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Reference: Asli, Hamdi El/Hamid, Lakhmaiss et. al. (2024). Impact of, human capital, economic factors, energy consumption, and urban growth on environmental sustainability in Morocco : an ARDL approach. In: International Journal of Energy Economics and Policy 14 (2), S. 656 - 668.
https://www.econjournals.com/index.php/ijeep/article/download/15601/7817/36471.
doi:10.32479/ijeep.15601.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(2), 656-668.

Impact of, Human Capital, Economic Factors, Energy Consumption, and Urban Growth on Environmental Sustainability in Morocco: An ARDL Approach

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Received: 02 November 2023 **Accepted:** 26 February 2024 **DOI:** https://doi.org/10.32479/ijeep.15601

ABSTRACT

This study aims to examine the impact of human capital, energy consumption, urbanization, growth, trade openness and foreign direct investment on Morocco's environmental sustainability using annual data from 1970 to 2019 and, in light of, recommend policy implications. We used the ARDL approach to identify the potential linkage between carbon emissions and the explicative variables. The ADF unit root test is used to check the stationarity of all variables, showed that five of them become stationary after first differentiation. The result from the bound test indicated the existence of a long run relationship which confirmed the existence of co-integration with high speed of adjustment towards the long-run equilibrium. We found that increase in human capital leads to decrease in carbon emissions, meanwhile increase in both economic growth and energy consumption generate an opposite result, other things equal. Our finding validates the theoretical frame work involved in this study (STIRPAT: Stochastic Impact by Regression on Population, Affluence, and Technology, 1997) that confirms the possibility of promoting environmental sustainability through reducing carbon emissions, rationalizing energy consumption, reorienting economic growth into an eco-friendly model, building and enhancing human capital through education, besides working on rising economic openness and investment attractiveness of Morocco.

Keywords: ARDL Approach, Economic Factors, Carbon Emissions, Human Capital, Energy Consumption, Urbanization
JEL Classifications: F18,I2,O4,R1,Q2,Q5

1. INTRODUCTION

Global warming is fatal for both developed and emerging countries, at both, the micro and the macroeconomic levels, with all its considered consequences on public health. Scholars like Mehmood et al. (2022), Shamsi et al. (2022), Bibi et al. (2022), Khairul Nizam et al. (2020), proved that low air quality leads to respiratory consequences include bronchitis, asthmatic infections, and lung problems; and neurological effects include high blood pressure, coronary disease, cardiac arrest, and dementia. Air pollution causes millions of premature deaths annually worldwide as demonstrated Qureshi et al. (2016), Tehreem et al. (2020), Nizam et al. (2020). Polluted air has also an impact on the quality of the food we consume as proved by Balasubramanian et al. (2021). As a consequence, Despite all those warnings studies, carbon emissions still world widely increasing. In Morocco for example they reached a record high in 2022 with "no end in sight to the rising trend," reported the World Meteorological Organization (WMO) in its provisional state of its 2023 annual report.

On the one hand, the nexus between carbon emissions and economic growth is complex and multifaceted, often described in the context of the Environmental Kuznets Curve hypothesis. Under this assumption, an inverted U-shaped relationship between environmental degradation (like high carbon emissions) and economic development with all its associated inputs is described (Kuznets, 1955).

On the other hand, Trade and foreign direct investment (FDI) have complex and multifaceted impacts on carbon emissions. Besides bringing advanced technologies and management practices that are more energy-efficient and less carbon-intensive, foreign inflows in renewable energy sectors, such as wind or solar power, contribute positively to reducing carbon emissions by promoting the use of clean energy sources. Thus, through Outsourcing Emissions, trade can promote specialization and the concentration of production in locations with comparative advantages, which leads to more efficient production processes, potentially reducing emissions per unit of output. We think that Trade influences consumption patterns by providing access to goods produced in different regions. Increased trade might lead to higher consumption, potentially increasing overall emissions due to greater production and transportation. We also think that Trade and FDI can potentially encourage the harmonization of environmental standards and regulations, so his can promote the adoption of stricter environmental policies, ultimately leading to lower emissions.

However, building Human capital by increasing education and awareness levels can lead to reduce energy consumption, waste generation, and overall carbon emissions. Educated individuals might be more likely to adopt sustainable practices in their personal lives and advocate for eco-friendly policies in their workplaces and communities. Highly skilled individuals often drive innovation and technological advancements in fields like engineering, science, and technology; they can develop and implement more energy-efficient processes, renewable energy technologies, and cleaner production methods, thereby reducing carbon footprints across industries. They might engage in advocacy efforts, support environmentally friendly policies, and push for changes in industries to reduce carbon emissions, play a role in influencing policies and regulations related to environmental protection. People who understand the impact of their actions on the environment are more likely to make choices that reduce their carbon footprint, such as using public transport, and conserving energy at home and work. It has proven for example that an additional year of tertiary schooling, as a specification of human capital accumulation through advanced education, is associated with a reduction in carbon emissions between 50.1% and 65.8% for 20 OECD most industrialized economies from 1870 to 2014 as demonstrated Yao et al. (2020), besides the well-known classic provided externalities to macroeconomic performance, such economic growth, higher labour productivity, increasing national income etc. as showed researchers like (Schultz, 1961; Romer, 1990; Becker, 1994), and to society all over with lower crime rates and greater democratic participation as demonstrated Sianesi and Reenen (2003).

2. LITERATURE REVIEW

The STIRPAT model stands for "Stochastic Impacts by Regression on Population, Affluence, and Technology." As reported York et al. (2003), it's an analytical framework used in environmental studies to analyze the impact of human activities on the environment, it became widely recognized by scientific community as an extension of the well-known IPAT model which was developed by Ehrlich and Holdren (1971), it employs statistical regression analysis to assess the relationships between human activities and environmental sustainability. STIRPAT provides a framework for understanding human impact on the environment, its equation essentially suggests that the environmental impact (I) is a product of three factors: population size (P), affluence (A), and technology (T). It implies that a reduction in any of these factors could potentially mitigate environmental impact. However, the introduction of the technology term in the STIRPAT model is ambivalent, while some studies include it in the error term, others considered it as a variable that must be considered separately. In this paper technology is approached by Human capital index, which is accounted on the average years of schooling, linearly interpolated by Barro and Lee (2013), based on Mincer's equation that gives comparable estimates of the average monetary returns of one additional year of education as mentioned (Psacharopoulos, 1994), and an assumed rate of return for primary, secondary, and tertiary education as reported (Caselli, 2005).

Different conclusive research papers related to the subject ofour study based on the STIRPAT model are represented in the Table 1 below:

3. DATA PRESENTATION AND MODEL CONSTRUCTION

3.1. Data Variables Description

Table 2 below gives a brief description of the variables mobilized in this study.

