Environmental Kuznets curve in South Africa:

To confirm or not to confirm?

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Abstract

This paper tests the Environmental Kuznets Curve (EKC) hypothesis on the latest available South African data by using the Autoregressive Distributed Lag (ARDL) econometric method. Using proxies for environmental quality such as CO_2 emissions, energy intensity and renewable energy, the long run relationship between growth in income per capita and environmental quality is tested; we find no conclusive evidence to support the EKC hypothesis. Given the unique nature of the South African economy being at its initial stages of development, the results may indicate that the economy is still transitioning through the early stages of the inverted U-shape Kuznets curve.

Keywords: Environmental Kuznets Curve; Economic Growth; Environmental Quality; South Africa

1. Introduction

The international environmental worries due to the effect of climate change have urged economies to adjust their usage of energy where possible and seek for greener alternatives. Large part of the reduction in emissions as a result is expected by the developed economies due to their higher access to investment capital. However, developing economies also have a significant role to play in the future especially nowadays that through globalization, opening of technology transfer and mobilized capital and labour has become easier (Ahmed and Long, 2012).

Human economic activity has played a significant role in this although the relationship between economic growth and development and environmental degradation is often debated in the literature (Bartozxczuk, Ma and Nakamori, 2002). The Environmental Kuznets Curve (EKC) illustrates the hypothesis that a country is performing environmentally worse at the early stages of economic growth and development but subsequently, as the economic growth rises, the environmental quality improves. The hypothesis draws from the income distribution theory developed by Kuznets (1955). His theory suggested that there is an inverted U-shape relationship between an indicator of income inequality and the level of income. In the case of EKC, an inverted U-shaped curve is expected between an indicator representing environmental degradation such as air emissions, water pollutants or energy intensity and the country's income. The first studies on EKC were conducted in the early 1990s by Grossman and Krueger (1991) and Shafik and Bandyopadthyay (1992).

Possible reasons to explain this phenomenon can be: (a) the transition of the economies from clean agricultural economies, to high polluting secondary sector-based economies and finally to clean service-based economies (Arrow et al., 1995); (b) at higher income levels, people do not worry about their surviving needs and tend to improve their preference for environmental quality; in other words, demand for goods and services in general increases slower than the demand for environmental quality (Bartoszczuk et al. 2002).

Although in theory, the hypothesis can be justified, the results of the empirical studies remain inconclusive. Various studies argue that the EKC relationship applies only for a few indicators. Global indicators are on the constant rise. Also, the turning points of global pollutants are estimated at higher incomes than the domestic ones, showing that people care more about the domestic environmental effects rather than the global ones. This discussion illustrates a major critique of the EKC applied studies: the choice of the environmental indicator can affect the confirmation or not of the EKC hypothesis. For example, Stern and Common (2001) argue that when using SO_2 emissions, the EKC hypothesis is confirmed (Grossman and Krueger, 1995; Panayotou, 1993; Selden and Song, 1994 and Shafik, 1994). An indicator of environmental quality that was not used to date to capture environmental quality is the use of renewable energy sources. Countries in the beginning of their developmental path are more interested in access to energy at whatever environmental cost but while they grow they tend to invest more on cleaner alternative forms of energy such as wind, solar and hydro. Hence, the shape of the relationship expected here is a U-shaped curve (opposite to the traditional EKC).

The main purpose of this paper is firstly to examine the existence of EKC for the South African case. South Africa is already in the initial stages of its own path of growth and development but in parallel the country is also committed internationally to reduce emissions and improve its environmental quality. Confirmation of the EKC hypothesis will show that further strengthening of the economic growth and development will contribute towards an environmentally-friendly future for the country. Additionally, the methodological contribution of the paper lies with the use of different indicators proxying environmental quality (CO_2 emissions, Energy intensity and Renewable energy use). The paper compares and contrasts the results depending on the choice of an indicator.

