confirming cointegration among the variables. Table 8 displays the results.

The results of the short-run dynamics show a significant and positive relationship between energy consumption and carbon emissions, while human capital has a negative association with carbon emissions. The estimated coefficient of human capital is significantly smaller in the short-run than the long-run estimated coefficients, suggesting that human capital decreases carbon emissions at a higher rate in the long run. Meanwhile, economic growth, urbanization, and foreign direct investment in the short run have similar results in the long run. The error correction term ECT (−1) describes the system's percentage speed adjusting to the long-run equilibrium. According to the results, our model has a speed of adjustment toward a long-term equilibrium of −0.640149. The fact that ECT (−1) has a negative and statistically significant coefficient confirms the long-term relationships among variables.

Table 8. Estimation of long-run and short-run results.

Long-Run Estimation				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LNHC	−1.627789 **	0.489856	−3.322994	0.0021
LNGDP	−0.156470	0.218173	−0.717182	0.4782
LNEC	1.683885 ***	0.284956	5.909272	0.0000
LNURB	0.000168	0.038208	0.004386	0.9965
LNFDI	0.057544	0.047882	1.201788	0.2377
Short-Run Estimation				
ΔLNHC	−1.042027 **	0.404269	−2.577561	0.0145
ΔLNGDP	−0.100164	0.140498	−0.712919	0.4808
ΔLNEC	1.077937 ***	0.289517	3.723225	0.0007
ΔLNURB	0.000107	0.024459	0.004386	0.9965
ΔLNFDI	0.036837	0.030378	1.212614	0.2336
ECT (−1)	−0.640149 ***	0.117604	−5.443244	0.0000

Note: *** and ** significant at 1% and 5% respectively. Source: author's calculation using E-Views 10.

4.3. Diagnostic Tests Results

The diagnostic tests results of serial correlation, heteroskedasticity, normality, and functional form presented in Table 9 indicate the stability of the model.

Table 9. Diagnostic tests results.

Items	Test	Probability Value
Serial correlation	Breusch–Godfrey serial Correlation LM test	0.9695
Normality	Jarque–Bera	0.4235
Heteroscedasticity	Breusch–Pagan–Godfrey	0.4594
Functional form	Ramsey RESET Test	0.3226
CUSUM	stable	
CUSUMsq	stable	

Source: author's calculation using E-Views 10.

In addition, the plots of CUSUM and CUSUM of squares in Figures 5 and 6 lie within 5 percent critical bounds, evidencing the stability of the models.

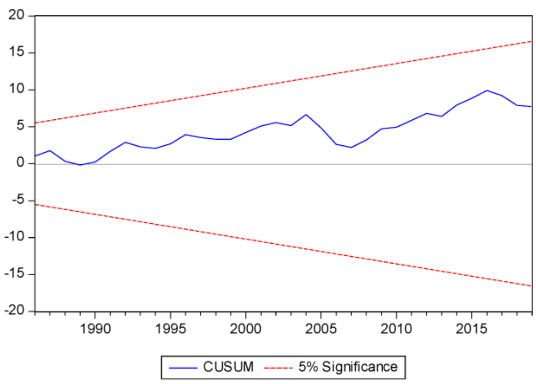

Figure 5. Plot of CUSUM.

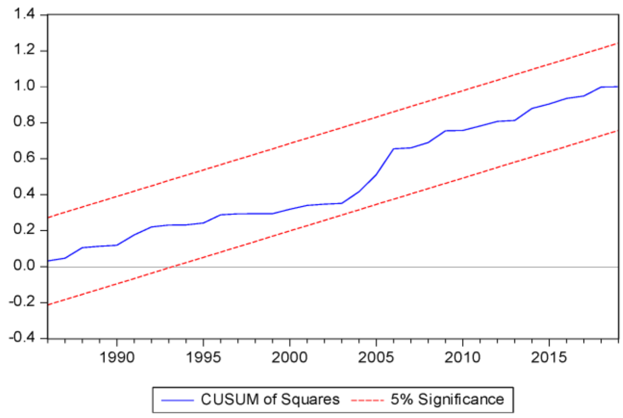

Figure 6. Plot of CUSUM of squares.

5. Discussion

The main objective of this paper is to identify long-term relationships between human capital and carbon emissions in Sri Lanka from 1978 to 2019. We use ARDL bounding tests to find long-run cointegration and the ARDL approach to check the long- and short-run elasticities between the variables. The results of cointegration tests indicate the variables' long-run equilibrium relationships.

