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Impact of Renewable Energy and Education on G-20 Environmental Degradation

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Abstract

The efforts of the G-20 for sustainable development continue to be pursued in order to improve human welfare while reducing pressure on ecological resources. The ecological footprint is used as a more comprehensive measure that can see the pressure on the environment that comes from human activities. Using panel data from 19 G-20 countries from 1992 to 2018, this study aims to analyze the dynamic linkages of economic growth, use of renewable energy and level of education to the ecological footprint of the G20 countries. This study uses the PMG-ARDL analysis method to see the dynamic relationship between variables and makes it possible to see cointegration or long-term relationships. The estimation results show that in the long run an increase in per capita income will follow the EKC hypothesis. However, the educational attainment of the increase in the average length of schooling of the G-20 countries does not follow the EKC hypothesis and has not been able to directly reduce the ecological footprint. The higher the education level of a person can put higher pressure on the environment. However, education will indirectly make an increase in the level of income to be able to get to the turning point so that an increase in income can have the possibility of reducing pressure on the environment. This shows that the level of education can make the stability of environmental conditions return to a state of balance more quickly if there is a disturbance or shock to the condition of environmental balance.

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INTRODUCTION

The decline in environmental quality caused by anthropogenic activities poses a severe danger to the planet's biosphere. Economic development is necessary to fulfill community well-being, improve living circumstances, and develop human resources. However, economic development is accompanied by a decrease in the quality of durability and function of the environment (Çakar et al., 2021). Environmental stressors are frequently measured using CO2 emissions (Adekoya et al., 2021; Danish et al., 2018; Munir et al., 2020; Pao & Chen, 2019). However, the effect of human activity on environmental pressures is not just observed from the volume of CO2 gas emissions. Due to human needs for food, water, energy, and infrastructure, which also result in resource depletion, waste emissions, land use change, and pollution, environmental resources are under stress (Ahmed & Wang, 2019, and Rudolph & Figge, 2017). A more thorough metric, the Ecological Footprint, may be used to assess it.

The Ecological Footprint (EF), a term first developed by Wackernagel and Rees in 1996, is a measurement of how pressure on the environment is applied in a country to meet human needs and may be compared to other nations. To determine how human consumption affects the ecosystem, the ecological footprint is calculated based on six categories of resource use, including grazing land for livestock, the ability to absorb CO2, agricultural land for food and fiber needs, Fishing, forest use, and land for infrastructure development (Danish et al., 2019). The need for human consumption of resources and absorption of waste has exceeded the productive capacity of Planet Earth, and Humans have been in a state of ecological backwardness since 1970, and this has continuously led to a decline in environmental quality (Global Footprint Network, 2022)

Meanwhile, to achieve sustainable development, in addition to increasing human welfare and development, the environment must be preserved. This is in accordance with the SDG's agenda to improve human welfare while reducing pressure on ecological resources. This target is a focus for global policymakers, especially in the G-20 countries. Based on Global Footprint Network, (2022) G-20 countries are the largest contributors to the carbon footprint in the world. 11 of the G20 countries account for 67.6% of the total carbon footprint. Additionally, the G20 countries account for two-thirds of the global population, use more than 80% of the world's energy (using 95% coal and 70% oil and gas), and produce the most plastic waste globally (Kumari et al., 2021) Moreover, 85% of all investments in renewable energy globally are made by the G-20 nations (Goldthau, 2017). Fuel energy also has propelled these countries' economic development, and they are under continual pressure to reduce their environmental impact.

The G20's strong representation and dedication to a better environment could lead to worldwide accords to prevent environmental deterioration (Ansari et al., 2021). The development of renewable energy sources and energy-efficient technologies is another area where these countries are investing heavily to meet the objectives of the Kyoto Protocol from 2005 and the Paris Agreement from 2015. These accords mark significant turning points in the international climate change process because, for the first time, they establish a legally enforceable commitment from all G20 nations to take aggressive measures to mitigate climate change and prepare for its effects. Throughout Indonesia's 2022 G20 Presidency, discussions about the environment and energy also focused on ensuring energy access, advancing smart and sustainable energy technologies, and advancing energy financing. Therefore, it is crucial to recognize that efforts to advance the welfare and human development as well as the switch to clean energy, influence the G20 countries' ability to maintain a sustainable environment.

The previous study indicates that the Environmental Kuznets Curve (EKC) hypothesis is used to predict how economic expansion would affect the quality of the environment (Charfeddine & Mrabet, 2017; Li & Xu, 2021; Ulucak & Bilgili, 2018). According to the EKC theory, economic expansion increases environmental degradation, while further economic growth decreases it (Grossman & Krueger, 1991.). As a result, the EKC hypothesis proposes an association between environmental quality and economic growth that accounts for the inverted u-shape. Meanwhile, the pressure on ecological resources that leads to environmental degradation results from human activities undertaken to achieve wealth.

The G-20 countries continue to strive to improve the quality of human capital from education which can be evaluated from the mean years of schooling. In G-20, from 1992-2018, developed nations have attained a higher level of education on average, such as Germany, Canada, the United States of America, and the United Kingdom, all of which have reached 14 years on the average education level. Developing nations like India, Brazil, China, and Indonesia continue to have a shorter average time spent in school than developed nations. As an effort to increase human capital, Education is a factor that must be examined in the environmental effect since it influences human behavior, which in turn influences attitudes, especially for environmental management (Chankrajang & Muttarak, 2017). However, the few studies that have examined education have failed to discover consistent findings.

Some literature finds that good human capital through increased education level can create awareness and encourage individuals to protect their environment (Chankrajang & Muttarak, 2017; Debrah et al., 2021; Harring et al., 2020). Education is an entry point for information and knowledge regarding awareness of good environmental management and more efficient and environmentally friendly energy use (Osuntuyi & Lean, 2022). However, other literature shows that a higher education level can put higher pressure on the environment. Increased education can increase the consumption of technology with excessive use of energy and encourage more consumptive behavior that produces more pollutants (Balaguer & Cantavella, 2018) and (Zhang et al., 2021). Moreover, most research assumes that an increase in educational level will affect the environment in one direction (e.g., a constant elasticity of education). This research will examine the possible change in impact as the schooling level increases basing it on the idea that more education can produce two opposing effects on environmental degradation, as occurs in the EKC hypothesis.

