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Article

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Does Education Sector Improve Environmental Quality in Saudi Arabia?

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ABSTRACT

Since the adoption of the Paris Agreement (UNFCCC, 2015), education has indeed been recognized internationally as an essential tool for informing, raising awareness and engaging the public in the fight against climate change. The current study utilizes the ARDL model to investigate the nonlinear relationship between economic growth, education and carbon emissions for Saudi Arabia over the period 2017-2020. The results show that primary education has no effect on CO_2 emissions while secondary and tertiary education have a negative effect on CO_2 emissions. The results also confirm the non-linear and the inverted U-shaped relationship between both CO_2 emissions and education (secondary and tertiary) and between CO_2 emissions and economic growth. Our results are important in terms of economic policy. First, they highlight the importance of human capital in environmental protection. Second, the current accumulation of knowledge is certainly a factor of economic growth but also of pollution growth. It is not a question of recommending a reconsideration of education policies whose intrinsic values are obvious. On the contrary, there is a need to introduce a change in the perception and role of education in favor of the environment.

Keywords: Environmental Kuznets Curve, CO_2 Emissions, Education, Economic Growth, Saudi Arabia
JEL Classifications: I25, O13, Q50

1. INTRODUCTION

The issue of the environment has received particular attention since global warming and other environmental problems have become increasingly critical. Since the 1990s, researchers have been testing the validity of the inverted U-shaped relationship between income and environmental quality, previously tested between income and income inequality by Kuznets in the 1950s and then in the 1970s between the intensity of natural resources use and income by the Club of Rome economists. Another class of research focused on the introduction of control variables into the EKC model. These variables are assumed to influence product and/or pollution. These additional explanatory variables generally relate to policy (Torras and Boyce, 1998), product structure (Panayotou, 1997), trade (Suri and Chapman, 1998) and the energy variable (Jobert et al., 2010). The addition of education was also considered, as it appears to be a good way to avoid a significant bias on the income coefficients. Namely, income and education are highly correlated (Schultz, 1988; Barro, 2001; Temple, 2001) and, in turn, education could have a direct impact on environmental quality.

Indeed, the level of education can help improve the economic condition of any economy while raising the environmental awareness of the common people. On the other hand, since EKC exists in a country, it is necessary to accelerate the process of economic growth so that the country can reach the threshold at which the degrading effects of economic activities on the environment begin to diminish and the ecological footprint begins to recover. In this case, if education can improve the economic situation of a country that ultimately reduces pollution, then it can easily be said that education can be used as a major source of reducing pollution in a country.

However, empirical results that consider education fail to find consistent results. Specifically, Gangadharan and Valenzuela (2001) and Hill and Magnani (2002) indicated that education worsens environmental quality; while the work of Ehrhardt-Martinez et al. (2002) and Williamson (2017) suggested that it has no influence. In contrast, Managi and Jena (2008) and Balaguer and Cantavella (2018) argued that education can improve environmental quality. Finally, Sapkota and Bastola (2017) found mixed results for the case of developing countries.

Nonetheless, EKC is well studied in the Saudi literature (Omri et al., 2019; Mahmood, 2022; Abbas et al., 2019), but studies that consider education in an environmental model are limited. To our knowledge, only two published studies attempted to identify the impact of education on CO_2 emissions. Alkhateeb et al. (2020) analyzed the effects of education, energy consumption and economic growth on CO_2 emissions in Saudi Arabia during the period 1971-2014. They found that primary education cannot affect CO_2 emissions, but secondary education has a negative effect while energy consumption has a positive effect on CO_2 emissions. In the long term, an inverted U-shaped relationship is found between CO_2 emissions and economic growth. They recommended improving secondary education to improve the Kingdom's environment and using a cleaner energy source to avoid the negative environmental consequences of economic growth. Although Omri et al. (2019) studied the role of human development on CO_2 emissions in Saudi Arabia, they found an insignificant effect.

Given the close relationship between the environment and education, Saudi Arabia is striving through a series of plans to preserve this relationship, despite the environmental problems caused by population growth and intensive industrial processes. In light of the above, this paper aims to analyze the path of the state of the environment and its behavior illustrated by CO_2 emissions during the stages of economic growth in Saudi Arabia. This analysis is done within the framework of the environmental Kuznets curve (EKC) which explains that the environment is placed as a very important good, i.e., a good whose demand increases with income.

The rest of the paper is organized as follows. Section 2 shows how education influences environmental quality. In section 3, we present the theoretical model. Section 4 presents the empirical results, and the last section is devoted to the conclusion and policy implication.

2. HOW DOES EDUCATION AFFECT THE ENVIRONMENT?

Education can have an effect on the environment through several channels. We distinguish two main approaches: the civic externality approach and the human capital approach.

The first approach consists in taking into account the civic externality of education. For some years now, education has been considered an essential vector of sustainable development and therefore of the fight against pollution. Robitaille (1998) considers it as "a permanent learning process contributing to the formation of citizens who have acquired knowledge, interpersonal skills, know-how and etiquette. This allows them to engage in individual and collective actions, based on the principles of interdependence and solidarity, which promote the harmonization of "person-society-environment" relations and the advent of ecologically viable, socio-politically equitable societies and economically just here and elsewhere, now and for future generations." Farzin and Bond (2006) identified three channels allowing a positive relationship between the level of education in a country and environmental quality indicator.

Firstly, the most educated individuals would be more aware of environmental problems and would therefore have behaviors and lifestyles in favor of improving the environment. Indeed, Bimonte (2002) found a positive relationship between the level of education and the demand for environmental protection. He also showed that education increases the minimum level of environmental quality that a given society requires for the same level of income.