Accumulation is linked to improved environmental quality due to lower CO_2 emissions. Sri Lanka is a lower-middle-income country aspiring to be upper-middle-income. Human capital development at a new and higher level will be critical to achieving this development goal. Sri Lanka is ranked 74th out of 157 economies in the HCI. It is South Asia's best-performing country. However, in addition to the top performers just mentioned, it lags behind East Asian economies such as China, Malaysia, Mongolia, Thailand, and Vietnam. Sri Lanka's human capital index (HCI) score is lower than that of European economies with comparable per capita income levels, such as Albania, and West Asian economies, such as Azerbaijan and Georgia. With education spending decreasing, emissions will increase faster unless the government invests more in educational access. The estimated coefficient of HC to the carbon emission is negative and statically significant, suggesting that a 1 percent increase in human capital decreases the carbon emissions by 1.627789 percent. Hence, an increase in human capital reduces carbon emissions. These results match with the results of previous studies. Their results claimed that when a country has a good stock of human capital, the demand for environmental quality rises. People seek ways to improve their environmental quality by planning their energy consumption, conserving natural resources, and developing new environmental technologies. Ahmed and Wang (2019) found a negative relationship between HC and the ecological footprint in India, implying that HC improves environmental quality [28]. Moreover, our results are in line with those who studied the human capital impact on environmental quality, such as Bano et al. (2018) for Pakistan [32], Li and Ouyang (2019) and Lin et al. (2021) for China [21,72], Zafar et al. (2019) for the United States [85], and Sapkota and Bastola (2017) for developing countries [73,89]. Moreover, Gnagoin et al. (2022) identified the inverted U-shaped relationship between human capital and CO_2 emissions for newly emerging economies [29].

We found a positive and statistically significant link between energy consumption and carbon emissions. Unfortunately, Sri Lanka is experiencing an energy shortage and relies heavily on carbon-intensive energy sources such as coal and oil, which emit significant amounts of CO_2. Coal is the dominant CO_2 emission source related to electricity and heat generation. By 2017, coal accounted for 61% while oil accounted for 31% [89]. According to Sri Lanka's National Energy Policy and Strategies, the country aspires to be carbon neutral by 2050 by making the best use of available energy and developing cleaner energy resources [90]. From the findings, it is clear that increasing energy consumption will significantly impact Sri Lanka's carbon emissions. Our outcomes are consistent with the studies of Naradda Gamage et al. (2017) [45], Gasimli et al. (2019) [19], and Uddin et al. (2016) [46] for Sri Lanka. Additionally, Abbasi et al. (2020) also discovered that energy consumption had a positive and significant effect on CO_2 emissions, showing that excessive energy consumption is an obstacle to long-term improvements in environmental quality in eight Asian countries, including Sri Lanka [91]. When compared to the findings of previous studies on other countries, these findings are similar to the results of Charfeddine (2017) for Qatar [92], Danish et al. (2017) for Pakistan [93], and Zaidi et al. (2019) for Asia-Pacific Economic Cooperation countries [94].

The effect of economic growth on carbon emissions is negative but insignificant. This finding indicates that the Sri Lankan economy has not yet reached the point where environmental degradation begins to reduce as affluence increases. According to the EKC hypothesis, the Sri Lankan economy is in its early stages of development [45]. Many studies have found a positive and statistically significant link between economic growth and carbon emission in the long run. Our findings are not similar to the outcome of previous studies of Rahman et al. (2021) [1], Wang et al. (2016) [17], Muhammad et al. (2020) [20], Yang et al. (2016) [95], Gamage et al. (2017) [45], Hanif (2018) [96], and Narayan et al. (2015) [97]. The coefficient of foreign direct investment is positive but insignificant. Our result does not support an evident negative or positive relationship between FDI and carbon emissions in Sri Lanka. Zafar et al. (2019) showed that FDI reduces the US's ecological footprint, implying that the US has attracted high-tech, non-CO_2-emitting FDI [85]. Kim (2020) revealed that FDI contributes to the increase in carbon emissions in Korea, but the coefficient is negligible [98]. Contrary to Kim, Hill et al. (2019) found that FDI inflows reduce air pollution intensities in Korea using provincial-level data [99]. Sapkota and Bastola (2017) found that FDI is positively related with carbon emission in Latin America [73]. This result is similar to the findings of the study of Bakhsh et al. (2017) for Pakistan [100]. The findings on urbanization are fascinating, as the coefficient of urbanization was not significant. This finding indicates that urbanization in Sri Lanka is not to blame for the accumulation of carbon emissions. This result is due to the fact that Sri Lanka's urbanization is occurring at a sluggish rate and at a low intensity.

6. Conclusions

The most significant finding of this study can help achieve Sustainable Development Goal "13", which focuses on combating climate change and its effects. As per the findings of this study, an increase in human capital reduces carbon emissions. This means Sri Lanka performs only moderately well on the HCI, with an overall score of 58 percent [101]. Last year, the Sri Lankan government allocated only 2–3% of the GDP for education. Unskilled workers are produced due to a lack of education, and educated people place a higher value on environmentally friendly activities such as greater use of recycling and selecting energy-saving appliances [28,41,58,59]. We can conclude that education can help to reduce the growth rate of carbon emissions in the long run.

From a policy perspective, this study can assist the Sri Lankan government in developing a comprehensive and effective plan for spending on education to increase productivity, which leads to economic growth consistent with endogenous growth theory while limiting carbon emissions growth. The Sri Lankan government and policymakers should prioritize human capital by investing in education and expanding educational facilities in the country. According to the findings of this study, energy consumption exacerbated environmental degradation in Sri Lanka during the study period. Sri Lanka has various renewable energy resources, including biomass, hydropower, solar, and wind. However, the use of renewable energy in Sri Lanka has decreased [102]. Hence, the Sri Lankan government should develop environmentally friendly sources of energy supply to reduce CO_2 emissions.

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