In addition, the use of fossil energy in economic activities is a major factor in environmental quality degradation, especially in increasing carbon emissions which give a greenhouse effect and environmental pollution due to the exploration of this fossil energy. Fossil fuels such as oil, gas, and coal are by far the biggest contributor to global climate change by contributing 75 percent of global greenhouse gas emissions and nearly 90 percent of sources of carbon dioxide emissions (United Nation, 2022).

To avoid the worst effects of climate change, emissions need to be halved by 2030 and reach net zero by 2050, as stipulated in the 2015 Paris Agreement. It is necessary to end dependence on fossil fuels and start switching to energy-efficient, clean, accessible, affordable, sustainable, and reliable. This is a big agenda for the G20 countries, which have committed to reducing the use of fossil energy to switch to green energy use.

In order to achieve the objectives of the study, Pooled Mean Group-Autoregressive Distributed Lag (PMG-ARDL) analysis was employed by allowing intercepts, short-run coefficients, and cointegration coefficients to vary between nations, PMG-ARDL adapts the cointegrated version of a standard ARDL model for a panel configuration. This model integrates past period lags of the independent and dependent variables as variables. Moreover, adjustments from environmental conditions and the influence of external variables do not occur instantly, so they tend to show changes that occur in the long term. The cointegration link or long-term association between the variables of educational attainment, economic development, renewable energy consumption, and ecological footprint may be seen using the PMG-ARDL. The PMG-ARDL makes it possible to see cointegration or long-term relationships from education, economic growth, and the use of renewable energy to ecological footprint.

Therefore, this research will fill the gap from previous research by analyzing the dynamic relationship of income, the use of renewable energy, and the role of education levels on the ecological footprint by seeing whether there is a cointegration relationship in the long term and adjustments in the short term of each variable. This study aims to analyze the dynamic linkage between economic growth, education level, and the use of renewable energy on environmental degradation in G20 countries and determine whether economic growth and education level in the G-20 countries affect environmental degradation by following the EKC theory.

Based on the theory and previous research, we make the following hypothesis first, the relationship between economic growth and the ecological footprint follows the EKC hypothesis. Second, the relationship between economic growth and the Education follows the EKC hypothesis. Last, and increase in the use of renewable energy will reduce the ecological footprint.

RESEARCH METHODS

To answer the research objectives, this study will use panel data on 19 G20 countries in the period 1992 to 2018. The countries used as the unit of analysis are Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, England, and the United States. This study uses Ecological Footprint as the dependent variable and the 3 variables are GDP per capita, mean year schooling, and renewable energy control variables are trade openness and natural resource rent.

Ecological Footprint (EF) is consumption which is the total consumption of biocapacity of a country in Global Hectares (hectares standard with world average productivity) source Global Footprint Network, The following elements are those included in (Galli et al., 2012)'s definition of the ecological footprint components: (1) Agricultural land that produces food from vegetables and fiber; (2) Grazing land and agricultural land that produces food from animals and other animal products; (3) Fishing grounds (both marine and freshwater) for the production of fish-based foods; (4) Forestry for the production of wood and other forest products; (5) Carbon Sequestration Areas for the storage of Carbon Dioxide Emitted by Human Activities; and (6) Built-Up Areas Demonstrating Lost Productivity Due to the Use of Physical Space for Housing and Other Infrastructure.

Mean Year Schooling (MYS) or the average length of schooling is the average number of years of education completed by residents of a country aged 25 years and over from UNDP. Some data from World Bank are Data are GDP per capita (GDP) is the gross domestic product divided by midyear population in constant 2015 U.S. dollars; Renewable Energy Consumption (RE), the percentage from use energy renewable of total usage energy; Trade Openness (OP) Trade Openness, is the sum of exports and imports of goods and services measured as a share of gross domestic product.; and total natural resources rents (NR), which is the percentage of natural resources' contribution to GDP.

The EKC theory is applied under the assumption that environmental degradation can be described as a squared income function. It is possible to identify a turning point by applying the quadratic function. The purpose of this is to pinpoint any potential turning moments. Additionally, this study attempts to apply this methodology to see environmental deterioration as a quadratic function of the education variable as well, which is related to studies (Balaguer & Cantavella, 2018); (Maranzano et al., 2022).

With an emphasis on the EKC phenomena, the following is this study's fundamental model.

$$\ln EF_{it} = \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{it}^2 + \beta_3 \ln MYS_{it} + \beta_4 \ln MYS_{it}^2 + \delta X_{it} + \varepsilon_{it} \text{ ..... (1)}$$

Where $\ln EF_{it}$ is the natural logarithm of the Ecological Footprint, $\ln GDP_{it}$ is the natural logarithm of per capita income, $\ln MYS$ is the natural logarithm of MYS, X_{it} is another variable ε_{it} it is the error term. The EKC hypothesis is supported by $\beta_1 > 0,\ \beta_2 < 0$ so that it follows the inverted U form with a turning point.

$$\frac{\partial EF}{\partial GDP} = (\beta_1 + 2\beta_2 \ln GDP)\frac{EF}{GDP} \text{ .... (2)}$$

So equation 2 is the total effect of GDP on EF or we can write in elaticity form:

$$\frac{\partial lnEF}{\partial lnGDP} = (\beta_1 + 2\beta_2 \ln GDP) \text{ .... (3)}$$

When reach the turning point or maksimum point slope = 0.

$$0 = \beta_1 + 2\beta_2 \ln GDP \text{ .... (4)}$$

$$GDP\ at\ turning\ point = e^{-\frac{\beta_1}{2\beta_2}} \text{ .... (5)}$$

The same step we can get the total effect of MYS on EF:

$$\frac{\partial EF}{\partial MYS} = (\beta_1 + 2\beta_2 \ln MYS)\frac{EF}{MYS} \text{ .... (6)}$$

Or we can write in elaticity form:

$$\frac{\partial lnEF}{\partial lnMYS} = (\beta_1 + 2\beta_2 \ln MYS) \text{ .... (7)}$$

$$MYS\ at\ turning\ point = e^{-\frac{\beta_3}{2\beta_4}} \text{ .... (8)}$$

The procedure for the estimation of the time series panel data begins with important econometric processes in the analysis existence check level stationarity/integration from all variable related. We use Levin, Lin, Chu (LLC) and Breitung; and Im Pesaran and Shin (IPS) to check the panel unit root in the data. After that, this study test for the cointegration between the variables. When two variables are not stationary but their linear combinations are stationary, the cointegration test is used to determine whether there is a long-term relationship between them.