Second, better educated populations have a greater capacity to use existing means and channels to express their environmental preferences. They can also organize themselves into pressure groups to obtain the implementation of environmental public policies. Wheeler et al. (1997) conducted an analysis of the factors that lead people to complain about environmental damage in China. They concluded that Chinese provinces with relatively lower education levels of the population have a lower marginal propensity to complain about environmental damage. They justify this by the fact that in the absence of education, people have little information to measure the risks and adverse effects of long-term environmental damage and are therefore only interested in their obvious impact. This could also be explained by the fact that less educated individuals have little confidence in their own ability to influence authorities. Empirical studies conducted by the World Bank (Huq and Wheeler, 1993) show that in the absence of effective government policies, communities with a high level of education undertake actions to control or reduce pollution emissions.

Despite the relative consensus on the positive effect of education, other authors believe that education is a pollution factor. Jorgenson (2003) considered that education has a positive effect on the ecological footprint. Educated individuals have more income and purchasing power and are encouraged to overconsume material goods. Indeed, the desire to live well without worrying about the consequences of the search for happiness through material goods and the ideological model of "consume more to be happier" (Princen et al., 2002) conveyed by advertising and the media led them to a greater material goods consumption. Considering that the overconsumption of goods is a factor of overexploitation of natural resources, educated individuals contribute to the degradation of the environment (air, soil, and water pollution). Its results conclude that the schooling rate has a positive and significant effect on the ecological footprint per capita.

According to the second approach, the accumulation of human capital increases labor productivity and thus income (Mankiw et al., 1992). According to the EKC hypothesis, the quality of the environment initially deteriorates with the increase in income and thus in the economic development process. At a certain threshold, the trend reverses and the increase in income can then be associated with an improvement in the environment. This is because the increase in income per capita generates the resources needed to reduce pollution. The effect of education on the environment is therefore indirect, twofold and dependent on the level of development of the economy.

Second, education facilitates the development and adoption of new, more productive and cleaner technologies. It stimulates the creation of knowledge and innovation through its research and dissemination functions that come from research centers and institutions, and promotes new ideas and knowledge. On the one hand, these institutions train a large number of engineers and scientists and thus a research sector favorable to pollution control, capable of developing environmental technologies. Many authors such as Wheeler and Mody (1992) and Rosentrater et al. (2013) showed the importance of international trade in the transfer and adoption of new cleaner technologies, allowing many countries to make technological leaps. Thus, the accumulation of human capital allows the reduction of pollution through the transfer of clean technologies and their assimilation and/or diffusion within economies.

Finally, education can change the export structure of economies that can become relatively more human capital intensive and thus relatively less dependent on polluting extractive exports and increase their capacity to install environmental protection policies. When pollution in a given economy is not regulated, its increase or decrease over time depends strongly on technological change and the nature of economic growth. Indeed, if the economy grows initially through the accumulation of polluting physical capital and later through the accumulation of non-polluting human capital, then pollution may appear as an inverted U-shaped curve.

3. BASELINE MODEL

As is well known, the EKC hypothesis generally assumes that environmental degradation can be expressed as a quadratic regression on income. This is intended to identify the existence of an inflection point. With this work, we aim to advance an answer to the issue of an EKC existence in the presence of education for the case of Saudi Arabia. The model is based on the approach adopted by some studies such as Balaguer and Cantavella (2018) and Alkhateeb et al. (2020). It corresponds to the specification of a relationship between the environmental indicator (CO_2), per capita income (GDP) and education (ED). The equation to be estimated is given as follows:

$$CO_{2t} = \alpha_0 GDP_t + \alpha_1 GDP_t^2 + \beta_0 Ed_t^i + \beta_1 (Ed_t^i)^2 + \mu_t \quad (1)$$

Where μ_t is an error term assumed to be independent and normally distributed. y_t represent per capita GDP, Ed_t^i (i=1, 2, 3) represent School enrollment tertiary (SET), School enrollment secondary (SES), and School enrollment primary (SEP), respectively. α_k and β_t are the coefficients of the explanatory variables k. Equation (1) allows us to test all possible forms of the relationship between per capita income and pollution on the one hand, and between per capita income and education on the other. Five forms of this relationship can be obtained depending on the values taken by the coefficients α_k and β_t: (1) if $\alpha_0 = \alpha_1 = 0$ and $\beta_0 = \beta_1 = 0$, then there is no relationship between income, education and pollution at the same time. (2) if $\alpha_0 > 0$; $\beta_0 > 0$ and $\alpha_1 = 0$ and $\beta_1 = 0$, then there is a positive linear relationship between income, education and pollution. (3) if $\alpha_0 < 0$; $\beta_0 < 0$ and $\alpha_1 = 0$ and $\beta_1 = 0$, then there is a positive linear relationship between income, education and pollution. (4) if $\alpha_0 > 0$; $\alpha_1 < 0$ and $\beta_0 > 0$; $\beta_1 < 0$, then the shape of the relationship between income and pollution and between education and pollution is an inverted U. In this case, the EKC hypothesis is verified. In the case of inverted U-shaped relationship, the economic value representing the turning point (τ^*) is measured by using $\tau^* = \exp(\frac{-\alpha_0}{2\alpha_1})$; and the educative value representing the turning point (τ_1^*) is measured by using $\tau_1^* = \exp(\frac{-\beta_0}{2\beta_1})$. (5) if $\alpha_0 < 0$; $\alpha_1 > 0$ and $\beta_0 < 0$; $\beta_1 > 0$, then the shape of the relationship between income and pollution and between education and pollution is U-shaped.

4. DATA AND METHODOLOGY

4.1. Data

The variables used in this study are gross domestic product per capita (GDP), carbon emissions per capita (CO_2), school enrolment secondary (SES), School enrollment tertiary (SET) and the School enrollment primary (SEP). Data on GDP and CO_2 are sourced from World Development Indicators (WDI) and Our World in Data, respectively. Data on SES, SET and SEP are sourced from the Government of Saudi Arabia (2022). These variables are examined for the case of Saudi Arabia during the period 1971-2020. All variables are converted into natural logarithms. Table 1 presents the data sources and measurement for this study.