3.2. Data Evolution Interpretation

3.2.1. Morocco's carbon emissions

As shown in the Figure 1, and according to the Global Carbon Budget. (2023), Morocco's carbon emissions have been exponentially rising since 1970, and has tripled since due to increasing demand on energy, so they grew substantially from 8 to 74 million tonnes rising at a half point increasing annual rate

Figure 1: Per capita CO_2 emissions in Morocco

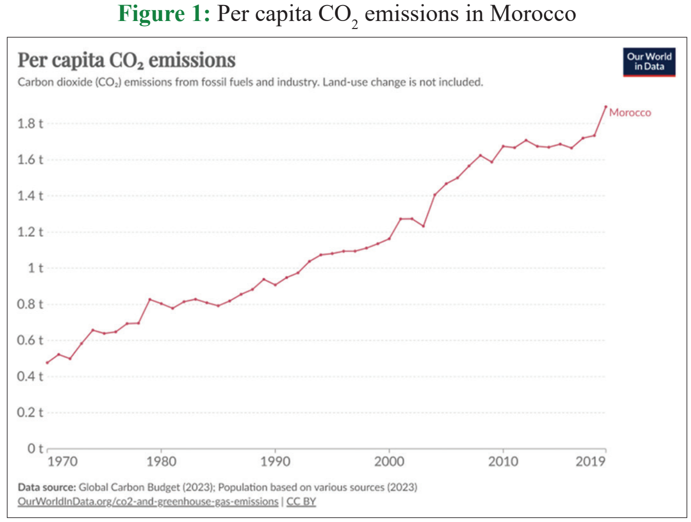


Table 1: Summary of literature review

Name of author	Research paper	Sample	Dependent variables	Independent variables	Results
Fan et al. (2006)	"Analyzing impact factors of CO_2 emissions using the STIRPAT model"	(1975-2000)	CO_2 emissions	Population-the percentage aged 15-64-GDP per capita-energy intensity and urbanization	PIB growth has the greatest impact on CO_2 emissions, and the population within 15 and 64 has the least impact. which has a negative impact on CO_2 emissions of countries of high income, while the impact is positive at other income levels
Dalton et al. (2008)	"Population aging and future carbon emissions in the United States"	multiple dynasties of heterogeneous USA household	CO_2 emissions	Households as the demographic unit-age structure of households	aging population reduces long-term emissions by almost 40% in a low-population scenario, and the effects of the aging process on emissions can be as large as, or larger than, those of technical change in some cases, given a closed economy, fixed substitution elasticity, and fixed labour supply over time
Behera and Vishnu (2011)	"Analysing the Impact of Anthropogenic Factors on Environment in India"	1960-2007	CO_2 emission	Urbanisation-population-service sector-industrial sector-GDP	Urbanization, population, service sector, industrial sector and GDP per capita had negative effects on environment.
Grunewald and Martínez-Zarzoso (2011)	"The Impact of Urbanization on CO_2 Emissions: Evidence from Developing Countries"	panel data model for a cross-section of 213 countries from 1960 to 2009	CO_2 Emissions	Urbanization -GDP-energy efficiency	obligations from the Kyoto Protocol have a measurable reducing effect on carbon emissions.
(Sanglimsuwan, 2012)	"The impact of population pressure on carbon dioxide emissions: Evidence from a panel-econometric analysis"	83 countries from 1980 to 2007	Dioxide emissions	Population- Working age population- Economic Growth	positive proportionality between population, working-age population and carbon emissions.
Cole and Neumayer (2004)	"Examining the Impact of Demographic Factors on Air Pollution"	86 countries over 20 years (1975-98)	CO_2 emissions SO2 emissions	GDP- manufacturing share- energy intensity- population growth-household size- age structure	CO_2 emissions with respect to population to be unity over the entire range of population sizes.SO2 emissions to be actually negative for very small population sizes, but to rise rapidly as population increases.
(Boutabba, 2014)	"Impact of Financial Development, Income, Energy and Trade on carbon Emissions"	Algeria, Egypt and South Africa over the period 1971-2015	carbon emissions	energy consumption-economic growth	aggregate energy consumption and economic growth have positive and significant impacts on carbon dioxide (CO_2) both in the long and short run in those countries
Narayan et al. (2016)	"Economic growth and carbon emissions"	A sample of 181 countries over the period 1960–2008	carbon dioxide emissions- CO_2 per capita	Real GDP per capita	21 out of 181 countries (12%) is clear evidence supporting the EKC hypothesis. 49 countries (27%), income growth will reduce emissions in the future.
Gregory and Galor (2016)	"Is economic growth compatible with reductions in carbon emissions? Investigating the impacts of diminished population growth"	an unbalanced yearly panel of cross-country data from 1950-2010	carbon emissions	Low fertility- total population- the age structure of the population and economic output	1% slower population growth could be accompanied by an increase in income per capita of nearly 7% while still lowering carbon emissions.
Antonakakis et al. (2017)	"Energy consumption, CO_2 emissions, and economic growth: An ethical dilemma"	106 countries from different income groups from 1971 to 2011.	carbon emissions	energy consumption and its subcomponents- Economic growth	effects of the various types of energy consumption on economic growth and emissions are heterogeneous on the various groups of countries and causality between total economic growth and energy consumption is bidirectional

(Contd...)

Table 1: *(Continued)*

Name of author	Research paper	Sample	Dependent variables	Independent variables	Results
Yao et al. (2019)	"Human capital and CO_2 emissions in the long run"	dataset for 20 OECD economies from 1870 to 2014	Carbon emissions	Average number of schooling years-GDP- domestic R&D share expenditure of GDP-total population	evidence of the social benefits of investing in advanced human capital and suggest a promising avenue for addressing climate change without impeding economic growth.
Zahoor et al. (2020)	" The dynamic linkage between natural resources, human capital, urbanization, economic growth, and ecological footprint in China"	1970 to 2016 for China	Ecological footprint-Ecological Carbon Footprint	Economic Growth- Natural Resources- Urbanization- Human Capital-	natural resource rent increases the ecological footprint. Urbanization and economic growth contribute to environmental degradation, whereas human capital mitigates environmental deterioration
Ganda (2019)	"impact of innovation and technology investments on carbon emissions in selected organisation for economic Co-operation and development countries"	selected OECD economies from 2000 to 2014.	carbon emissions	the number of triadic patent families-spending on research and development -the number of researchers,- renewable energy consumption	renewable energy consumption and spending on research and development have a statistically significant negative relationship with carbon emissions. The number of triadic patent families illustrates a positive and significant relationship with carbon emissions
Wang et al. (2021)	"Impacts of urbanization on carbon emissions: An empirical analysis from OECD countries"	33 high-income countries over the period from 1960 to 2014	carbon emissions	economic growth - energy efficiency - final energy consumption of the industry - transport and residential sectors	Developed countries tend to have the same negative impacts of urbanization on carbon emissions, for each 1% increase in urbanization rate, CO_2 emissions per capita decrease by 0.015%, total CO_2 emissions decrease by 0.012%, and CO_2 emission intensity decrease by 0.009%.

Source: Author's own elaboration

that reached a maximum of 14.22% in 1973 and then decreased to 9% in 2019. While Morocco's emissions were comparatively low (0.18 %) to 2017' World Emissions average, but remain high on average than lower middle income countries (World Bank, 2017).

3.2.2. Energy consumption

As shown in the Figure 2, Morocco is still rely on fossil fuels for energy generation and transportation, considering the transition to renewables is slower than anticipated and the fluctuations in renewable energy availability (e.g., variability in solar or wind power), The country remains heavily reliant on energy imports. Over the last decade, energy-related CO_2 emissions increased by 2.4% per year in total, and 1.0% per capita.