After that the Pedroni cointegration test employed in this study. An analysis of the first difference serves as the foundation for the Engle-Granger cointegration test. The residual must be I(0) or stationary at level if the variable is cointegrated. Pedroni method is used to test whether there is a long-term relationship between variables in the panel data. Pedroni proposed a test for cointegration that allows for heterogeneous intercepts and there is a trend coefficient in each cross section (Ekananda, 2016).

After test for the panel unit root and panel cointegration we can conclude that the condition to use PMG-ARDL was fulfilled. The Autoregressive Distributed Lag (ARDL) model is an OLS estimate that takes into account both the lag of the dependent and independent variables. Due to the bias brought on by the association between the difference in the regression mean and the error, the usual regression estimation of the ARDL model in panel data with individual effects is troublesome. Because of this, the Pooled Mean Group (PMG) estimator by Pesaran, Shin, and Smith is a well-liked substitute (Pesaran et al., 1999). The cointegration form of the straightforward ARDL model is modified for panel settings in this model by permitting various intercepts, short-run coefficients, and cointegration coefficients throughout the cross sections.

This study uses the Pooled Mean Group-Autoregressive Distributed Lag (PMG-ARDL) estimation method developed by (Pesaran et al., 1999). This method can avoid the problem of non-stationary data because this method accepts variables that have integration on I(1) and I(0) but cannot be used on variable I(2). This model is also a consistent and efficient estimation method because this method includes lags on the dependent and independent variables which will eliminate the endogeneity problem, namely there is a correlation between the independent variable and the error term in the model (Pesaran et al., 1999).

Where y is the dependent variable and X_lis the independent variable, where l is the number of variables, i is the individual and t is the variable time. ε_(1,ij)is an error term. For empirical the empirical model in this study is as follows:

$$\Delta \ln EF_{it} = \phi_i EC_{it} + \sum_{j=1}^{p-1} \lambda_{1j} \Delta \ln EF_{t-j} + \sum_{j=1}^{q-1} \theta_{ij} \Delta X'_{i,t-j} + \varepsilon_i \quad (9)$$

Where ΔX is the explanatory variabels vectors:

$$\Delta X = \begin{bmatrix} \Delta \ln GDP^2 \\ \Delta \ln GDP \\ \Delta \ln MYS^2 \\ \Delta \ln MYS \\ \Delta RE \\ \Delta NR \\ \Delta OP \end{bmatrix} \quad (10)$$

Based on equation 10, the error correction equation is expressed in:

$$EC_{it} = \sum_{j=1}^{p} \delta_{1j} \ln EF_{t-j} - \sum_{j=1}^{q} \beta_{ij} X'_{i,t-j} + \varepsilon_i \quad (11)$$

Where:

$$X = \begin{bmatrix} \ln GDP^2 \\ \ln GDP \\ \ln MYS^2 \\ \ln MYS \\ RE \\ NR \\ OP \end{bmatrix} \quad (12)$$

Where the symbol Δ denotes the first different operator, $i = 1,2,\dots,N$ and $t = 1,2,\dots,T$ displays the cross sectional and temporal dimensions. $\ln$ GDP is the natural logarithm of GDP, $\ln \text{GDP}^2$ denotes the squared form of $\ln$ GDP, $\ln$ MYS denotes the natural logarithm of Mean year of schooling, $\ln \text{MYS}^2$ denotes the quadratic form of ln MYS, RE shows Percentage of Renewable energy used, NR shows the Natural resource rent, and OP shows the trade openness. EC_{it} it is related to the coefficient ϕ_i which indicates a long-term relationship. The variable EC_{it} is formed by pooled mean group estimation in equation (1). The coefficient shows ϕ_i velocity of coefficient adjustment and must negative and significant by stats below range between 0 and -1. Selection of lag from variables in research this based on criteria best lag determination according to Akaike Information Criterion (AIC).

Finally, in order to perform a robustness test on the estimation results, Panel dynamic ordinary least squares (DOLS) would be performed to validate the PMG results against the model's suspected endogeneity and serial correlation issues. Panel DOLS is well-known for its ability to address model issues of endogeneity and serial correlation (Sulaiman & Abdul-Rahim, 2020).

RESULTS AND DISCUSSION

The summary statistics of the data for each variable considered in this investigation are shown in appendix 1. The average ecological footprint of G-20 nations is 4.56 global hectares, with a standard deviation of 2.24 global hectares. The United States, with a value of 9.283 Global Hectare, has the highest average EF level, while India has the lowest, at 0.940 Global Hectare.

On Average The G-20 nations have GDP per capita of US$ 21,470, with a standard deviation of US$ 16,553, which demonstrates the diversity in the income levels of the people in each nation. The USA, a developed nation and the country with the greatest average GDP per capita at 50,394,536 USD and the country with the lowest value is India at 1,048,249 as a developing country. The G-20 countries use 14.632 percent of renewable energy on average out of their total energy consumption, with a high standard deviation at 14.192 percent.

The country that utilizes the most renewable energy is Brazil, where they account for 45.246 percent of the total energy consumed on renewable energy Saudi Arabia uses the least renewable energy, with only 0.013 percent of the total energy consumed there coming from renewable sources. In the G-20 nations, the population aged 25 and above attends school for an average of 9.74 years, with a standard deviation of 2.96 years. The USA and Germany have the longest average schooling durations at 13 years, while India has the shortest average schooling durations at 4,667 years.

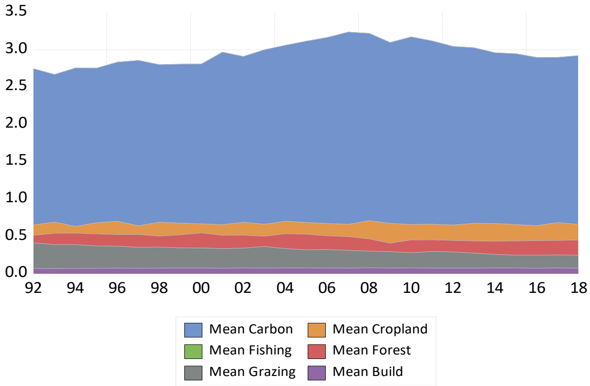

Figure 1. Ecological Footprint of G-20 Countries by Land Use 1992-2018.
Source: Data Processed, 2022

Figure 1 illustrates the breakdown of the ecological footprint that made up the average among the G-20 nations during the period of the research year. The ecological footprint of carbon is the largest contributor to the ecological footprint of the overall ecological footprint in the G-20 countries, followed by the ecological footprint from land use for agriculture, forest land use, livestock farming, infrastructure development, and the smallest is the ecological footprint of ocean use. This shows that the pressure on the environment that causes a decrease in environmental quality in the G-20 countries is largely contributed by the impact of human activities that produce pollution in the form of carbon emissions.