Table 2 shows that all variables are normally distributed; thus, the interrelation coefficients between CO_2 emissions and GDP are significantly and positively correlated. The interrelation coefficients between CO_2 emissions and education are significant and positively correlated. The interrelation coefficients between CO_2 emissions and education are significant and positively correlated. It is not too surprising that the coefficient of the partial Pearson correlation between CO_2, GDP, SE and EC is the highest. It denotes the importance of education for economic development and the strength of dependence on fossil fuel resources, which in turn create higher pollution.

4.2. Methodology

To test the EKC hypothesis and achieve the objectives of this study, several steps in the econometric methodology are used.

4.2.1. Unit root tests

The first step in our analysis is to ensure the stationarity of the series or the order of integration of each of them. This step is important insofar as the use of non-stationary variables in a regression can have consequences such as obtaining non-efficient coefficients,

Table 1: Definition of variables and data sources

Variables	Symbol	Measurement	Sources
Carbon dioxide emissions per capita	CO_2	Tonnes	Our world in data
Gross domestic product per capita	GDP	Constant 2015 US$	WDI
School enrolment secondary	SES	% gross	Government of Saudi Arabia
School enrolment primary	SEP	% gross	
School enrolment tertiary	SET	% gross	

Table 2: Descriptive statistics and correlation matrix

Variables	CO_2	GDP	SET	SES	SEP
Mean	2.687	9.962	2.637	0.892	1.410
Median	2.665	9.835	2.744	0.891	1.424
Maximum	2.980	10.538	4.198	1.164	1.516
Minimum	2.281	9.624	0.540	0.329	0.807
SD	0.179	0.285	0.933	0.236	0.095
Skewness	−0.261	1.006	−0.350	−0.684	−0.148
Kurtosis	2.312	2.480	2.457	2.618	3.474
Jarque-Bera	1.368	7.917	1.442	3.702	0.346
Probability	0.504	0.119	0.486	0.157	0.841
Observations	44	44	44	44	44
Pearson's correlation tests					
CO_2	1				
GDP	0.772	1			
SET	0.552	0.732	1		
SES	0.511	0.972	0.927	1	
SEP	0.284	0.621	−0.273	0.254	1

non-optimal predictions and invalid significance tests (Granger, 1969). A time series is stationary if its mean and variance do not vary with time, otherwise it is said to be non-stationary. Nelson and Plosser (1982) believe that most economic variables are non-stationary. This view is supported by Van Kampen (1955) who adds that series become stationary when they are differentiated once or more. The analysis of non-stationary time series has become an indispensable exercise in current econometric practice, in order to avoid the problems posed by the use of non-stationary variables. We used the tests of Dickey and Fuller Augmented (1979) and Phillips and Perron (1988). These tests take into account the possibility of autocorrelation of residuals in their construction. Traditionally, the Augmented Dickey-Fuller (ADF) (1979) and Phillips and Perron (1988) unit root tests are used to study the stationarity of time series. The first proposes to control the autocorrelation directly in the model by including one or more differentiated autoregressive terms. The second, the Phillips and Perron test, proposed a correction of the OLS estimators and the associated Student statistics.

The ADF and PP unit root tests have the ability to interpret the time series whether it is stationary or not. However, these tests do not identify unknown structural breaks in the series. The latter suffer from a problem of low power to reject the null hypothesis of series stationarity, especially for short period data. To address this shortcoming, we additionally implement the unit root test of Zivot and Andrews (1992). This test allows us to test the existence of a unit root given a structural break. This test is based on the null hypothesis of the presence of a unit root against the alternative hypothesis of stationarity with a single break at an unknown date.

4.2.2. The cointegration test approach

After determining the order of integration of the series, the next step is to detect the existence of cointegration relationships. If the variables are integrated in the same order, it is possible that there is an overall movement of the variables. Cointegration tests, which are considered an extension of stationarity tests, allow us to detect that the integrated variables of the same order have the same stochastic trend and therefore a cointegration relationship. The concept of cointegration can be defined as a systematic long-term co-movement between two or more economic variables (Yoo, 2006). Pesaran et al. (2001) suggested a cointegration approach testing the limits of an Autoregressive Distributed Lag (ARDL) model that can solve some of the problems arising from the Johansen and Juselius (1990) approach. This approach is applicable even if the series are I (0), I (1) or a combination of I (0) and I (1). Unlike the Johansen and Juselius (1990) cointegration test, the ARDL model shows both the short- and long-term relationship between the variables. Equation (1) is transformed as follows:

$$\Delta CO2_t = \sum_{j=1}^{p} \alpha_{1,j} \Delta CO2_{t-j} + \sum_{j=1}^{p} \alpha_{2,j} \Delta GDP_{t-j} + \sum_{j=1}^{p} \alpha_{3,j} \Delta GDP_{t-j}^2 + \sum_{j=1}^{p} \alpha_{4,j} \Delta Ed_{t-j}^i + \sum_{j=1}^{p} \alpha_{5,j} (\Delta Ed_{t-j}^i)^2 + \rho_1 CO2_{t-1} + \rho_2 GDP_{t-1} + \rho_3 GDP_{t-1}^2 + \rho_4 Ed_{t-1}^i + \rho_5 (Ed_{t-1}^i)^2 + \varepsilon_t \quad (2)$$

Where ε_t is an error term. The verification of the cointegration relationship is carried out using the "Bounds Test." This consists of conducting an F-test on the hypothesis $\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = 0$ against the alternative hypothesis $\rho_1 \neq \rho_2 \neq \rho_3 \neq \rho_4 \neq \rho_5 \neq 0$. The F-statistic, thus calculated, is compared to two critical thresholds: A lower band BI and an upper band BS, generated by Pesaran et al. (2001). If the F-statistic is below the lower band, the null hypothesis of non-cointegration is not rejected, whereas if the F-statistic is above the upper band, the null hypothesis is rejected, thus indicating the existence of a cointegrating relationship between the variables. On the other hand, if the F-statistic lies between the two bounds, the Bounds Test is said to be inconclusive. Once the Bounds Test has confirmed the cointegration between the variables, the long-term (equations [3]) and short-term (equations [4]) coefficients can be studied.