3.2.3. Economic growth

As shown in the Figure 3, the Moroccan economy performed well in last two decades. Morocco's GDP growth rate rose continually by focusing on sectors that had growth potential, such as the aeronautical, automobile, and solar energy industries. Encouraged by the positive results and improved indicators, Morocco strove to close its economic gap quickly and join the ranks of upper-middle-income countries. Over the last two decades, Morocco's GDP grew by an average of 3.9% per year in total, and 2.5% per capita.

Figure 2: KWH energy consumption per person in Morocco

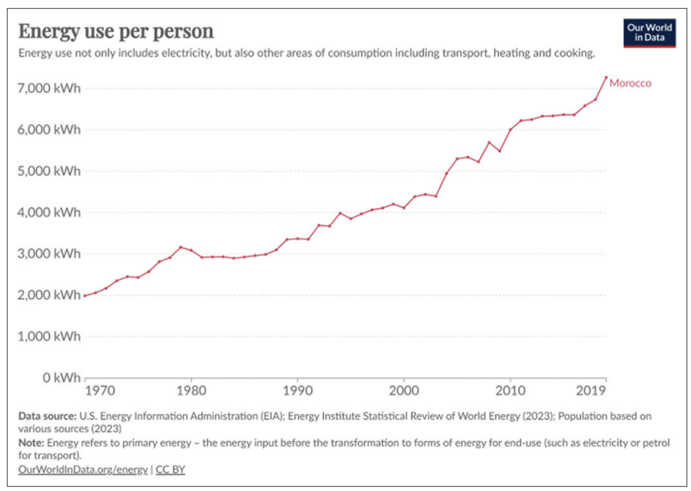


Figure 3: GDP per capita in Morocco

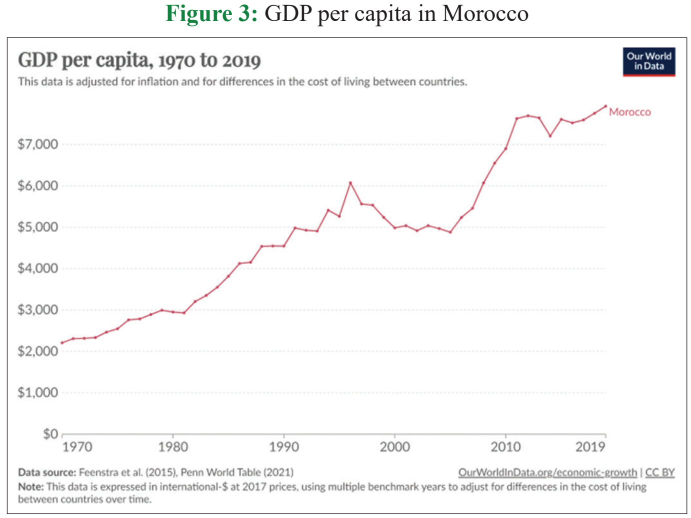


Table 2: Variables' description

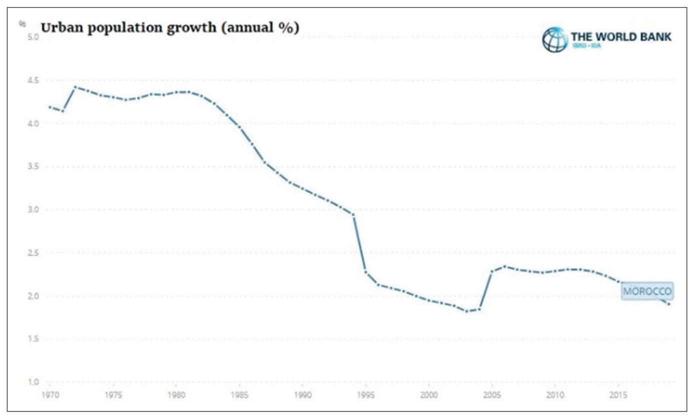
Variables	Acronyms	Description	Unit of measurement	Data source
CO_2 emissions	CO_2	Carbon dioxide (CO_2) emissions from fossil fuels and industry devided by population	tons per capita	Our world in data
Human capital index	HCI	Human capital index based on years of schooling and assumed rate return to education	Unitless according to Feenstra et al. (2015)	Penn world Table 10.0
Gross Domestic Product	GDP	Gdp per capita	GDP per capita in international-$ at 2017 prices	The World Bank, World Development Indicators (2023)
Foreign direct investment	FDI	Net inflows as a percentage of GDP	% of GDP	The World Bank, World Development Indicators and
Energy consumption per person	ENC	Primary energy consumption per capita	kilowatt-hours per person per year.	Our world in data
Urban growth	URB	Urban population Growth	growth rate	The World Bank, World Development Indicators
Trade openness	TRD	sum of exports and imports of goods and services measured as a share of GDP	% of GDP	The World Bank, World Development Indicators

Source: Authors' own elaboration

3.2.4. Urbanization

from 1970 to 2019 the population of Morocco increased from 15.27 million to 36.30 million people, urban rate have pursuit proportionally this tendency as it shown in the Figure 4: today 60% of Moroccans already reside in urban areas, as opposed to 35% in 1970. Because Morocco is a drought-prone country, rural-urban migration is permanently sustaining urban population growth. According to estimates from the National Statistics Institute (Haut Commissariat au Plan), by 2050, nearly 3/4 of the country's population will be urban which will lead to the increasing concentration of economic activities in cities, which account for 75% of the country's GDP and 70% of investment at the national level as demonstrated Lall et al. (2019).

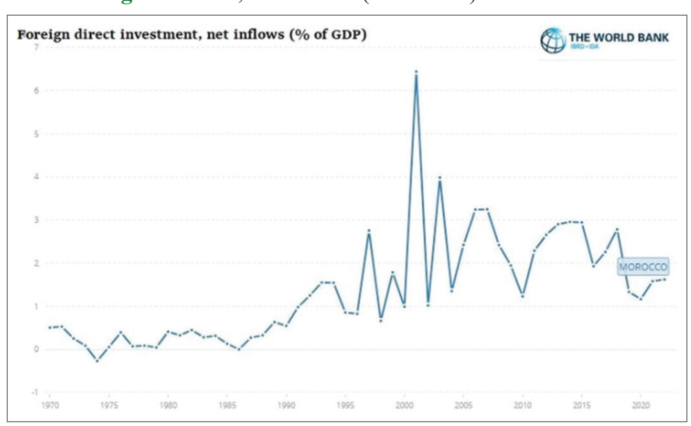
Figure 4: Urban population growth (annuel %) in Morocco



3.2.5. Foreign direct investment inflows

As shown in the Figure 5, FDI curve have seen major peaks over the last two decades. Morocco's strategic geographical location, stability, and government incentives have been key factors in attracting FDI over the last 20 years. The country has implemented policies to encourage investment in sectors like renewable energy, automotive manufacturing, and technology. Additionally, its proximity to Europe and strong trade relations have contributed to FDI inflows. In recent years, Morocco has seen increased interest from international companies looking to invest in sectors such as renewable energy, particularly in wind and solar projects. The automotive industry has also been a significant recipient of FDI, with several global manufacturers establishing production facilities in the country. Government initiatives like the Industrial Acceleration Plan (2014-2020) and various free trade agreements previously mentioned have further encouraged FDI inflows by offering incentives, tax breaks, and streamlined procedures for foreign investors.