In addition, it is interesting to examine the scatterplot depicted in Figure 2 to determine if human activities aimed at creating prosperity, such as increasing income, human capital through education, and efforts to transition to renewable energy, have an effect on the ecological footprint. As observed in Figure 3, the pattern indicates that in countries with low levels of income, an increase in GDP per capita continues to raise the ecological footprint, indicating that environmental pressure is increasing. However, it appears that countries with a higher level of prosperity have been able to lower their ecological footprint due to the pattern of rising GDP per capita. This shows that the association between income levels and environmental deterioration in the G-20 countries may follow a pattern similar to the EKC hypothesis.

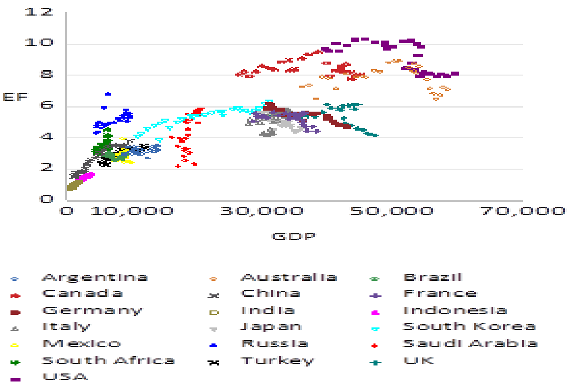

Figure 1. Scatter plot between ecological footprint and GDP Percapita
Source: Data Processed, 2022

The scatter Figure 3 depicts the association pattern between the ecological footprint and the mean year of schooling. The majority of countries with higher results for years of schooling are still increasing their ecological footprint.

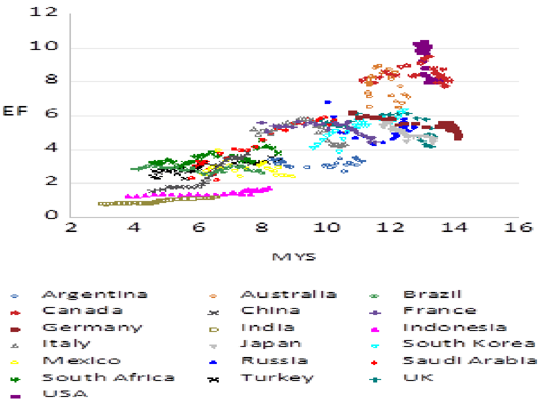

Figure 3. Scatter plot between ecological footprint and mean year of schooling
Source: Data Processed, 2022

Nevertheless, the ecological footprint has decreased in a number of nations with a higher mean number of years in education. It is therefore required to do more empirical study of the occurrence of the EKC hypothesis, which will be described in detail in the following section. The association pattern between the ecological footprint and the utilization of renewable energy can be seen in the scatter plot. It is apparent that the majority of nations with more use of renewable energy would minimize their ecological footprint.

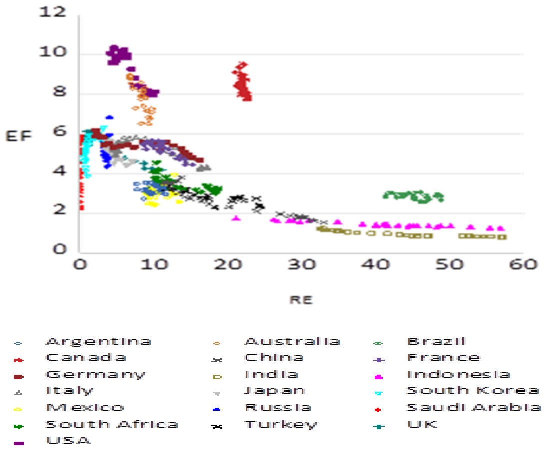

Figure 4. Scatter plot between ecological footprint and renewable energy consumption
Source: Data Processed,2022

Before analyzing the estimation approach further, a stationarity test is used. This study, utilizing the Im, Pesaran, and Shin W-stat and ADF-Fisher Chi Square stationarity tests. In unit root testing at the level, it can be seen from table 1, that all variables are not stationary except for the NR Natural Resource Rent which are already significant at the level in both tests. Meanwhile, at the first difference level, all variables have been declared stationary at a significance level of 1%. The results of the unit root test show that all variables are not stationary at the level but at the first different level they are stationary so that they have the possibility of being integrated with the first order. Thus, an adequate modeling estimation technique is the PMG-ARDL approach that supports the unit root test.

Table.1 Panel Unit Root Test

	Im, Pesaran and Shin W-stat		ADF - Fisher Chi-square	
	Level	**Δ**	**Level**	**Δ**
LNEF	2,8082	-11,7889 ***	22,4793	204,610***
LNGDP	1,1846	-8,3053***	35,0308	141,439***
LNMYS	0,1559	-3,1043***	53,7072**	67,7379***
RE	4,3463	-10,5787***	21,2591	187,679***
NR	-1,49507*	-13,9143***	44,9950*	242,615***
TO	-0,97288	-11,9062***	0,4412	205,890***

Note: *** Represents 1% statistical rejection level; ** Represents 5% statistical rejection level; * Represents 10% statistical rejection level
Source: Data Processed, 2022

Cointegration test is then used in this study to see whether there is a similar shift toward examining the link between variables over time. Continue the cointegration test to determine if the variables have a unit root but are integrated in the same order. The null hypothesis was presumed to be rejected by the test of the model's variables if there was a deterministic trend component at the data level, indicating cointegration between the variables in the equation.