$$CO_{2t} = \sum_{j=1}^{p} \beta_{1,j} CO_{2t-j} + \sum_{j=1}^{p} \beta_{2,j} GDP_{t-j} + \sum_{j=1}^{p} \beta_{3,j} GDP_{t-j}^2 + \sum_{j=1}^{p} \beta_{4,j} Ed_{t-j}^i + \sum_{i=1}^{p} \beta_{5,j} (Ed_{t-j}^i)^2 + \eta_t \quad (3)$$

$$\Delta CO_{2t} = \sum_{j=1}^{q} \gamma_{1,j} \Delta CO_{2t-j} + \sum_{j=1}^{q} \gamma_{2,j} \Delta GDP_{t-j}$$
$$+\sum_{j=1}^{q} \gamma_{3,j} \Delta GDP^2_{t-j} + \sum_{j=1}^{q} \gamma_{4,j} \Delta Ed^i_{t-j} + \sum_{j=1}^{q} \gamma_{5,j} (\Delta Ed^i_{t-j})^2 + \vartheta_t \quad (4)$$

In addition, to confirm the long-term coefficient of the ARDL model, we used the FMOLS (Phillips and Hansen, 1990), DOLS (Stock and Watson, 1993), and CCR (Park, 1992) approach to improve the long-term ARDL model results.

4.3. Bayer-hanck Cointegration Test Approach

The drawback of this method is that it is not applicable if any of the variables are integrated of order two I (2) (Pesaran et al., 2001). To address this shortcoming, we used the combined cointegration test developed by Bayer and Hanck (2013) because of its superiority in generating reliable estimates by combining the results of different cointegration tests namely those of Engle and Granger (1987), Johansen (1991), Boswijk (1994) and Banerjee et al. (1998). In addition, it reports Fisher's F-statistics to determine the significance level of the coefficients. According to Abid and Alotaibi (2020), the formula is given below:

$$EG - JOH = -2\left[\ln(P_{EG}) + \ln(P_{JOH})\right] \quad (5)$$

$$EG - JOH - BO - BDM = -2\left[\ln(P_{EG}) + \ln(P_{JOH}) + \ln(P_{BO}) + \ln(P_{BDM})\right] \quad (6)$$

Where P_{EG}, P_{JOH}, P_{BO}, and P_{BDM} are the P-values of cointegration tests of Engle and Granger (1987); Johansen (1991); Boswijk (1995) and Banerjee et al. (1998) respectively.

4.4. Causality Analysis

When the results of the cointegration test support the absence of cointegration relationships between the variables, we estimate a VAR model and then recover the impulse response functions and the error variance decomposition. On the other hand, if cointegration tests confirm the presence of long-term relationships, the residuals from the long-term equilibrium equations are used to estimate the error correction models (VECM) in the third step. The VECM is a restriction of the VAR. It contains a cointegration term represented by an error correction term (ECT) and constrains the endogenous variables to converge to the cointegration relationships while allowing for dynamic short-term adjustments (Karim et al., 2012). Error correction implies that changes in endogenous variables are a function of the level of disequilibrium in the cointegration relationship it recovers. The error correction model is written as follows:

$$\Delta CO_{2t} = \sum_{j=1}^{p} \alpha_{1,j} \Delta CO_{2t-j} + \sum_{j=1}^{p} \alpha_{2,j} \Delta GDP_{t-j}$$
$$+\sum_{j=1}^{p} \alpha_{3,j} \Delta GDP^2_{t-j} + \sum_{j=1}^{p} \alpha_{4,j} \Delta Ed^i_{t-j}$$
$$+\sum_{j=1}^{p} \alpha_{5,j} (\Delta Ed^i_{t-j})^2 + \tau\, ECT_{CO2,t-1} + \varepsilon_t \quad (7)$$

Where Δ is the first difference operator, $j = (1,\ldots.p)$ is the optimal number of delays determined by the AIC information criteria. The ECT_{CO2t-1} term in each of the equations is the error correction term shifted by one period.

To test the short-term causal relationship, the Wald test technique (statistics) was used to capture the significance of the estimated coefficient using the variation of the stationary variables. To test the long-term causal relationship, we used the *t*-student test for the ECT_{CO2t-1} term.

5. EMPIRICAL RESULTS AND DISCUSSION

5.1. Unit Root Tests

The estimation of model (1) and the choice of the empirical method will be conditioned by the statistical properties of the series. We will thus proceed to unit root tests. We will consider successively the augmented Dickey-Fuller test (Dickey and Fuller 1979, ADF), the Phillips and Perron test (1988, PP) and the Zivot and Andrews test (1992, ZA), which takes into account the breaks in the series. In the latter test, the null hypothesis assumes that the series has a unit root with no breaks, while the alternative hypothesis assumes that the series is stationary with a single break at an unknown date.

Table 3 shows that all series (CO_2, GDP, SES) are stationary in first difference. On the other hand, the series (SET, SEP) are stationary in level and therefore none of them is integrated of order 2. Table 4 presents the Zivot and and rews unit root test. The results in this table are consistent with those of the ADF and PP unit root tests since the (CO_2, GDP, SES) series are I(1) and the (SET, SEP) series are I(0). Moreover, it is shown that data breaks occurred in 1990-1991 for GDP and CO_2 emissions; that is, during the Gulf War, which supports our choice to introduce the dummy variable. Education shows a structural break in 2016. This coincides with the date of the announcement of the Kingdom's Vision 2030 on

Table 3: Unit root test

Variables	Integrated order	ADF	PP	1
CO_2	Level	−2.343	−2.343	I (1)
	First difference	−6.614***	−6.650***	
GDP	Level	−2.502	−1.494	I (1)
	First difference	−3.957***	−5.437***	
SET	Level	−2.950**	−2.472**	I (0)
	First difference	-	-	
SES	Level	−1.167	−1.696	I (1)
	First difference	−3.100***	−5.044***	
SEP	Level	−6.353***	−6.353***--	I (0)
	First difference	-		