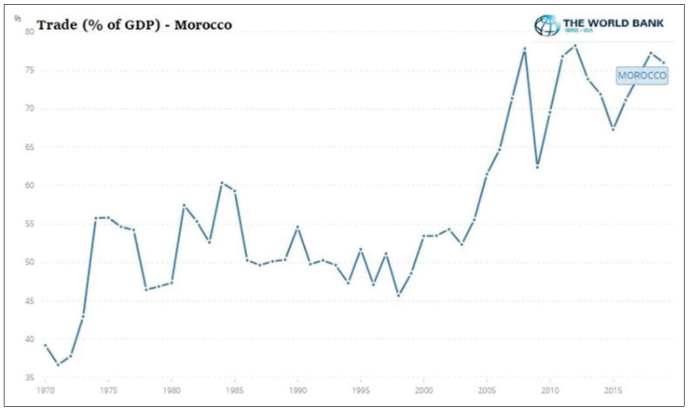
Figure 5: FDI, net inflows (% of GDP) in Morocco



3.2.6. Trade openness

As described in the Figure 6, trade have seen a net evolution, because Morocco has joined the WTO when signing GATS (general agreement on trade and services) in 1996 and have concluded many MAFTAS (Morocco free trade agreements) declined on groupings, bilateral and multilateral pacts from 1996 to 2005, for instance, with the European union in 1996, with several Arab and Islamic countries such Egypt, Jordan, Tunisia, Turkey, and the United Arab Emirates in1998,with the Arab League, and among the Mediterranean Arab countries (Agadir Agreement, 2001), with the US in 2005, which procured to Morocco relative high economic openness and attractiveness of inflows and direct investments since.

Figure 6: Trade (% of GDP) in Morocco



3.2.7. Human capital

Over the last 20-years, Morocco made progress in developing its human capital. A prominent national program driving the development of the country's human capital was the National Human Development Initiative (NHDI) lunched in 2005 which had as a main goal to rehabilitate dysfunctions of Morocco's development trajectory, such as high poverty in rural areas, social exclusion in urban areas, and the lack of opportunities and resources available to vulnerable populations, When the NHDI was launched in 2005, Morocco struggled in some aspects of human capital development and aimed to improve particularly its education and health indicators. In the education sector, the country's net primary school enrolment was 86.7%, slightly below the world average of 86.8% and the MENA average of 89.0%. The indicators for secondary school net enrolment, however, were much worse, with Morocco at only 40.1% in 2005, far behind the world average of 58.5% and the MENA average of 65.5%.Morocco struggled to improve its human capital outcomes since the 1990s. Enrolment rate in primary school was 52.4% in 1990; by 2013 it has risen to over 98%. Since 2000, investments in education have been large and sustained, between 5 and 6% of GDP. As reported by Benkassmi and Abdelkhalek (2020), Moroccan children are fully immunized. Coupled with this has been careful management of communicable diseases, including through the use of international partnerships. In 2019, Morocco had achieved a level of human capital development roughly the same as those of comparable neighbour countries (as measured using the World Bank's Human Capital Index). Morocco's 2019 HCI was lower than the average for the MENA region but higher than the average for countries in its income group. All those actions and achievements leaded to a pure ascendant human capital index's increasing as shown by the curve of the Figure 7 below.

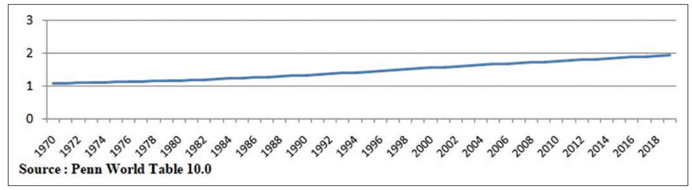
3.3. Model Construction

The specification of the STIRPAT model as reported by Aguir Bargaoui et al. (2014) is:

$$\mathrm{I} = \alpha P_i^b A_i^c C_i^d e_i$$

The constant α scales the model, b, c and d are the exponents of P which design population, A which design affluence and T which design technology, that must be estimated and e is the error term. The subscript i indicates that these quantities (I, P, A, T and e) vary across observational units. An additive regression model in

Figure 7: Index of human capital per person in Morocco



which all variables are in logarithmic form facilitates estimation and hypothesis testing.

Accordingly to the STIRPAT Model, and tor our data presentation above, we estimate the following functional form:

CO_2=f (HCI, GDP, ENC, URB, FDI, TRD)

Where CO_2 is carbon emissions per person as a proxy of environmental impact, GDP is Per capita Gross Domestic Product as a proxy of affluence, URB is urban population growth rate as a pointed proxy of population, HCI is Human capital index as a proxy of technical standard of production. ENC is energy consumption per person, FDI is Foreign Direct Investment net Inflows as a percent of GDP, TRD is trade openness as a percent of GDP. FDI and TRD were implemented both in the model as a control variables.

4. AN ARDL ANALYSIS OF THE NEXUS BETWEEN CARBON EMISSIONS AND EXPLANATORY FACTORS

4.1. The ARDL Model Presentation

Our empirical strategy consists of using the Autoregressive Distributed Lags (ARDL) model to exam the statistical relationship between CO_2 emissions as dependable variable and human capital index as independent besides the control variables summarized below. In our model, outcomes will be investigated by two different methods, the Bounds Testing Approach (BTA) as developed by Pesaran and Shin (1999), and the Error Corrector Model (ECM) as developed by Pesaran et al. (2001). The methodology framework of ARDL-ECM is schematized as shown in following Scheme 1:

4.2. The ARDL Model Specifications

The standard ARDL/BTA model is:

$$\Delta(Y)_t = \alpha_0 + \delta_1 Y_{t-1} + \ldots + \delta_s Y_{t-s} + \beta_1 X_{t-1} + \ldots + \beta_s X_{t-s} + \ldots \varepsilon_t$$

Where is the intercept, X_t is the matrix of integrated/co integrated variables, δ are long-run coefficients, ρ are short-term coefficients and ε_t are random disturbances.

ECM is the 2nd analytical approach of ARDL model which identifies short-run relationships among the variables and examine the adjustment of the dependent variable by the long term. An ARDL/ECM model is standardly expressed as:

$$\Delta(Y)_t = \alpha_0 + \delta_1 Y_{t-1} + \delta_2 X_{t-1} + \sum_{i=0}^{p} \rho_1 \Delta Y_{t-i} + \sum_{i=0}^{q} \rho_2 \Delta X_{t-i} + \varepsilon_t$$

Where ρ are short-term coefficients, δ_I are the long-term ones, p and q are the lag order for the independent and dependent variables, respectively, ε_t are random disturbances as reported Engle and Granger (1987), and thereafter Hassler and Wolters (2006).