Table 2. Pedroni cointegration test

Alternative hypothesis: common AR coefs, (within-dimension)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	1,1278	0,1297	-1,1908	0,8831
Panel rho-Statistic	-0,4171	0,3383	1,3458	0,9108
Panel PP-Statistic	-5,851	0,0000	-4,5987	0,0000
Panel ADF-Statistic	-5,3341	0,0000	-5,9291	0,0000

Alternative hypothesis: individual AR coefs, (between-dimension)		
	Statistic	Prob.
Group rho-Statistic	2,247164	0,9877
Group	-5,566835	0,0000

PP-Statistic		
Group ADF-Statistic	-6,244872	0,0000

Source: Data Processed, 2022

Seven statistics are used in the pedroni approach technique development to test the null hypothesis. Panel statistics (within dimension) and individual Statistics make up the seven statistics that test the null hypothesis (between dimensions). While between-dimension tests rely on the unique autoregressive coefficients of each panel member country, within-dimension tests compute the common autoregressive coefficient. Table 2 shows that at 1% significance level, three out of seven within-dimensions statistics reject the null hypothesis (no cointegration). Since the majority of the test results reject the null hypothesis, cointegration or a long-term link between the variables is evident.

After fulfilling the prerequisite (equilibrium relationship between the variables) of the model estimate approach, this study examined the magnitude of cointegration in terms of coefficients. An analysis of the short-long dynamics between the dependent variable and its explanatory variables was conducted using a panel PMG-ARDL. By using the criteria to get the best selection model the best lag is PMG-ARDL (2, 2, 2, 2, 2, 2, 2, 2). That all lags used are lag 2 with the smallest AIC. Table 3 column (2) shows that in the long run the effect of GDP per capita on the ecological footprint is statistically significant following the quadratic form. With the coefficient on GDP 〖 (β ̂〗 _1) which is positive and the coefficient on GDP2 (β ̂_2) which is negative, it shows the shape of an inverted parabolic curve or an inverted U shape. This shows that the EKC hypothesis occurs in G-20 countries. In accordance with the EKC theory that initially along with the increase in income, there was a trend pattern of increasing ecological footprint which indicated an increase in pressure on the environment. The composition effect happens when the economy transitions from a resource-intensive economy to a technology-intensive economy focused on services and knowledge as a result of the growing demand for greater environmental quality.

Furthermore, the technical effect occurs as technology advances where old technology is replaced by cleaner technology will reverse the production process from being polluted to cleaner. In the G20 countries, then as the economy grows further, the demand for better environmental quality increases, changing the economic structure from a resource-intensive economy to a technology-intensive economy based on services and knowledge. Henceforth, technical effects occur as technology advances where old technology is replaced by cleaner technology which will reverse the production process from becoming polluted to become cleaner. The relationship between income levels and environmental degradation according to the EKC hypothesis is in accordance with research conducted by (Charfeddine & Mrabet, 2017; Danish et al., 2019; Ulucak & Bilgili, 2018).

Then there is a turning point, with the assumption of ceteris paribus, at the per capita income level:

$$(\widehat{GDP}^{*}) = \exp\left(-{}^{\beta_1}/_{2\beta_2}\right)$$
$$= \exp\left(-{}^{0{,}9506}/_{2*(-0{,}0427)}\right)$$
$$= 68.175{,}3712\ USD \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

It is predicted that in G-20 nations, once per capita income reaches a level of USD 68.175,3712 USD the EKC curve will turn, and countries with incomes above that level will be able to reduce environmental pressure.

Table 3. Result of PMG-ARDL Estimation

Variable	Extended Model		Restricted Model	
	Coefficient	**SE**	**Coefficient**	**SE**
(1)	**(2)**	**(3)**	**(4)**	**(5)**

		Long Run Equation		
$\ln GDP$	0,9506***	0,2696	-3,4981***	0,5747
$\ln GDP^2$	-0,0427***	0,0151	0,2108***	0,0326
$\ln MYS$	-1,3414***	0,1493	-	-
$\ln MYS^2$	0,3853***	0,0487	-	-
RE	-0,0178***	0,0016	-0,0221***	0,0012
NR	0,0095***	0,0020	0,0043***	0,0010
TO	-0,0013***	0,0003	0,0009**	0,0005
		Short Run Equation		
ECT_{t-1}	-0,4409**	0,1810	-0,2615***	0,0914
$D\ln EF_{t-1}$	-0,0663	0,1233	-0,1274	0,0819
$D\ln GDP$	27,9238	26,0258	37,4908	24,2230
$D\ln GDP_{t-1}$	20,5061	34,3572	-15,2773	11,9531
Variable	**Extended Model**		**Restricted Model**	
	Coefficient	**SE**	**Coefficient**	**SE**
(1)	**(2)**	**(3)**	**(4)**	**(5)**
$D\ln GDP^2$	-1,3643	1,3205	-1,8479	1,2365
$D\ln {GDP^2}_{t-1}$	-1,2018	1,7204	0,6695	0,6148
$D\ln MYS$	-141,7286	179,2922	-	-
$D\ln MYS_{t-1}$	27,5362	146,4232	-	-
$D\ln MYS^2$	25,2980	34,8135	-	-
$D\ln {MYS^2}_{t-1}$	-3,3611	28,4013	-	-
DRE	0,4709	0,3646	0,4916	0,1203
DRE_{t-1}	0,0979	0,4437	0,0078	0,0210
DNR	0,2399	0,4576	-0,0324	0,4950
DNR_{t-1}	0,4946	0,0862	0,0318	0,0156
DTO	0,0003	0,0011	-0,0007	0,0010
DTO_{t-1}	-0,0006	0,0013	-0,0003	0,0010
C	-0,9705**	0,3810	4,1171***	1,4500
S,E, of regression	0,0030		0,0510	
Sum squared resid	0,0491		0,6789	
Log likelihood	1265,358		1125,9590	
AIC	-3,6466		-3,4072	

Note: *** Represents 1% statistical rejection level; ** Represents 5% statistical rejection level; * Represents 10% statistical rejection level

Source: Data Processed, 2022

of income from ecological footprint as shown in equation (3.8) the total effect is expressed in $\frac{\partial lnEF}{\partial lnGDP} = (\beta_1 + 2\beta_2 \ln GDP)$. The average per capita income in the G-20 countries in 2018 is USD 25.534.4884 so we can simulate that, assuming ceteris paribus, every 1 percent increase in per capita GDP will increase the ecological footprint by 0.084 percent. The average income of the G-20 countries is still below the turning point so that at this income level an increase in GDP still increases the ecological footprint.