***, and ** denote the 1%, and 5% level of significance respectively

Table 4: Zivot and andrews tests

Variables	Level		1st difference		Decision
	T-stat	Break	T-Stat	Break	
CO_2	−3.957	1975	−7.053***	1990	I (1)
GDP	−3.820	1994	−7.301***	1991	I (1)
SET	−6.035***	2016	-	-	I (0)
SES	−3.268	2016	−6.955***	1981	I (1)
SEP	−7.172***	2016	-	-	I (0)

25 April 2016. Overall, the various unit root tests reveal that none of the variables is integrated of order 2 or above.

5.2. Cointegration Results

After having determined the order of integration of the different variables as well as the optimal lag of the selected model via the AIC criterion, the ARDL approach is used for cointegration in order to determine the long-term relationship between the variables. The "Bound Test" is used to calculate an F-statistic for the models (Table 5). This tests the null hypothesis that the coefficients of the lagged variables are zero. Table 5 proves the existence of a long-term cointegration relationship between the three variables. For example, the estimated F-statistic for the F_{CO2} (CO_2/GDP/SET) model is equal to 6.254 which is compared to the critical values below and above the significance level of 10%, 5% and 1%. The test statistic is above the upper bound (5.85, 4.89, and 3.76 respectively). For the second F_{CO2} (CO_2/GDP/SES) model, the estimated F-statistic value is equal to 5.814, which is above the critical upper bound values at 5%. For the third model of FCO_2 (CO_2/GDP/SEP), the estimated F-statistic value is 6.057 and it is above the critical values of the upper bound at 1%. Therefore, the null hypothesis of no cointegration is rejected and the existence of a long-term relationship between the variables is concluded for all three models. Thus, the Bayer and Hanck (2013) model also confirms this long-term relationship between the variables. Moreover, the CUSUM and CUSUM squared tests show that the estimated parameters are stable over the study period.

The stability of the environmental model in the ARDL model is examined using the CUSUM and $CUSUM_{sq}$ tests proposed by Brown et al., (1975). These tests are applied on the residuals of the model, the CUSUM test is based on the sum of the residuals. It represents the curve of the cumulative sum of the residuals together with 5% of the critical lines. Thus, the parameters of the model are unstable if the curve lies outside the critical zone between the two critical lines, and stable if the curve lies between the two critical lines. The same procedure is applied to perform the $CUSUM_{sq}$ test, which is based on the sum of the square of the residuals. The graphical representation of these two tests is applied to the selected model. The figures 1-3 show the representation of the curve of the sum of the residuals and the sum of the square of the residual between the critical lines indicating the stability of the model.

The long-term equilibrium relationships, which are estimated by the ARDL approach, are presented in Table 6. For all three models, the long-term elasticity of CO_2 emissions per capita with respect to GDP per capita (GDPP) is equal to (15.247, 13.048, 20.342) and is statistically significant, implying that a 1% increase in real GDP per capita would induce an increase of (15.24%, 13.04% and 20.342%) in CO_2 emissions per capita, respectively. The negative sign of the coefficient of the variable $GDPP^2$ - which is also statistically significant - supports the hypothesis that CO_2 emissions decline when the country in question reaches high income levels. This result supports the EKC hypothesis that the level of CO_2 emissions initially increases with income, then stabilizes before declining. Thus, we introduced the education variable (tertiary and higher) in the models (M1and M2), respectively. For models M1 and M2, the results show that the effect of the secondary and tertiary education variables on emission ($\frac{\partial CO_2}{\partial SES} = \beta_0 + 2\beta_1 SES_t$) and ($\frac{\partial CO_2}{\partial SET} = \beta_0 + 2\beta_1 SET_t$) respectively, follows an inverted U-shaped form as in the case of income. The cointegrating relationships that can be interpreted as the long-term effects of an increase or decrease in the growth rate of the variables considered represent the long-term elasticities. The estimated coefficients of these relationships are all statistically significant at the 1 and 5% level except for primary education.

Secondary and tertiary education have a negative and statistically significant effect. This means that increasing secondary education has pleasant environmental effects in terms of reducing CO_2 emissions. Education facilitates the development and adoption of new, more productive and cleaner technologies. It stimulates the creation of knowledge, innovation through its research and dissemination functions from research centers and institutions and promotes new ideas and knowledge. On the one hand, these institutions train many engineers and scientists and thus a pro-

Table 5: Results of the bounds and Combined test of cointegration

Estimated model	F_{CO2}(CO_2/GDP/ GDP^2/SET/SET^2)	F_{CO2}(CO_2/GDP/ GDP^2/SES/SES^2)	F_{SEP} (CO_2/GDP/ GDP^2/SEP/SEP^2)
ARDL bounds test for cointegration			
Optimal lag length (AIC)	(2,0,2,1,1)	(1,2,0,0,1)	(1,2,1,0,0)
F-statistics (bound test)	6.254***	5.814**	6.057***
Critical values	1%	5%	10%
Lower bounds I (0)	5.02	4.65	3.19
Upper bounds I (1)	5.85	4.89	3.76
R^2	0.58	0.56	0.59
Adj. R^2	0.34	0.36	0.31
F-statistics	8.541*	9.045*	10.087*
Bayer and Hanck (2013) combined cointegration			
Optimal lag	2	1	1
EG-JOH	15.514**	18.378**	13.547**
Fisher's (1932) critical values at 5% level of significance		12.854	
EG-JOH-BDM	44.650**	56.049**	60.687**
Fisher's (1932) critical values at 5% level of significance		23.668	

*** and ** represents significance at the 1%, 5% levels, respectively. The Akaike Information Criterion (AIC) is used to determine the optimal lag