The rest of the paper is structured as follows. Section 2 presents a brief literature review of recent papers investigating the EKC hypothesis. Next in section 3, a theoretical background of the hypothesis is discussed, followed by the econometric methodology and finally a description of the data. The empirical results are presented in section 4, while section 5 discusses the results and concludes.

2. Brief literature review

The literature has shown extensive interest in the relationship between economic growth and environmental degradation, with focus on pollutant emissions. The original work proposing the inverted U-shape of the Environmental Kuznets Curve (EKC) hypothesis was done by Grossman and Krueger (1991) and since then there has been a vast amount of research done on the validity of the EKC hypothesis. Table 1 summarises selected recent studies on EKC for various countries using a variety of methodologies but also indicators.

Stern and Common (2001) test for the existence of the EKC hypothesis for the period 1960-1990, using a sample of 73 countries and SO_2 emissions as a proxy to environmental quality. The results show that the inverted U-shape only occurs when the high income countries are included in the sample. Similarly, Jobert et al. (2012) find that the overall inverted U-shape curve is due to the results from the high income countries dominating the results of the 55 countries tested during the sample period 1970-2008. Bartoszczuk et al. (2002) tested for the possible existence of the EKC in developed countries for the period 1960-1996 using carbon dioxide emissions. The existence of the inverted U-shape EKC was confirmed. Similarly, Canas et al. (2003) and Vehmas et al. (2007) test this hypothesis using 16 industrialised countries and 15 EU member countries, respectively. Both of these papers find support for the existence of the inverted U-shape EKC hypothesis. Conversely, Focacci (2005) and Kohler (2013) find no support for the existence of the inverted U-shape EKC for Brazil, India and China and South Africa, respectively. Extensive reviews of the literature on the existence and robustness of the EKC are done by Dinda (2004) and Stern (2004).

All in all, from the sample of papers used in Table 1, it can be concluded that the existence of the inverted U-shaped EKC can be confirmed – mostly for developed countries –, however there seems to be no agreement on the levels of the turning points.

Table 1. Selected studies on the Environmental Kuznets Curve

Study	Time period	Countries	Methodology	Variables used	Result/Outcome
Ahmed and Long (2012)	1971-2008	Pakistan	ARDL bounds	Per capita CO_2 emissions, per capita real GDP, energy consumption per capita, trade openness ration, population growth	Confirms inverted U-shaped EKC in long-run.
Bartoszczuk et al. (2002)	1960-1996	Developed European countries	Agent based model	Per capita CO_2 emissions, GDP per capita	Hesitant agreement with EKC. Turning points vary between countries.
Borhan and Ahmed (2012)	1996-2006	Malaysia	Simultaneous equation model, Two stage least squares (2SLS)	Real GDP per capita, Biochemical Oxygen demand (BOD), Cadmium (CD), Arsenic (AS)	The EKC relationship is found to exist for BOD and GDP per capita.
Borhan et al. (2012)	1965-2010	Asean 8	3 equation simultaneous model, 2SLS model	Carbon monoxide, GDP per capita, population density	EKC confirmed. Exists simultaneous relationship between carbon monoxide and GDP. Carbon monoxide has a negative, significant relationship with GDP.
Canas et al. (2003)	1960-1998	16 industrialised countries	Quadratic and cubic models, FE and RE	GDP per capita, Direct material input (DMI) per capita	Inverted U-shape confirmed.
Esteve and Tamarit (2012)	1857-2007	Spain	Threshold cointegration techniques	Per capita CO_2, per capita real GDP	Confirms EKC. Threshold per capita income of 8266 euros, reached in 1986.
Focacci (2005)	1975-1997, except India 1970-1997	Brazil, India, China	Macroeconomic indicators	CO_2 emissions levels, per capita GDP, energy intensity	EKC doesn't hold true for developing countries
Harbaugh et al. (2001)	1977-1988, 1971-1992	SO_2: 45 countries, TSP: 30 countries, Smoke: 21 countries	RE, FE model	SO_2, Total suspended particulates (TSP), smoke, real GDP per capita, political structure, investment, population density, trade	There is little, if any, empirical support for existence of inverted U-shaped EKC. Economic growth neither helps nor harms the environment.
Jobert et al. (2012)	1970-2008	55 countries	Bayesian shrinkage framework	Per capita CO_2 emissions, real per capita GDP, per capita energy consumption	EKC is rejected for 49 out of 51 countries. Emergence of overall inverted U-shape curve due to high income countries, increase GDP