Applied to our study, the ARDL/BTA model's equation is presented as:

$$CO_2=c+\delta_1 HCI_t+\delta_2 GDP_t+\delta_3 ENC_t+\delta_4 URS_t+\delta_5 FDI_t+\delta_6 TRDt+\varepsilon_t \quad (1)$$

Converting equation (1) to log-linear form:

$$LnCO_2=c+\delta_1 LnHCI_t+\delta_2 LnGDP_t+\delta_3 LnENC_t+\delta_4 LnURB_t+\delta_5 LnFDI_t+\delta_6 LnTRD_t+\varepsilon_t$$

Where t is the time series operator: δ_1, δ_2, δ_3, δ_4, δ_5, δ_6 are the coefficients of HC, GDP, ENC, URB, FDI, and TRD respectively; $\varepsilon_t$represents random disturbances

Applied to our case in the log-linear form, the ARDL/ECM model is expressed as:

$$\begin{aligned}\Delta \ln CO_2 = {} & c+\sum_{i=1}^{p}\alpha_{1i}\Delta CO_{2t-i}+\sum_{i=0}^{q}\beta_{1i}\Delta \ln HC_{t-i} \\ & +\sum_{i=0}^{q}\beta_{2i}\Delta \ln GDP_{t-i}+\sum_{i=0}^{q}\beta_{3i}\Delta \ln ENC_{t-i} \\ & +\sum_{i=0}^{q}\beta_{4i}\Delta \ln URB_{t-i}+\sum_{i=0}^{q}\beta_{5i}\Delta \ln FDI_{t-i} \\ & +\sum_{i=0}^{q}\beta_{6i}\Delta \ln TRD_{t-i}+\gamma\ ECT_{t-1}+\mu_t\end{aligned} \quad (2)$$

Where Δ is the 1st difference operator, p and q are respectively the adequate lags length for both dependent and independents variables, coefficients are shown through α, β and λ, while μ represents white noise error.

We construct two hypotheses from Equation (2), which represents long-run relationships.

The 1st of which is the null hypothesis (H_0: $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0$) with no cointegration, and the 2nd of which is the alternative hypothesis (H_1: $\lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \neq 0$).

If there is cointegration, the error correction model (ECM) representation is specified as:

$$\begin{aligned}\Delta \ln CO_2 = {} & c+\sum_{i=1}^{p}\alpha_{1i}\Delta InCO_{2t-i}+\sum_{i=0}^{q}\beta_{1i}\Delta \ln HC_{t-i} \\ & +\sum_{i=0}^{q}\beta_{2i}\Delta \ln GDP_{t-i}+\sum_{i=0}^{q}\beta_{3i}\Delta \ln ENC_{t-i} \\ & +\sum_{i=0}^{q}\beta_{4i}\Delta \ln URB_{t-i}+\sum_{i=0}^{q}\beta_{5i}\Delta \ln FDI_{t-i} \\ & +\sum_{i=0}^{q}\beta_{6i}\Delta \ln TRD_{t-i}+\gamma\ ECT_{t-1}+\mu_t\end{aligned} \quad (3)$$

Where, ECT represents the error correction term.

4.3. Initial Presentations, Pre-test Analysis Results

4.3.1. Descriptive statistics

Main results from Table 3 show that; the mean and median values for all variables are largely consistent; their standard deviation has the same order of volatility except for LNFDI which is a little bit volatile. Skewness values for all variables fall within −0.5 and 0.5, so their distribution is almost symmetrical, except for LNHCI which is high since it is superior than 1.

4.3.2. Multivariate correlation analysis

Table 4 represents a multivariate correlation matrix of Pearson's correlation coefficients applied to our dataset variables which measures the strength of the linear relationship between each two variables, commonly named The Pearson and Spearman correlations, as reported Bonett and Wright (2000).

Results from Table 4 indicate a strong positive correlation between the dependent variable and the other endogenous variables except for LNURB which indicates a strong negative one.

4.3.3. Principal component analysis (PCA)

PCA is a multivariate analyzing technique in which observations are described by several inter-correlated quantitative dependent variables represented into a set of new orthogonal variables called principal components, the pattern of similarity of the observations are displayed as points in maps, as reported (Pearson, 1901).

Next Table 5 gives a PCA summary.

Results from Table 5 show that the 1st principal direction which corresponds to the dependent variable explains roughly 76% of the information contained in the correlation matrix below, the 2nd corresponding to LNHCI, roughly 11%, and so on. Furthermore, the cumulative proportion of information explained by the 1st two

Table 3: Summary of descriptive statistics

	$LNCO_2$	LNHCI	LNGDP	LNENC	LNURB	LNFDI	LNTRD
Mean	0.049077	0.153088	8.423045	8.266523	1.053559	-0.332004	4.021687
Median	0.074284	0.052474	8.506668	8.271057	0.965076	-0.012650	3.993854
Maximum	0.636463	0.660518	8.977643	8.891163	1.486394	1.863170	4.359552
Minimum	−0.740767	0.031718	7.700275	7.595203	0.600540	−5.870378	3.602211
SD	0.380431	0.219804	0.386125	0.357146	0.325679	1.453015	0.194183
Skewness	−0.213686	1.661163	−0.337516	0.042852	0.132701	−1.334556	0.125786
Kurtosis	2.025933	3.809405	2.011532	1.910952	1.344452	5.577556	2.432348
Jarque-Bera	2.357192	24.36038	2.984869	2.486191	5.856827	28.68325	0.803159
Probability	0.307710	0.000005	0.224825	0.288490	0.053482	0.000001	0.669262
Sum	2.453840	7.654420	421.1522	413.3262	52.67795	−16.60022	201.0844
Sum Sq. Dev.	7.091669	2.367374	7.305532	6.250100	5.197262	103.4514	1.847652
Observations	50	50	50	50	50	50	50

Source: Author's computation using E-views 9 principal directions is roughly 88 (76+12) %, which is highly significant regarding the importance of the two variables in our study.

4.3.4. Lag length determination

It is necessary to determine the optimal lag length for the underlying ARDL model in which the disturbance terms are not serially correlated, as reported (Mallik, 2008). These lag numbers are selected by different information criteria: Likelihood Ration (LR), Akaike Information Criterion (AIC), Schwartz-Bayesian Information Criterion (SC), final prediction error (FPE), Hannan-Quinn information criterion (HQIC). Table 6 stands as a summary.

As results from Table 6 show, all criterions indicate that the 1st order is the optimal lag length for our ARDL/VCEM model, except for Akaike information which indicates the 4th order.

4.3.5. Stationarity test

A stationary time series is one whose statistical properties do not depend on the time at which the series is observed as reported Kwiatkowski et al. (1992). Variables' integration, either in 0 or in the 1st order, or both (cointegration) is fundamental to achieve the ARDL bound test as demonstrated Pesaran et al. (2001). To verify our time series stationarity, the augmented Dickey-Fuller test is used, as demonstrated Cheung and Lai (1995). Table 7 gives a summary.

Table 7 shows that some variables are integrated at the level form and others at the 1st difference level. These results consent us to apply ARDL/BTA, based on the presence of con-integration between time-series variables since all of them are integrated at I (0) or I (1).

4.3.6. Optimal lag order selection

To select adequate lag order when the VAR model is subject to restrictions of cointegration there is multiple information criterias such as Akaike (AIC), Schwarz (SC) and Hannan-Quinn (HQ) and Forecast Prediction Error among others as reported (Lütkepohl and Poskitt 1996).