Table 6: ARDL estimation

Regressor	Dependent variable CO_2		
	Model 1	Model 2	Model 3
Panel A: Long-run estimation			
GDP	15.247** (0.016)	13.048*** (0.000)	20.342** (0.038)
GDP^2	−1.125*** (0.001)	−0.629** (0.013)	−1.004** (0.038)
SET	0.028** (0.029)	-	-
SET^2	−0.210*** (0.000)	-	-
SES	-	0.297 (0.022)**	-
SES^2	-	−0.211*** (0.000)	-
SEP	-	-	6.035 (0.151)
SEP^2	-	-	2.672 (0.146)
D_{1990}	0.188*** (0.000)	0.504*** (0.000)	0.356*** (0.000)
Panel B: Short-run estimation			
ΔCO_2	0.482*** (0.002)	0.257** (0.028)	0.405*** (0.005)
ΔGDP	17.080*** (0.006)	12.589** (0.012)	15.088** (0.016)
ΔGDP^2	−0.869*** (0.005)	−0.281*** (0.000)	−0.272** (0.044)
ΔSET	2.557*** (0.001)	-	-
ΔSET^2	−0.315*** (0.008)	-	-
ΔSES	-	11.083*** (0.000)	-
ΔSES^2	-	−0.176*** (0.004)	-
ΔSEP	-	-	0.090 (0.181)
ΔSEP^2	-	-	0.272 (0.408)
ECT_{t-1}	−0.710*** (0.000)	−0.820*** (0.000)	−0.473 (0.220)
ΔD_{1990}	0.140*** (0.000)	0.202*** (0.000)	0.185 (0.220)
Panel C: Residual diagnostic tests			
R^2	0.674	0.857	0.773
F-stat	2.963	4.84	5.981
DW statistics	2.589	2.381	2.446
Serial correlation	1.235	1.325	1.105
Heteroskedasticity	1.288	1.345	1.279
Jarque–bera	2.804	2.664	2.771
Ramsey RESET test	0.266	0.283	0.304
CUSUM and SUSUM square	Stable	Stable	Stable

pollution research sector capable of developing environmental technologies. This negative relationship between secondary education and CO_2 emissions corroborates the conclusion of Balaguer and Cantavella (2018) who found that increasing education levels can reduce CO_2 emissions. In addition, Zafar et al. (2019) and Bano et al. (2018) also found negative effects of human capital on CO_2 emissions and ecological footprint respectively. In sum, it is retained that education (secondary and tertiary) is likely to significantly negatively influence environmental degradation. This suggests that Saudi Arabia has an interest in investing in the education of its people and improving the quality of its educational systems in order to promote economic growth and improve environmental quality.

In the relationship between education and CO_2 emissions, primary education has a non-significant impact on CO_2 emissions. These results are logical because primary education is a very early stage of human capital, and individuals or even groups at this level do not have sufficient knowledge, understanding or resources to act on the environment. Because of the lack of decision-making capacity, primary education alone cannot do enough to give someone exposure to their country's emissions and environmental portfolio. Thus, primary education does not play any of its positive or negative roles in the environmental profile in Saudi Arabia. This may be due to the fact that primary education and the age of students are not capable enough to convey the message of environmental awareness. The negative influence of education at the tertiary and secondary levels thus corroborates some of the results of empirical growth models that assert the importance of human capital accumulation not only on economic growth but also on environmental quality. However, the insignificance of the first education variable invites questions about the internal efficiency of first education in Saudi Arabia. Indeed, Mingat and Tan (1996) showed that in low-income countries, primary education is the best investment; in middle-income countries, it is increased investment in secondary education that is socially more profitable; and in high-income countries, university education has the highest return. Based on this analysis, the World Bank in 1996 urged many Asian countries to better allocate their resources among the different education sub-sectors, with an emphasis on the primary level. As a result, the government should revise the primary education curriculum to convey the message of a clean environment at this level.

In fact, the robustness of the model requires diagnostic tests of serial correlation (LM statistic), heteroscedasticity (Breusch-Pagan-Godfrey), normality of the residuals (Bera-Jarque statistic) and functional form (Ramsey RESET) at the 5% statistical level. Therefore, the residuals of the model can be described by a Gaussian white noise process. The short-term results are presented in Table 6 (Panel B).

As we can see, in addition to income, the importance of education variables is also confirmed in the short term. Moreover, the coefficient of the error term (ECTt-1) is negative and statistically significant at the 1% threshold, which confirms the relationship established in the long term between CO_2 per capita, income per capita and the education rate (higher and tertiary). This coefficient shows the speed of adjustment towards the long-term equilibrium after short-term shocks. Thus, according to the estimated coefficients, it can be stated that the deviations from the long-term equilibrium level of CO_2 emissions will be corrected by about 71% and 82% in the 1st year for tertiary and secondary education, respectively. This result is highly expected and especially necessary as the role of education in stimulating growth is confirmed. Our results are consistent with those of Romer (2000). Indeed, Romer's (2000) results showed that the role of education is not only to improve labor productivity but also to design new manufacturing processes and improve the ability to adopt new technologies, in order to stimulate economic growth and improve environmental quality.

5.3. Causality Results

To determine the direction of causality, we must examine the results of the VECM model. The sources of causality can be identified from the significance test of the independent variables coefficients in the VECM model. The results of the Granger causality test are presented in Table 7 below. The first column shows the effect of CO_2 emissions on other variables, the second column shows the effect of economic growth on other variables. The third, fourth and fifth columns show the impact of each type of education on other variables. Our results show that there is a unidirectional relationship from GDP to CO_2 emissions. This implies that an increase in GDP causes an increase in CO_2, but an increase in CO_2 does not necessarily cause an increase in GDP. Environmental policies, which aim at reducing CO_2 emissions, will therefore have no negative impact on economic growth. Our results also showed a unidirectional causality from GDP to education (higher and tertiary). The fact that growth causes tertiary and higher education indicates that improvements in GDP lead to increases in national wealth. This improvement in national wealth leads to more State investment in education, notably through the acquisition of teaching tools, the construction of school infrastructure and the granting of subsidies. These actions encourage people to send their children to school and motivate them to stay in school longer. This leads to an improvement of the education indicators in these levels of education.