					decreases emissions, while in low income countries emissions and GDP are positively correlated.
Kohler (2013)	1960-2009	South Africa	ARDL, Granger causality tests, Impulse response (IR) tests	Per capita real GDP, per capita CO_2 emissions, commercial energy use per capita, foreign trade	Long-run: energy consumption , income, foreign trade, squared income all $\rightarrow CO_{2.}$ IRV: income has no effect on $CO_{2.}$
Kunnas and Myllyntaus (2010)	1950-2001	Finland	Generalised least squares (GLS)	Per capita GDP, SO_2 emissions per capita	Inverted U-shape curve, with a turning point of $13000, at 37kg.
Lipford (2010)	1950-2004	G8+5 countries	Linear, squared and cubed equations	CO_2 emissions, per capita real GDP	Global carbon emissions will rise with rising income.
Martinez-Zarzoso and Bengochea-Morancho (2004)	1975-1998	22 OECD countries	Pooled mean group estimator	CO_2 emissions per capita, GDP per capita (in $1993 PPP)	N-shape EKC for majority of countries (but heterogeneity among them). Turning point: $4914-$18364.
Orubu and Omotor (2011)	SPM:1990-2002, OWP:1980-2002	SPM:47 African countries, OWP:6 African countries	Ordinary Least Squares (OLS), Random Effects (RE), Fixed Effects (FE)	Suspended particle matter (SPM), Organic water pollutants (OWP), per capita income, population density, education	SPM: inverted U-shape exists, thus supporting EKC hypothesis. Turning point: $84.32-$366.39. OWP: Results mixed. OLS-conventional EKC (turning point $739.93), FE & RE-U-shape EKC (turning point $822.71-$2030.81), Cubic form-N-shaped EKC (turning point $133.91-$232.42). Evidence more in favour of rising pollution as per capita income increases.
Saboori et al. (2012)	1980-2009	Malaysia	Autoregressive distributed lag (ARDL), Vector Error Correction Model (VECM)	Per capita CO_2 emissions, real per capita	Inverted U-shape relationship between per capita CO_2 emissions and per capita real GDP exist, thus confirming the EKC. Turning point of per capita real income US$ 4700, achieved in 2006. EKC confirmed in short-run. GDP $\rightarrow CO_2$ in the long-run, but no causal relationship between these two in the short-run.
Shahbaz et al. (2013)	1980-2010	Romania	ARDL bounds	Energy emissions per capita, real GDP per capita, energy consumption per capita	Confirms EKC in both long-run and short-run.
Song et al. (2008)	1985-2005	China (29	Dynamic OLS and within	GDP per capita, waste gas emissions per	Inverse U-shape between per capita

		Provinces)	OLS	capita, solid wastes generated per capita, waste water emissions per capita	pollution and per capita GDP for waste gas emissions (turning point: 29017 yuan) and solid wastes (turning point: 9705 yuan). Inverse N-shape for waste water (turning point: 28296 yuan).
Stern and Common (2001)	1960-1990	73 countries (two thirds middle-low income)	Logarithmic quadratic RE, FE models	GDP per capita, Sulfur emissions per capita	Sulfur emissions per capita are a monotonic function of GDP per capita when using global sample. Inverted U-shape function of income when use sample of high income countries. Reductions in emissions are time related rather than income related.
Vehmas et al. (2007)	1980-2000	15 EU member countries	Linking analysis	Domestic extraction (DE), Direct Material Input (DMI), Domestic Material Consumption (DMC), Physical Trade Balance (PTB)	Some support for the existence of the EKC.

Notes: CO_2 stands for carbon dioxide, SO_2 stands for sulphur dioxide, GDP stands for Gross Domestic Product.