As shown in Graph 1, the model with the lowest correspondent (AIC) value is ARDL (2,0,0,4,4,2,3). The appropriate lag lengths (p) corresponding to each variable, such as lnCO2, lnHC, lnGDP, lnEC,lnENC, lnURB, lnFDI, and lnTRD in Equation (2), are 2, 0, 0,4, 4,2 and 3 respectively. Consequently, equation (2) is specified as:

$$\begin{aligned}\Delta \ln CO_2 = {} & c + \sum_{i=1}^{2} \alpha_{1i} \Delta CO_{2t-i} + \beta_1 \Delta \ln HC \\ & + \beta 2 \Delta \ln GDP + \sum_{i=0}^{4} \beta_{3i} \Delta \ln ENC_{t-i} \\ & + \sum_{i=0}^{4} \beta_{4i} \Delta \ln URB_{t-i} + \sum_{i=0}^{2} \beta_{5i} \Delta \ln FDI_{t-i} \\ & + \sum_{i=0}^{3} \beta_{6i} \Delta \ln TRD_{t-i} + \lambda_1 \ln CO_{2t-i} + \lambda_2 \ln HCt - i \\ & + \lambda_3 \ln GDP_{t-i} + \lambda_4 \ln ENC_{t-i} + \lambda_5 \ln URB_{t-i} \\ & + \lambda_6 \ln FDI_{t-i} + \lambda_6 \ln TRD + \mu_t \end{aligned} \tag{4}$$

Table 4: Pearson correlation matrix

	$LNCO_2$	LNHCI	LNGDP	LNENC	LNURB	LNFDI	LNTRD
$LNCO_2$	1.000000						
LNHCI	0.601785	1.000000					
LNGDP	0.948744	0.629567	1.000000				
LNENC	0.991202	0.670530	0.941800	1.000000			
LNURB	−0.866826	−0.409521	−0.859650	−0.854724	1.000000		
LNFDI	0.708384	0.393386	0.676300	0.703834	−0.753016	1.000000	
LNTRD	0.810483	0.672261	0.716226	0.815422	−0.513230	0.467262	1.000000

Source: Author's computation using Eviews 9

Table 5: Principal component analysis

Number	Value	Difference	Proportion	Cumulative	Cumulative
				Value	Proportion
1	5.355640	4.521819	0.7651	5.355640	0.7651
2	0.833820	0.447897	0.1191	6.189460	0.8842
3	0.385924	0.092128	0.0551	6.575384	0.9393
4	0.293795	0.210178	0.0420	6.869179	0.9813
5	0.083618	0.039950	0.0119	6.952797	0.9933
6	0.043668	0.040132	0.0062	6.996465	0.9995
7	0.003535	---	0.0005	7.000000	1.0000

Source: Author's calculation using E-Views 9

Table 6: Lag order selection results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	149.3671	NA	4.84e-12	−6.189874	−5.911603	−6.085632
1	426.3179	457.5708*	2.46e-16*	−16.10078	−13.87460*	−15.26684*
2	466.4785	54.12960	4.19e-16	−15.71646	−11.54239	−14.15283
3	526.6723	62.81090	3.93e-16	−16.20314	−10.08117	−13.90982
4	596.1298	51.33811	4.25e-16	−17.09260*	−9.022724	−14.06958

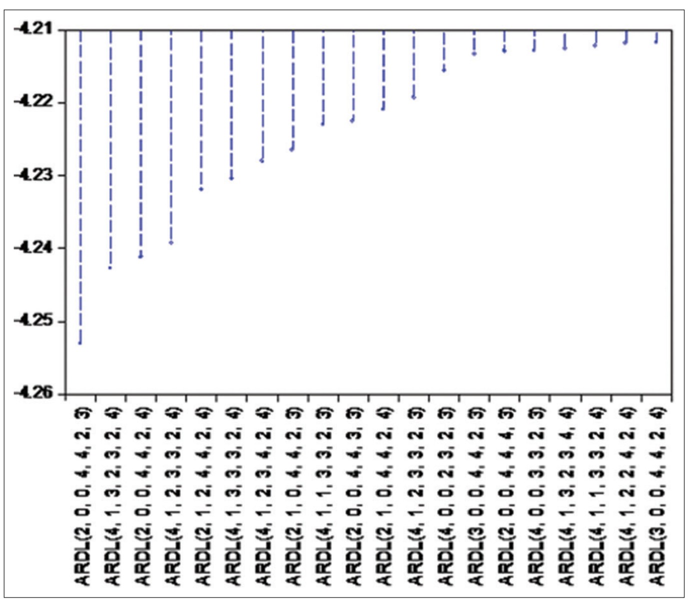
*Mean lag order selected by the criterion. Source: Author's calculation using E-Views 9.

Table 7: Unit root test results table (ADF)

Null Hypothesis: The variable has a unit root							
At Level	**$LNCO_2$**	**LNHCI**	**LNGDP**	**LNENC**	**LNURB**	**LNFDI**	**LNTRD**
With Constant							
t-Statistic	−1.6044	−0.0069	−1.3036	−0.7128	−0.6770	−1.7399	−1.7826
Prob.	0.4728n0	0.9532n0	0.6207n0	0.8338n0	0.8427n0	0.4052n0	0.3846n0
With constant and trend							
t-Statistic	−3.5933	−1.2568	−2.9717	−2.8294	−1.7684	−5.3854	−2.7498
Prob.	0.0408**	0.8868n0	0.1510n0	0.1942n0	0.7044n0	0.0003***	0.2223n0
Without constant and trend							
t-Statistic	−1.0176	0.6345	3.6776	4.5419	−2.1821	−1.7639	0.9743
Prob.	0.2736n0	0.8500n0	0.9999n0	1.0000n0	0.0293**	0.0739*	0.9104n0
At first difference	**d ($LNCO_2$)**	**d (LNHCI)**	**d (LNGDP)**	**d (LNENC)**	**d (LNURB)**	**d (LNFDI)**	**d (LNTRD)**
With Constant							
t-Statistic	−8.3946	−6.7630	−3.4293	−7.6303	−4.9357	−12.0828	−7.3535
Prob.	0.0000***	0.0000***	0.0147**	0.0000***	0.0002***	0.0000***	0.0000***
With constant and trend							
t-Statistic	−8.4541	−7.0327	−3.4810	−7.5541	−4.8827	−11.9565	−7.2852
Prob.	0.0000***	0.0000***	0.0532*	0.0000***	0.0013***	0.0000***	0.0000***
Without constant and trend							
t-statistic	−6.3466	−6.6601	−2.6160	−3.1101	−4.6476	−12.2033	−7.2108
Prob.	0.0000***	0.0000***	0.0100***	0.0025***	0.0000***	0.0000***	0.0000***

a: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (no) Not Significant, b: Lag Length based on SIC, c: Probability based on MacKinnon (1996) one-sided P-values. Source: Author's calculation using E-Views 9

Graph 1: Akaike information criteria



Source: Author's computation using eviews 9

4.4. ARDL Model Parameters Estimation

ARDL estimations are ordinary least squares regressions that use lags of both the independent and dependent variables as regressors. The model is autoregressive, in the sense that dependent variable is explained (in part) by lagged values of itself. It also has a distributed lag component, in the form of successive lags of the explanatory variables. Table 7 gives a numerous parameters estimation of our ARDL model.

Results from Table 7 reveal that the determination coefficient is too strong in the sense that the dependent variable $LNCO_2$ is largely explained by lagged values of itself and of those of the explanatory variables which their p values are lower than 5%, the most of all.