Moreover, the results obtained in this study confirm the conclusions of Atala (2009) in the case of Cameroon, who states that economic growth has a positive effect on the level of education. Nevertheless, it also concludes that economic growth contributes more to secondary and higher education levels than primary education, which is not exactly the case in this study given the presence of the neutrality hypothesis obtained between economic growth and primary education. However, these results are in contradiction with those of Pritchett (2001). This author justifies his results with three arguments for sub-Saharan Africa. First, the institutional environment of these countries encourages people with access to education to engage in rent-seeking,

Table 7: Granger non-causality tests

Models	Short-run					Long-run	Joint test				
	ΔCO_{2t}	ΔGDP_t	ΔSET_t	ΔSES_t	ΔSEP_t	ECT_{t-1}	ΔCO_{2t}, *ECT*	ΔGDP_t, *ECT*	ΔSET_t, *ECT*	ΔSES_t, *ECT*	ΔSEP_t, *ECT*
	F-statistics					*T*-statistics	Joint *F*-statistics				
ΔCO_{2t}	–	8.021** (0. 022)	7.278** (0.44)	5.025*** (0.000)	9.045 (0.126)	−0. 032*** [−8.450]	–	5.678***	8.147***	6.543**	4.988***
ΔGDP_t	1.564 (0.305)	–	2.101 (0.148)	4.127 (0.146)	5.044 (0.153)	−0.258** [−4.750]	4.033***	–	2.689**	7.581***	5.589**
ΔSET_t	2.052 (0.132)	5.123** (0.041)	–	1.534 (0.202)	3.245** (0.047)	−0.483*** [−6.450]	5.146**	7.341***	–	4.867**	7.554***
ΔSES_t	3.488 (0.402)	6.497*** (0.000)	2.117 (0.410)	–	1.057 (0.412)	−0.056*** [−7.756]	4.188***	3.764**	9.021***	–	8.581***
ΔSEP_t	1.098 (0.602)	3.043 (0.127)	1.534 (0.236)	3.087** (0.030)	–	−0.053*** [−0.857]	6.071*	5.258***	4.134**	3.055**	–

Figures in brackets are Student test statistics, while those in parentheses are P-values. ***Coefficient significant at 1%, **Coefficient significant at 5%, and *Coefficient significant at10%. *ECT*-error correction term in the VEC model

Figure 1: Plots of CUSUM and $CUSUM_{sq}$ in the presence of SEP for the ARDL model

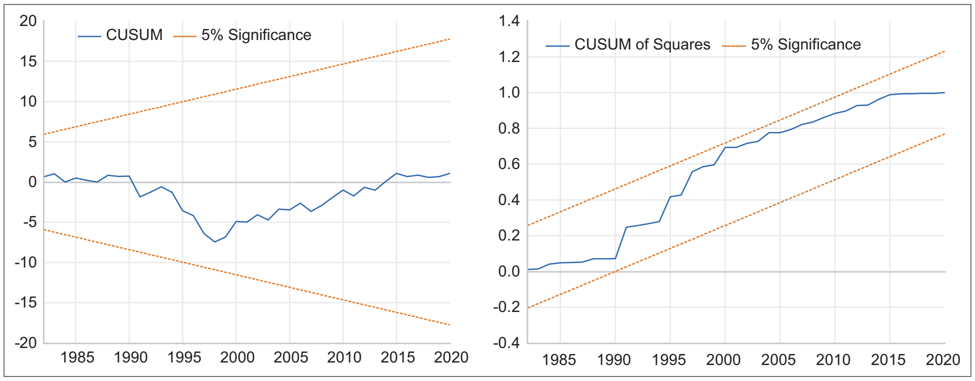


Figure 2: Plots of CUSUM and $CUSUM_{sq}$ in the presence of SES for the ARDL model

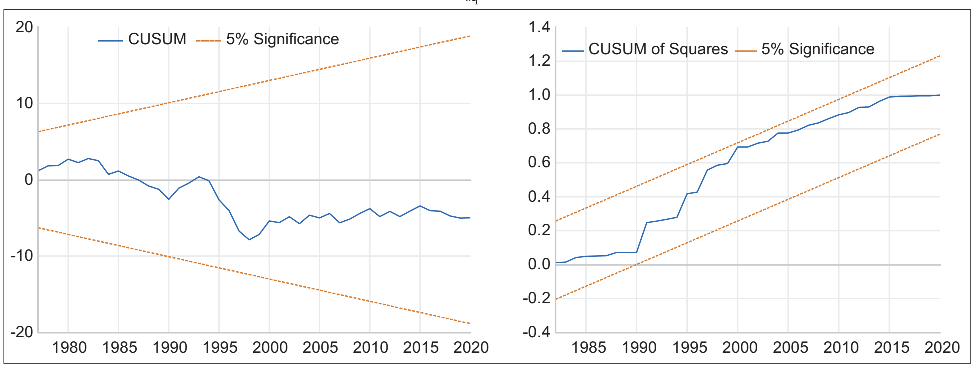
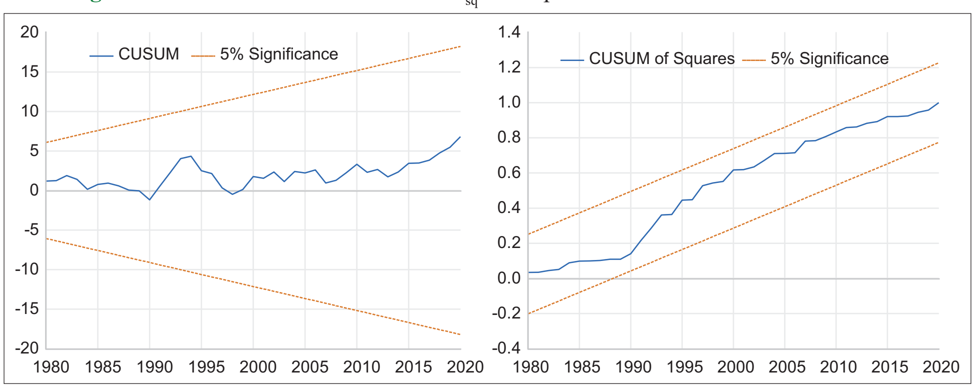


Figure 3: Plots of CUSUM and $CUSUM_{sq}$ in the presence of SET for the ARDL model



particularly through predatory behavior (e.g., corruption). Second, the marginal return on the number of years of education is decreasing due to the rapid increase in the labor supply of educated labor in the face of a stagnant and mainly public labor demand. Finally, he concludes that the quality of education is so low and inadequate to the region's needs that its effect on growth becomes marginal. Thus, our results also show a unidirectional causality from education level (tertiary and secondary education) to CO_2 emissions, except for primary education. The results obtained are consistent with those of Alkhateeb et al. (2020), who demonstrated for the case of Saudi Arabia that primary education cannot affect CO_2 emissions, but secondary education has a negative effect while energy consumption has a positive effect on CO_2 emissions.