3. Research Method

3.1. Theoretical model

Numerous studies have estimated EKCs for certain air and water pollutants as well as other indicators proxying environmental performance. As noted Arrow et al. (1995) and Stern et al. (1996), these estimated regressions are reduced-form relationships which mean that they reflect correlation rather than a causal relationship. Nevertheless, these studies provide evidence that, for at least those pollutants involving local short-term health hazards, market and institutional mechanisms have eventually brought about a reduction in environmental damage during the course of economic growth (Cole et al. 1997).

Cole et al (1997) extended past empirical studies by including more environmental indicators such as carbon dioxide, methane, and others. "The employment of a reasonably comprehensive data set permits the examination of a number of hypotheses relating to the association between economic growth and the environment. First, that pollutants with a local short-term impact (e.g., suspended particulate matter) will have estimated turning points at lower per capita income levels than those environmental indicators whose impact is more global in nature (e.g., carbon dioxide)" (Cole et al. 1997).

The basic model is: $E_t = f(Y_t, X_t)$ where E_t denotes the environmental indicator in per capita form in the country at year t, Yt denotes per capita income in the country at year t, and Xt represents exogenous factors, such as trade intensity and the level of technology in the country at year t. In our analysis, we will follow Cole et al. (1997) with the idea of using different indicators for South Africa and compare the results. The basis of the theoretical model is adopted from Stern and Common (2001) showed in equation 1:

$$\ln(EQ)_t = \alpha_i + \beta_1 \ln\left(\frac{GDP}{P}\right)_t + \beta_2 \left(\ln\left(\frac{GDP}{P}\right)\right)_t^2 + \varepsilon_t \qquad (1)$$

Where EQ is the indicator measuring environmental quality (here, CO_2emissions or Energy intensity or Renewable energies); P is population; GDP is the Gross Domestic Product; ε is a ra ndom error term; the α_i is a constant term; at a time period t.

An environmental quality path exists if there is a statistically significant relationship between an environmental indicator and income. A path displays a turning point if $\beta_1 > 0$ and $\beta_2 < 0$ in equation (1).

3.2. Econometric methodology

In the literature, a number of studies use cointegration techniques to test for the existence of a long-run relationship among variables. In this paper, the bounds testing autoregressive distributed lag (ARDL) model is preferred for the analysis of level relationships (Pesaran & Shin, 1999; Pesaran, Shin, and Smith, 2001). Apart from detecting the existence of a long-run relationship among time series, this method can also estimate the size of this relationship. Prior knowledge of the stationarity attributes of the time-series is not necessary according to this method, provided that the series are up to second order of integration[1].

Following various studies that preferred the ARDL approach to EKC applications (recent examples in Kohler, 2013; Ahmed and Long, 2012; Saboori et al., 2012; Shahbaz et al., 2013), firstly we estimate a model with the variables in first differences (Equation 2) and subsequently, an *F*-statistic test is conducted to determine if additional lags for the variables result in significant coefficients (Equation 3).

Equation 2

$$\Delta EQ_t = \mu + \sum_{k=1}^{n} B_k \Delta EQ_{t-k} + \sum_{k=1}^{n} C_k \Delta GDPP_{t-k} + \sum_{k=1}^{n} G_k \Delta (GDPP_{t-k})^2$$

Equation 3

$$\Delta EQ_t = \mu + \sum_{k=1}^{n} B_k \Delta EQ_{t-k} + \sum_{k=1}^{n} C_k \Delta GDPP_{t-k} + \sum_{k=1}^{n} G_k \Delta (GDPP_{t-k})^2 + \delta_1 EQ_{t-1} + \delta_2 GDPP_{t-1}$$

where Δ denotes the first difference operator, *EQ* is the environmental quality indicator chosen (in our case CO_2 emissions or energy intensity or renewable energies); *GDPP* is the GDP per capita, B_k and

[1] These results are available upon request from the authors.