Table 8: ARDL (2,0,0,4,4,2,3) parameters estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
$LNCO_2$(-1)	0.011471	0.179100	0.064047	0.9495
$LNCO_2$(-2)	0.343303	0.174395	1.968538	0.0607
LNHCI	−0.103629	0.055171	−1.878336	0.0725
LNGDP	0.119116	0.066557	1.789680	0.0861
LNENC	0.912038	0.140000	6.514572	0.0000
LNENC(-1)	−0.039055	0.198362	−0.196887	0.8456
LNENC(-2)	−0.499007	0.203280	−2.454772	0.0217
LNENC(-3)	0.170727	0.134503	1.269316	0.2165
LNENC(-4)	0.258874	0.114302	2.264834	0.0328
LNURB	0.015477	0.100575	0.153883	0.8790
LNURB(-1)	0.090188	0.141222	0.638626	0.5291
LNURB(-2)	0.320822	0.148648	2.158267	0.0411
LNURB(-3)	−0.211143	0.131503	−1.605616	0.1214
LNURB(-4)	−0.190677	0.111022	−1.717469	0.0988
LNFDI	−0.001247	0.004998	−0.249409	0.8052
LNFDI(-1)	−0.012156	0.005044	−2.409880	0.0240
LNFDI(-2)	−0.012096	0.004829	−2.504887	0.0194
LNTRD	−0.016454	0.066346	−0.247999	0.8062
LNTRD(-1)	−0.048195	0.065526	−0.735508	0.4692
LNTRD(-2)	−0.091789	0.067903	−1.351765	0.1891
LNTRD(-3)	−0.155297	0.067136	−2.313148	0.0296
R-squared	0.997001	Mean dependent var		0.110408
Adjusted R-squared	0.994376	S.D. dependent var		0.330202
S.E. of regression	0.024762	Akaike info criterion		−4.253048
Sum squared resid	0.014716	Schwarz criterion		−3.378480
Log likelihood	119.8201	Hannan-Quinn criter.		−3.925429
F-statistic	379.8947	Durbin-Watson stat		2.323394

Source: author's calculation using E-Views 9

4.5. ARDL Bound Test for Cointegration

An ARDL bounds test for cointegration involves an extra *F*-test on the lagged levels of the independent variable(s) in the ARDL equation as proved Pesaran et al. (2001). Then the calculated F-statistic is compared with critical values, if it exceeds the upper value, then the H_0 is rejected. If it falls within the bounds then the test is inconclusive. Lastly, if it falls below the lower value, it implies that there is no co-integration as demonstrated (Narayan, 2005).

As shown in Table 8, F-value =4.828933 exceeds the upper bound at the 5% level. Therefore, we can reject H_0 of no level relationship, in favour of the existence of co-integration and the presence of a long-run relationship between dependent and independent variables.

4.6. Long-Run and Short-Run Dynamics

As shown in Table 9, The variables that are statistically significantly determine that carbon emissions is associated with human capital, economic growth and energy consumption by the long term: The theoretical coefficient for human capital has expected a negative significant sign, which indicates its efficiency in the Moroccan case during the period under discussion, this means in the long run, increase in human capital leads to decrease in dioxide emissions. In the opposite way, the long run coefficients of economic growth and energy consumption have expected a priori theoretical sign which are positives, this means in the long run, increase in both economic growth and energy consumption leads to increase in dioxide emissions, other things equal, it suppose that a 1% increase in economic growth and energy consumption will leads to 18.46% and 124.54%,respectively, increase in carbon emissions, while a 1% increase in human capital will leads to 16.6% increase in carbon emissions.

The results of the short-run dynamics show only a significant and positive relationship between energy consumption and carbon emissions. The estimated coefficient of energy consumption is significantly smaller in the short-run than the long-run estimated coefficients, suggesting that energy consumption increases carbon emissions at a higher rate in the long run. Meanwhile, other variables don't give too much significant information in the short run.

Table 9: Results of the ARDL bound test

Test Statistic	Value	K
F-statistic	4.828933	6
	Critical Value Bounds	
Significance	**I0 Bound**	**I1 Bound**
10%	2.12	3.23
5%	2.45	3.61
1%	3.15	4.43

Source: Author's computation using Eviews 9

Table 10: Long run and short run ARDL presentation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
		Long run coefficients		
LNHCI	−0.160610	0.061379	−2.616682	0.0151
LNGDP	0.184612	0.074420	2.480685	0.0205
LNENC	1.245421	0.234655	5.307463	0.0000
LNURB	0.038230	0.084195	0.454071	0.6539
LNFDI	−0.039518	0.020239	−1.952600	0.0626
LNTRD	−0.483139	0.297995	−1.621298	0.1180
		Short run coefficients		
D ($LNCO_2$(-1))	−0.343303	0.174395	−1.968538	0.0607
D (LNHCI)	−0.103629	0.055171	−1.878336	0.0725
D (LNGDP)	0.119116	0.066557	1.789680	0.0861
D (LNENC)	0.912038	0.140000	6.514572	0.0000
D (LNURB)	0.015477	0.100575	0.153883	0.8790
D (LNFDI)	−0.001247	0.004998	−0.249409	0.8052
D (LNTRD)	−0.016454	0.066346	−0.247999	0.8062
ECT (−1)	−0.645226	0.208764	−3.090696	0.0050

Source: author's calculation using E-Views 9

4.7. Vector Error Correction Model

The error correction term (ECT) measures the link between the short-run and the long run as reported Engle and Granger (1987). It is developed from the long-run model and shows how variables quickly converge to equilibrium as proved Hassler and Wolters (2006). ECT has a negative and significant value of $-1 \leq -0.645226 \leq 0$. Which confirms the long-term relationships between our variables implying an annual adjustment of about 64.52% to the long-term equilibrium which matches with ARDL model characteristics of acceptability.

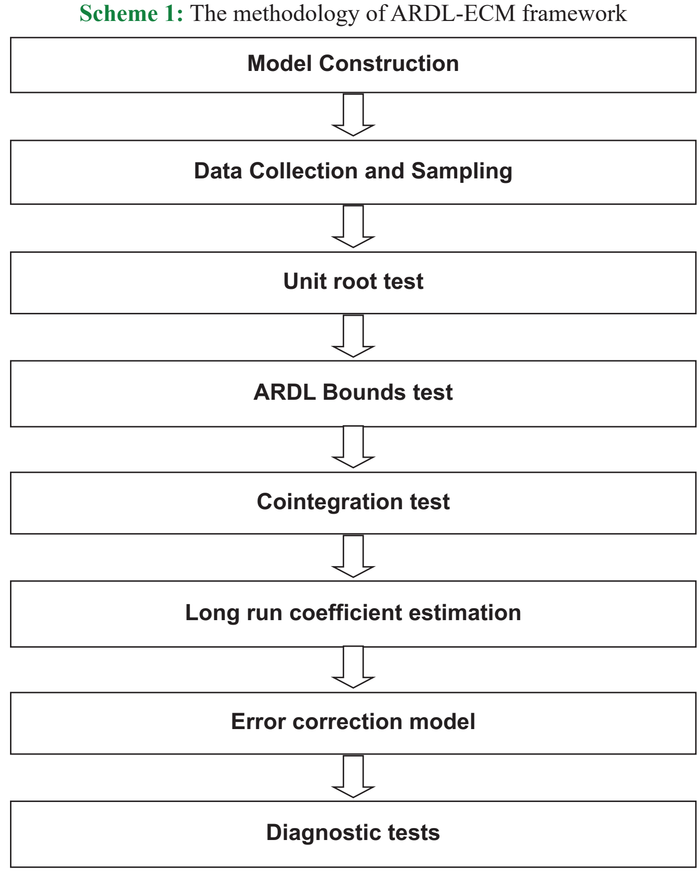
4.8. Post Estimation Diagnostics and Stability Tests

As reported Mauricio (2008), Residuals are critical data at the model's diagnostic check point, where one seeks indications that either assesses the model's capability, provides directions along which it might be modified which implicates serial correlation, normality, and heteroscedasticity as reported Bera and Jarque (1981). Table 11 below regroups these tests.