In the long term, the error correction term is significant at the 1% level, i.e., the differences between the actual values and the long-term values will be corrected with the coefficients of the ECT in each period. So, the causality test shows that in the long term there is a bidirectional relationship between CO_2 emissions and economic growth and between CO_2 emissions and education, and also between GDP and education. These results confirm the conclusions of Balaguer and Cantavella (2018) for Australia, Zafar et al. (2019) for the United States, Ma et al. (2019) for 200 papers, and Bano et al. (2018) for 60 papers.

6. CONCLUSION AND POLICY IMPLICATIONS

The debate on the impact of education on CO_2 emissions in Asian countries is ongoing in the economic literature. Some studies assert the importance of education on CO_2 emissions in this part of the world while others are quite reluctant about the ability of education to negatively influence CO_2 emissions. In Saudi Arabia, this discrepancy is even more pronounced when considering the different levels of education with respect to the different impacts of each level of education on CO_2 emissions. It seems important to understand the strengths and weaknesses of the Saudi educational system in order to identify the basis for a new and ambitious policy. One of the issues at stake is to show how the education policy could be associated with the economic growth policy. In order to achieve this, it was necessary to rely on the fact that the world is now governed by the "knowledge economy," because although the expansion of primary education allows the schooling of the greatest number of individuals, it is still unable to provide the economy with human capital capable of capturing the international externalities of knowledge.

This paper considers that education might not only be an important factor in an inverted U-shaped relationship between income and environmental degradation, but it might also be a key factor that directly affects the environment. Our results suggest that the overriding question of whether economic growth implies an increase or a decrease in CO_2 emissions cannot be an easy one without considering the role of education. In addition, it is suggested that the effect of each level of education is not even identified if a linear relationship between the level of education and the level of pollution emissions is assumed. Excluding a quadratic education variable could lead to a substantial bias on the income coefficients. Therefore, we should be cautious before putting forward environmental policies based on the income turning point in a standard EKC model or even assuming a constant elasticity of emissions related to education. For this reason, this study aimed to investigate the relationship between education, economic growth and CO_2 emissions for the case of Saudi Arabia during the period 1971-2020. It was then also necessary to consider the levels of primary, secondary and higher education that can assume this role. To do so, the approach was to analyze the effect of each level of education on environmental quality, introducing them separately into an ARDL model and selecting some strategic variables with the most significant and relevant contributions. The results confirm the EKC hypothesis for both the GDP-CO_2 emissions and education (secondary and tertiary)-CO_2 emissions relationship for Saudi Arabia. Moreover, the effect of primary education is found to be insignificant, but an increase in secondary and tertiary education is useful for reducing CO_2 emissions.

For Saudi Arabia, investing much more in primary education will allow it to remain a commodity-based economy. On the other hand, the secondary and tertiary sectors of the economy will remain underdeveloped as their promotion depends on the development of secondary and higher education. In this case, the government will have to decide on capital-intensive production (Alkhateeb, 2020). Investing in secondary and higher education, on the other hand, will allow the country to transform its raw materials into finished products and will allow the education system to support the training of sufficient numbers of qualified teachers. In addition, investing in primary and secondary education should be a priority to raise not only the quality of the tertiary level of education but also to improve the quality of the environment. However, accompanying measures will have to follow these actions to ensure their effectiveness. This will include the fight against administrative inertia, corruption and poor governance. It will also be necessary to set up structures to monitor the projects initiated in the field of education. To overcome the problems of training-employment adequacy, the Saudi government will have to ensure the implementation of the recent reforms contained in the Vision 2030 which aim to cover the economy's skills needs, improve environmental quality, and strengthen the reception and infrastructure capacities. Saudi Arabia has certainly made efforts to invest in education and environmental protection, but it must work to improve the effectiveness of these investments and to establish conditions for optimal management of State resources in order to boost economic growth and thus promote social and environmental development.

Our results are important in terms of economic policies. First, they highlight the importance of human capital in protecting the environment. The current accumulation of knowledge and know-how is certainly a factor of economic growth but also of pollution growth. This does not imply recommending a rethinking of education policies whose intrinsic values are obvious. On the contrary, there is a need to introduce a change in the perception and role of education in favor of the environment. This is all the more important for developing countries (DCs) as the achievement of the Millennium Development Goals (MDGs) in education will be followed by environmental degradation. Secondly, there is a free rider phenomenon in some countries in the fight against global warming. Moreover, since investments are a key factor in economic growth and a determinant of pollution, the reduction of these effects will necessarily be accompanied by the implementation of ecologically clean investments. Finally, the divergence of pollution at the global level and in developing countries requires the transformation of the Kyoto Protocol, which should include technology transfer agreements and the promotion of cleaner investment and development.

However, this work requires further development. Indeed, using average years of schooling to measure the education of populations seems easy and straightforward, though tricky in practice. For example, although an increase in this indicator of education in a country may have a positive effect on economic growth, it may be at the expense of the quality of education received or provided. In such a situation, the relationship between growth and the number of years of education could be genuinely negative. Taking into account the quality of education and the institutional factors involved in the education system will allow future work to refute or confirm the conclusions reached in this paper.

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