Next, we will be continuing to examine the impact of mean-year schooling level on the environment. Based on table 3 column (2), In the long run, the effect of education level on ecological footprint is the coefficient of the quadratic variable (β_4) is positive and the coefficient of the non-quadratic variable (β_3)is negative and both are significant with a significance level of 1% in the model. This shows that the EKC hypothesis does not apply to the relationship between educational level and ecological footprint in the G-20 countries. This coefficient means that an increase in the average length of schooling in G-20 countries has not been able to reduce the ecological footprint or pressure on the environment.

Furthermore, it is interesting to see the total effect of length of schooling on the ecological footprint as shown in equation (3.15) the total effect is expressed in ∂lnEF/∂lnMYS =(β_3+2β_4 ln⁡MYS), the G-20 average of mean year schooling in 2018 is 10,8134 year, so we can simulate that, assuming ceteris paribus, then every 1 percent increase in the average length of schooling will increase the ecological footprint by 0.4932 percent. The higher the value of the mean years of schooling still increases the ecological footprint. The longer schooling turns out to be unable to raise awareness of better environmental management. Longer schooling is ineffective at promoting an appreciation for better environmental management.

Consequently, the lengthening of schooling still increases the ecological footprint. This is consistent with previous research by (Hill & Magnani, 2002.; and Sarwar et al., 2021) which demonstrated that higher education as measures of human resource quality is not significantly effective in preventing environmental degradation. Education level can actually increase environmental stress by increasing consumption of technology with excessive energy use and by encouraging more polluting consumption behaviors.

In the long term, increasing the use of renewable energy is significant in reducing environmental degradation in the G-20 countries. In the long term, an increase of 1 percent in the proportion of renewable energy use from total energy use will reduce the ecological footprint by 0.0178 percent. This demonstrates that the G-20 countries' efforts to transition to renewable energy sources have delivered major environmental benefits. the higher the use of renewable energy which is cleaner and more ecologically friendly, it would further reduce environmental deterioration. This finding is in line with research by (Alola et al., 2019) and (Chankrajang & Muttarak, 2017) that to reduce this increasing ecological footprint is only possible by adopting or increasing consumption of clean energy and these countries must reduce their dependence on traditional energy use.

In the control variable used, natural resource rent also has a significant effect on increasing the ecological footprint. An increase of 1 percent in the proportion of natural resource utilization to total GDP will increase the ecological footprint by 0 .0095 percent. Where more and more exploration of natural resources will increase pressure on the environment which causes degradation of the environment. This is consistent with previous research (Aladejare, 2022; and Majeed et al., 2021) that, as economic agents continue to strive for better economic growth and development, more pressure is placed on the energy demand, which further encourages additional investments in further exploitation of natural resources, when this occurs, environmental degradation is exacerbated.

Meanwhile, when compared with the restricted equation (column 4), which does not take into account the effect of length of education, the relationship between per capita income and environmental degradation has a coefficient in the opposite direction to the extended model. With the coefficient on GDP 〖 $(\hat{\beta}_1)$ which is negative and the coefficient GDP2 $(\hat{\beta}_2)$ which is positive on the restricted model, the relationship between ecological footprint and per capita income does not follow the EKC hypothesis. This shows that without considering the effect of the level of education, an increase in income will continue to increase environmental degradation. Here it can be seen that education has an influence on increasing income to be able to get to the turning point so that increasing income can have the possibility of reducing pressure on the environment. According to (Hill & Magnani, 2002) that, in the long term, growth by itself will not solve most of the environmental problems. The relationship between environmental degradation and income is unstable between countries, time or pollutants caused by omitted variables by eliminating the influence of others variable such as educational level in the relationship between income level and environmental degradation.

The renewable energy and natural resource rent variables influence in the same direction in both models but trade openness in the restricted equation has not been able to reduce environmental degradation because of the Trade openness Pollution Halo Hypothesis which states that trade can reduce global environmental degradation through investment that efficient and environmentally friendly carried out by multinational companies around the world so that there is an exchange of information and knowledge between countries so that educational variables need to be considered in the model.

In the short-term equation, all variables in the previous 2-year lag period have no significant effect on the ecological footprint. this shows that these variables can only have an effect in the long run. However, there is a significant cointegration form of the relationship between these variables as indicated by the coefficient error correction (ECTt-1). The ECT value is -0.4409 and is significant at the 1% level. Indicating that when there is shock in environment conditions, in the short run per capita GDP growth, renewable energy consumption growth, average school year growth, natural resource rent growth, and total population growth have contributed to correcting the results deviation every year of about 44.09% to get to the balance again. When compared to the restricted model, which has a smaller error correction coefficient of -0.2615, it shows that without the old education variable entering the model, the tendency of these variables to cointegrate towards balance will be longer. This shows that education can make the stability of environmental conditions return to a state of balance more quickly if there is a disturbance or shock to the condition of environmental balance.

Lastly, in order to perform a robustness test on the estimation results, estimation with Panel Dynamic Ordinary Least Squares (DOLS) is also carried out. This study estimated the same model using panel DOLS with one leading and one lagging as a robustness test to dispel any doubts regarding the perceived endogeneity problem connected with the long-run PMG estimates. Panel DOLS is renowned for its capacity to address endogeneity and serial correlation issues (Sulaiman & Abdul-Rahim, 2020).

Thus, the results of panel DOLS would serve not only as a robustness test, but also as a diagnostic test for the long-run PMG-ARDL model against endogeneity bias and serial correlation. The panel DOLS results are shown in the second section of Table 6. According to the results, all variables included in the model were correctly signed. This conclusion supports better and verifies the outcome derived from PMG's long-term estimates.

Table 4. Robustness Check

	PMG-ARDL Long Run Model		**Panel DOLS**	
Variable	Coefficient	SE	Coefficient	SE
$\ln GDP$	0.9506***	0.2696	1.1568***	0.3098
$\ln GDP^2$	-0.0427***	0.0151	-0.0461**	0.0178
$\ln MYS$	-1.3414***	0.1493	-5.2625***	1.3799
$\ln MYS^2$	0.3853***	0.0487	1.2589***	0.3336
RE	-0.0178***	0.0016	-0.0105***	0.0029
NR	0.0095***	0.0020	0.0082	0.0059
TO	-0.0013***	0.0003	-0.0002	0.0014
S.E. of regression	0.0491		0.0698	
Sum squared resid	0.4419		0.2439	

Note: *** Represents 1% statistical rejection level; ** Represents 5% statistical rejection level; * Represents 10% statistical rejection level

Source: Data Processed, 2022

CONCLUSION

This study intends to examine the dynamic relationships between economic growth, the usage of renewable energy, and educational attainment on the ecological footprint of the G20 countries. The estimation outcomes demonstrate that the EKC hypothesis will be followed by an increase in per capita income over the long term. The ecological footprint will initially increase with an increase in income, but after reaching the maximum income level, the ecological footprint will continue to decline.