4.8.1 Serial correlation decision rule

- H_0: There is no autocorrelation in the model
- Alter hypothesis: there is auto correlation in the model

Scheme 1: The methodology of ARDL-ECM framework



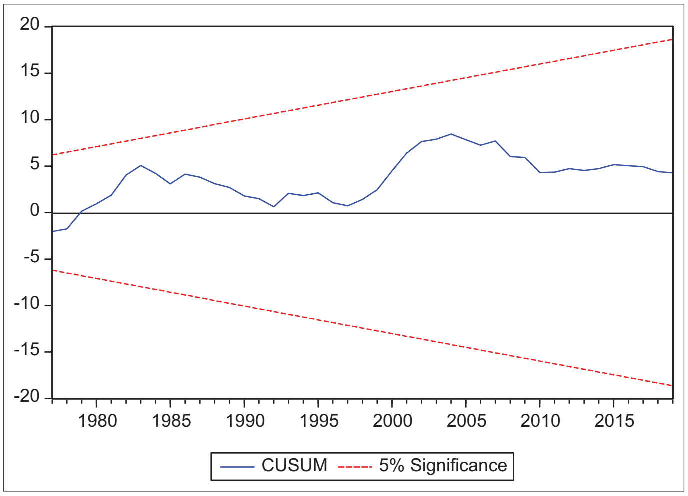
Source: Author's own elaboration

Table 11: Post diagnostic tests results

Items	Test	F-statistic	Probability value
Serial correlation	BreuschGodfrey serial Correlation LM test	1.289966	0.2862
Normality	Jarque-Bera	1.803470	0.405865
Heteroscedasticity	Breusch-Pagan-Godfrey	1.904432	0.1020
Functional form	Ramsey RESET Test	2.790579	0.1023
CUSUM	Stable		
CUSUMsq	Stable		

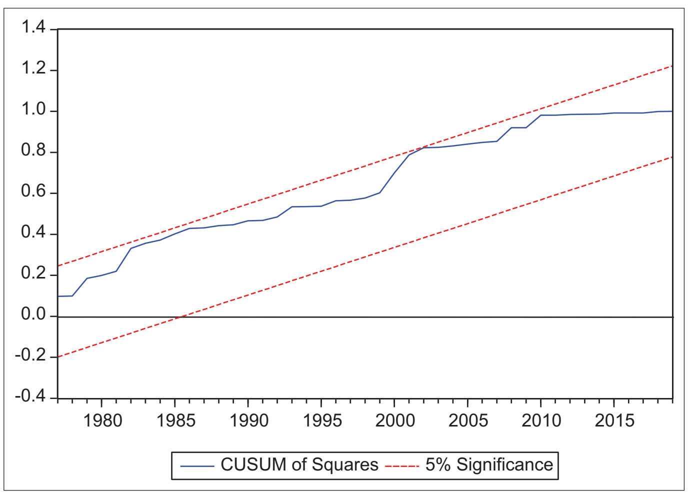
Source: author's calculation using E-Views 9

Plot 1: Cumulative sum of recursive residuals



Source: EViews output based on author's computation

Plot 2: Cumulative sum of squares of recursive residuals



Source: EViews output based on author's computation

4.8.2. Normality Decision Rule

- H_0: Residuals are normally distributed
- Alter hypothesis: residuals are not normally distribute

4.8.3. Heteroscedasticity Decision Rule

- H_0: data is homoscedastic
- Alternative hypothesis: data is heteroscedastic

Results from Table 11 indicate that the H_0 of no serial correlation could not be rejected, so there is no autocorrelation in our model. The Jarque-Bera test indicated that residuals are normally distributed. The RESET test showed evidence of incorrect functional specification of the model through a rejection of H_0. Data is homoscedastic because test is rejecting constancy of the variances, while CUSUM test and CUSUM of squares test are stables over time which makes them suitable for making long run decision as it shown in Plot 1 and Plot 2 below.

5. DISCUSSIONS, CONCLUSION AND POLICY IMPLICATIONS

Various studies have been dedicated to the examination of the determinants of carbon emissions in a number of cases around the world. We chose of them those applied for countries such Morocco regarding the same category of economic growth, group income and range of population and urbanisation to establish a pertinent comparison in term of outputs:

From Asia, a similar study over the period from 1996 to 2020 in Kazakhstan for example lead by Asif and Almagul 2022 found that 1% increase in economic growth, energy use, and urbanization cause an increase in CO_2 emissions by 0.14%, 0.81%, and 1.28% in Kazakhstan, respectively in the long run. From central Europe Hatmanu et al. (2022) checked the relationships between CO_2 emissions and their determinants in Romania and Bulgaria using an ARDL approach over the period from 1980 to 2019, their results showed that there are long term relationships between CO_2 emissions per capita and the determinant factors taken into account in both countries; however, while the inverted N-shape of EKC is significant in the case of Bulgaria, this does not happen in the case of Romania although the model which includes the inverted U-shape of EKC is significant for both countries. From Latin America, (Raihan, 2023) demonstrated that a 1% increase in Chilean economic growth, urbanization, industrialization, and tourism will increase Chile's CO_2 emissions by 0.62%, 0.24%, 0.15%, and 0.1%, respectively over the period from 1990 to 2020. Just nearby Morocco, Chekouri et al. (2020) examined the driving factors of CO_2 emissions using the STIRPAT model in the case of Algeria during the period from 1971 to 2016, and found that the population has a positive and significant effect on CO_2 emission, the energy use is found to be the second most contributing factor to CO_2 emissions followed by urbanisation and GDP per capita. Consequently, our study converge in term of results with similar studies emphasizing the fact that economic factors, energy consumption, urbanization have are rising carbon emissions while human capitalization is reducing them.

This study has been conducted with the ultimate objective to identify long-term relationship between human activities such human capital, energy consumption, economic growth and attractiveness, trade openness, urbanization and carbon emissions in Morocco from 1970 to 2019. We used ARDL/BTA to find long-run cointegration and the ARDL/ECM approach to check the long and short run dynamics between the variables. We found that increase in human capital leads to significant decrease in carbon emissions, while increase in both economic growth and energy consumption generates an opposite result, other things equal.

In the light of this study, we propose some guidelines policy implications to take in consideration by the Moroccan state, essentially, it should: enhance the promotion of the national human capital by more spending on public education and civic formation as we demonstrated previously (Hamdi and Azeroual, 2023), accelerate its energy transaction into renewables in order to decrease its reliability on fossil fuel resources, fix a long term plan of carbon neutralization, tax carbon emissions by their sources especially from the industrial sector, orientate its economic growth to eco labelled products, services, and processes of productions in order to maintain its environmental sustainability. All these actions must be taken, together and simultaneously, urgently by the short term.

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