C_k, are the coefficients of lagged $\Delta GDPP$, to be estimated. The null hypothesis for the *F*-statistic is $\delta_1=\delta_2=0$ (no long-run relationship or no co-integration).

The *F*-statistic distribution is non-standard and hence the critical values have to be calculated. Pesaran et al. (2001) and Narayan (2005) both develop two bounds of critical values where the upper bound applies when all variables are integrated of order 1 and the lower bound when all of them are stationary. If the *F*-statistic for a particular level of significance lies between the lower and upper bounds, then *conclusive inference cannot be made* (Ziramba, 2008). If the test statistic is higher than the upper bound [smaller than the lower bound], the null hypothesis cannot [can] be accepted and hence the conclusion is that there is cointegration [no cointegration].

In order to estimate the above equations, the appropriate lag length has to be decided. To do so, a simple vector autoregressive (VAR) model of the variables is estimated. From there, a suite of criteria, such as the Akaike Information Criterion (AIC), the Schwarz Information Criterion (SIC), the Hannan-Quinn (HQ) and the Final Prediction Error (FPE), are applied to determine the lag order in the test equation.

3.3. Data

The study focuses on the period from 1960 to 2010 depending on data availability (energy intensity and renewable energy production series are only available from 1971 onwards). The environmental quality indicators (CO_2 emissions per capita, Energy intensity, and Renewable energy production) and the population series are derived from the World Development Indicators (WDI) of the World Bank. The GDP per capita series is derived from the South African Reserve Bank (SARB). All the series are used in their natural logarithm forms. Table 2 summarises the descriptive statistics of the study.

Table 2: Descriptive statistics

	LNCO2CAP	**LNENINT**	**LNGDPP**	**LNREN**
Mean	2.172685	-2.516359	10.35142	20.91780
Median	2.197283	-2.492579	10.34248	21.00148

Maximum	2.337677	-2.383222	10.50210	21.89234
Minimum	1.988717	-2.717419	10.24803	18.53401
Std. Dev.	0.107593	0.103717	0.064487	0.701417
Skewness	-0.216243	-0.596231	0.674823	-1.549966
Kurtosis	1.898954	2.146870	2.975526	6.222258

4. Empirical results

The unit root testing of each of the variables have concluded that all of first order of integration except the renewable energy use that is stationary (I(0))[2]. Before proceeding with the estimation of the ARDL model, the lag length should be determined. Employing a suite of different criteria as mentioned in the previous section, the optimal number of lags for Model 1 (dependent variable: CO_2 emissions) and Model 2 (dependent variable Energy Intensity) is zero while for Model 3 (dependent variable: Renewable energy usage) is one (Table 3).

Table 3: Lag selection criteria

	Model 1 CO_2 emissions				**Model 2 Energy Intensity**				**Model 3 Renewable energy use**			
	AIC	**SIC**	**FPE**	**HQ**	**AIC**	**SIC**	**FPE**	**HQ**	**AIC**	**SIC**	**FPE**	**HQ**
0	-3.772	-3.692	0.000	-3.742	-5.115	-5.025	2.06E-05	-5.084	-0.648	-0.558	1.79E-03	-0.618
1	-8.131	-7.890	0.000	-8.041	-8.243	-7.974	9.02E-07	-8.152	-2.595	-2.326	2.56E-04	-2.503
2	-8.075	-7.673	0.000	-7.925	-8.215	-7.766	9.32E-07	-8.061	-2.616	-2.167	2.52E-04	-2.463
3	-7.951	-7.389	0.000	-7.741	-8.016	-7.388	1.15E-06	-7.802	-2.421	-1.793	3.08E-04	-2.207
4	-7.827	-7.104	0.000	-7.557	-7.850	-7.041	1.37E-06	-7.574	-2.274	-1.466	3.62E-04	-1.999
5	-7.685	-6.802	0.000	-7.356	-7.774	-6.786	1.51E-06	-7.437	-2.143	-1.155	4.22E-04	-1.806
6	-7.723	-6.680	0.000	-7.334	-7.668	-6.501	1.74E-06	-7.270	-2.113	-0.945	4.50E-04	-1.715

Table 4 presents the results of the ARDL models. Panel A reports the critical values of Pesaran et al. (2001) and Narayan (2005). Both papers generated critical values for specific non-standard F-distribution, however, Pesaran et al. (2001) generated them using samples of between 500 and 1000 observations. Narayan (2005), on the other side, argues that Pesaran et al.'s (2001) critical values might not be appropriate for smaller samples. Given, that they regenerated critical values using samples of 30 to 80 observations.