The Increase in the average length of schooling in G-20 countries has not been able to reduce the ecological footprint or pressure on the environment. The higher the level of education still can actually put a higher pressure on the environment, the increase in education can increase a more consumptive behavior towards ecological resources. Increased consumption of these ecological resources will continue to exceed the biocapacity of the planet earth so that it will continue to reduce environmental quality. Meanwhile, the use of renewable energy in the G-20 countries has significantly reduced the ecological footprint.

Another finding from this study is that although education has not been able to reduce environmental degradation, education will indirectly increase income levels to reach a turning point so that increased income has the possibility of reducing pressure on the environment. without the old variable, education is included in the model, the tendency of these variables to cointegrate towards a balance of longer duration. This shows that the level of education can make the stability of environmental conditions return to a state of balance more quickly if there is a disturbance or shock to the condition of environmental balance.

Since education has not been able to have a direct effect on reducing environmental degradation. Therefore, the G-20 forum needs to carefully adopt a policy of increasing the role of environmental awareness in reducing problems related to degradation through educational institutions. There needs to be a policy to encourage behavior change between individuals that must be included in the school curriculum from elementary education to higher education, education improvements will be accompanied by increased awareness of better environmental management.

The use of renewable energy significantly reduces the ecological footprint. This shows that the efforts of the G-20 countries in transitioning to clean energy have started to show noticeable results by reducing environmental degradation. So that the G-20 countries must remain highly committed to transition policies to clean energy by lowering the usage of clean energy and exploring transitions to technologies that are more ecologically friendly. So that with an expansion in human resources that raises the need for the use of technology will be supported by a policy of giving and enabling access to technologies that are more ecologically friendly.

REFERENCES

Ahmed, Z., & Wang, Z. (2019). Investigating the impact of human capital on the ecological footprint in India: An empirical analysis. *Environmental Science and Pollution Research*, *26*(26), 26782–26796. https://doi.org/10.1007/s11356-019-05911-7

Aladejare, S. A. (2022). Natural resource rents, globalisation and environmental degradation: New insight from 5 richest African economies. *Resources Policy*, *78*. https://doi.org/10.1016/j.resourpol.2022.102909

Alola, A. A., Bekun, F. V., & Sarkodie, S. A. (2019). Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe. *Science of the Total Environment*, *685*, 702–709. https://doi.org/10.1016/j.scitotenv.2019.05.139

Ansari, M. A., Haider, S., & Masood, T. (2021). Do renewable energy and globalization enhance ecological footprint: an analysis of top renewable energy countries? *Environmental Science and Pollution Research*, *28*(6), 6719–6732. https://doi.org/10.1007/s11356-020-10786-0

Balaguer, J., & Cantavella, M. (2018). The role of education in the Environmental Kuznets Curve. Evidence from Australian data. *Energy Economics*, *70*, 289–296. https://doi.org/10.1016/j.eneco.2018.01.021

Çakar, N. D., Gedikli, A., Erdoğan, S., & Yıldırım, D. Ç. (2021). Exploring the nexus between human capital and environmental degradation: The case of EU countries. *Journal of Environmental Management*, *295*. https://doi.org/10.1016/ j.jenvman.2021.113057

Chankrajang, T., & Muttarak, R. (2017). Green Returns to Education: Does Schooling Contribute to Pro-Environmental Behaviours? Evidence from Thailand. *Ecological Economics*, *131*, 434–448. https://doi.org/10.1016 /j.ecolecon.2016.09.015

Charfeddine, L., & Mrabet, Z. (2017). The impact of economic development and social-political factors on ecological footprint: A panel data analysis for 15 MENA countries. In *Renewable and Sustainable Energy Reviews* (Vol. 76, pp. 138–154). Elsevier Ltd. https://doi.org/ 10.1016/j.rser.2017.03.031

Danish, Baloch, M. A., & Wang, B. (2019). Analyzing the role of governance in CO2 emissions mitigation: The BRICS experience. *Structural Change and Economic Dynamics*, *51*, 119–125. https://doi.org/10.1016/j.strueco.2019.08.00

Debrah, J. K., Vidal, D. G., & Dinis, M. A. P. (2021). Raising awareness on solid waste management through formal education for sustainability: A developing countries evidence review. *Recycling*, *6*(1), 1–21. https://doi.org/10.3390 /recycling6010006

Ekananda, M. (2016). *Analisis Data Time Series untuk ekonomi dan Bisnis, 2nd Edition* (1st ed., Vol. 1). Mitra Wacana Media.

Galli, A., Kitzes, J., Niccolucci, V., Wackernagel, M., Wada, Y., & Marchettini, N. (2012). Assessing the global environmental consequences of economic growth through the Ecological Footprint: A focus on China and India. *Ecological Indicators*, *17*, 99–107. https://doi. org/10.1016/j.ecolind.2011.04.02

Global Footprint Network. (2022). *Climate Change*. https://www.footprintnetwork.org/our-work/climate-change/

Goldthau, A. (2017). The G20 must govern the shift to low-carbon energy. *Nature*, *546*(7657), 203–205. https://doi.org/10.1038/546203a

Grossman, G. M., & Krueger, A. B. (n.d.). *Economic Growth And The Environment**. https://academic.oup.com/qje/article/110/2 /353/1826336

Harring, N., Jagers, S. C., & Matti, S. (2020). Higher education, norm development, and environmental protection. *Higher Education*, *79*(2), 291–305. https://doi.org/10.1007/ s10734-019-00410-7

Hill, R. J., & Magnani, E. (n.d.). *An Exploration Of The Conceptual And Empirical Basis Of The Environmental Kuznets Curve*.