[2] The results of the stationarity tests can be provided by the authors upon request.

Table 4: ARDL Cointegration results

Panel A						
Critical values	1%		5%		10%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Pesaran et al. (2001)	6.840	7.840	4.940	5.730	4.040	4.780
Narayan (2005)	7.560	8.685	5.220	6.070	4.190	4.940
Panel B						
Model 1 CO_2 emissions		1.609060				
Model 2 Energy Intensity		1.948723				
Model 3 Renewable energy use		1.369598				
				No cointegration		

The sample size in our case comprises of 51 observations, which makes Narayan's (2005) critical values more relevant. As Panel B of Table 4 reports, all models present test-statistics substantially lower than both the Pesaran et al. (2001) and Narayan (2005) lower bound critical values even at the 10% level of significance.

The results show overall that there is no cointegration among the set of variables for the three models, showing that there is a lack of a long-run relationship of any direction. Kohler (2013) also confirms the "absence of a statistically significant long run relationship between growth in income per capita and CO_2 emissions" for South Africa.

5. Conclusion and Discussion

Appreciating the importance of the per capita income to the environmental quality of a country, as that is illustrated in numerous studies in the literature, this paper aims to examine, on the one side, the existence of an EKC type of relationship in South Africa; and on the other side, whether the confirmation of the EKC hypothesis is dependent on the environmental indicator. Hence, following the Stern and Common (2001) theoretical model and the commonly used ARDL econometric methodology, the paper investigates possible differences stemmed from the choice of CO_2 emissions per capita, Energy intensity or Renewable energies as proxies for environmental quality.

If the relationship is confirmed, then if economic development is successfully performed, although combined with numerous problems, it can be separated or even assist improving environmental quality. The results support a lack of a long run relationship between environmental quality (using any of the three indicators) and GDP per capita. South Africa, although among the biggest emerging economies (BRICS), is still in the beginning of its developmental path since its political conditions stabilized only 20 years ago. Thus, a possible explanation for the absence of a U-shaped EKC is that the country has not reached a threshold point where environmental quality is important for the policy makers and the population in general.

Kohler (2013) although confirming the same finding, attributes the results to endogeneity issues between the two variables in question and the foreign trade indicator that he employed. In our case, we tried to avoid such a problem, but the findings remain the same. In the literature, a number of other control variables are used on top of the main two of the EKC such as population growth, energy use; so it would be interesting in the future to examine what difference a new factor would make in the confirmation or not of the EKC hypothesis.

Moreover, the selection of the specific functional form and econometric methodology is also debatable. A number of papers have suggested that panel data techniques are most appropriate because they can capture differences between developed and developing economies and their specific EKC path. The results (taking maybe into account possible cross-sectional dependency) might give a new perspective to the CO_2- GDP relationship, for example Cowan et al. (2014) found for South Africa a positive causality from GDP to CO_2 emissions. Also, Fouquau, Destais and Hurlin (2009) have suggested a regime switching approach trying to capture the non-linear attributes of the relationship between environmental quality and income per capita.

To conclude, more research and specific examination of the EKC for the South African case is required in the future. We plan to proceed by taking into account issues such as the correct proxy for environmental quality (certain type of emissions? energy use? energy intensity? renewable energy?), use of control variables (foreign trade? population?); appropriate research method (which functional form? which econometric methodology?) and others. If the EKC hypothesis for the country is confirmed in the future, a more specific question of where the threshold is should be examined and answered too.

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