Kumari, N., Kumar, P., & Chandra Sahu, N. (n.d.). *Do energy consumption and environmental quality enhance subjective wellbeing in G20 countries?* https://doi.org/10.1007/s11356-021-14965-5/Published

Li, X., & Xu, L. (2021). Human development associated with environmental quality in China. *PLoS ONE*, *16*(2 February). https://doi.org/10.1371/journal.pone.024667 7

Majeed, A., Wang, L., Zhang, X., Muniba, & Kirikkaleli, D. (2021). Modeling the dynamic links among natural resources, economic globalization, disaggregated energy consumption, and environmental quality: Fresh evidence from GCC economies. *Resources Policy*, *73*. https://doi.org/10.1016/ j.resourpol.2021.102204

Maranzano, P., Bento, J. P. C., & Manera, M. (2022). The Role of Education and Income Inequality on Environmental Quality: A Panel Data Analysis of the EKC Hypothesis on OECD Countries. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031622

Osuntuyi, B. V., & Lean, H. H. (2022). Economic growth, energy consumption and environmental degradation nexus in heterogeneous countries: does education matter? *Environmental Sciences Europe*, *34*(1). https://doi.org/10.1186/s12302-022-00624-0

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association*, *94*(446), 621–634. https://doi.org/10.1080/01621459.10474156

Rudolph, A., & Figge, L. (2017). Determinants of Ecological Footprints: What is the role of globalization? *Ecological Indicators*, *81*, 348–361. https://doi.org/10.1016/j.ecolind.2017.

Sarwar, A., Khan, M. A., Sarwar, Z., & Khan, W. (2021). Financial development, human capital and its impact on economic growth of emerging countries. *Asian Journal of Economics and Banking*, *5*(1), 86–100. https://doi.org/10.1108/ajeb-06-2020-0015

Sulaiman, C., & Abdul-Rahim, A. S. (2020). The impact of wood fuel energy on economic growth in Sub-Saharan Africa: Dynamic macro-panel approach. *Sustainability (Switzerland)*, *12*(8). https://doi.org/ 10.3390/SU12083280

Ulucak, R., & Bilgili, F. (2018). A reinvestigation of EKC model by ecological footprint measurement for high, middle and low income countries. *Journal of Cleaner Production*, *188*, 144–157. https://doi.org/10.1016/ j.jclepro.2018.03.191

United Nation. (2022). *Renewable energy – powering a safer future*.

Zhang, L., Godil, D. I., Bibi, M., Khan, M. K., Sarwat, S., & Anser, M. K. (2021). Caring for the environment: How human capital, natural resources, and economic growth interact with environmental degradation in Pakistan? A dynamic ARDL approach. *Science of the Total Environment*, *774*. https://doi.org/10.1016/ j.scitotenv.2021.145553.

APPENDIX 1. Descriptive Statistics

Country	Statistics	EF	MYS	GDP	RE	NR	TO
Argentina	Mean	3,1930	9,7900	11794,9700	9,8090	2,8270	29,0914
	Std Deviasi	0,2120	1,0350	1681,8420	1,0920	1,7610	8,7308
Australia	Mean	7,7980	11,7220	48920,6260	8,2540	4,0590	40,3957
	Std Deviasi	0,7380	0,4290	7003,1080	0,9590	2,1170	2,8449
Brazil	Mean	2,8260	6,0570	7598,8230	45,2460	2,7300	23,4784
	Std Deviasi	0,1440	1,2470	1048,5280	2,1520	1,0830	4,1385
Canada	Mean	8,4350	12,8610	37166,7900	21,9170	2,5780	67,7662
	Std Deviasi	0,4460	0,8620	5996,2290	0,3690	1,0920	7,0806
China	Mean	2,5500	6,2170	4264,4830	20,8040	3,6060	43,4424
	Std Deviasi	0,7870	0,8580	2688,4890	8,3670	2,1450	10,9750
France	Mean	5,2250	10,0450	34134,5320	10,9690	0,0540	53,4754
	Std Deviasi	0,3600	1,1040	2895,3720	1,9090	0,0120	6,9156
Germany	Mean	5,4380	13,0520	36325,0640	8,0300	0,1170	67,8621
	Std Deviasi	0,3740	1,1230	3834,6690	5,0080	0,0600	16,7030
India	Mean	0,9400	4,6650	1048,2490	43,5970	2,9870	36,5723
	Std Deviasi	0,1420	1,0810	409,0410	8,5230	1,2660	12,5649
Indonesia	Mean	1,4270	6,5470	2435,8300	39,9650	6,6920	54,7919
	Std Dev	0,1400	1,3560	635,0430	9,6940	2,2310	11,7611
Italy	Mean	5,0970	9,2390	31311,0220	9,3320	0,0980	49,6001
	Std Dev	0,5440	0,8770	1755,4580	4,8670	0,0430	6,4547
Japan	Mean	5,0180	12,4300	32476,4560	4,6090	0,0190	25,6009
	Std Dev	0,3720	0,5310	1959,6280	1,0030	0,0070	7,3063
South Korea	Mean	5,3170	11,0450	21060,4330	1,2810	0,0260	72,1276
	Std Dev	0,6240	0,8390	6292,4520	0,8290	0,0080	17,3440
Mexico	Mean	2,8390	7,4570	8797,2820	10,7600	3,8650	55,3814
	Std Dev	0,3500	0,9350	675,9280	1,5550	1,5890	12,8456
Rusia	Mean	5,1670	11,9170	7284,0060	3,5330	13,4530	55,8983
	Std Dev	0,5090	0,8080	1930,1750	0,2500	4,8600	12,9187
Saudi Arabia	Mean	4,3050	7,9150	18752,6130	0,0130	36,9200	73,3000
	Std Dev	1,2010	1,5590	1186,9970	0,0060	10,2960	11,4142
South Africa	Mean	3,4950	6,2410	5511,5310	13,4870	4,3010	49,3017
	Std Dev	0,3820	1,2550	670,1290	3,3510	1,6910	7,9784
Turkey	Mean	2,9320	12,8610	7986,6360	16,5690	0,4170	47,6056
	Std Dev	0,3350	2,8660	2068,5400	4,2760	0,2450	6,7737
UK	Mean	5,3710	11,7750	40668,0810	3,2430	0,7170	54,2734
	Std Dev	0,6220	1,2880	4743,3080	3,1880	0,2730	4,6671
USA	Mean	9,2830	13,0780	50394,5400	6,5645	0,8680	25,4601
	Std Dev	0,8950	0,1710	5794,5500	1,9857	0,3430	3,3126
Panel	Mean	4,5600	9,7430	21469,5200	14,6320	4,5510	48,7066
	Std Dev	2,2430	2,958	16552,9300	14,1920	8,7220	18,1367
	Obs	513,0000	513,0000	513,0000	513,0000	513,0000	513,0000