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Institutional Structure and Environmental Pollution: An Application within the Framework of the Environmental Kuznets Curve Hypothesis

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ABSTRACT

The EKC hypothesis explains the relationship between economic growth and environmental degradation. However, criticisms of its fundamental assumptions suggest that this relationship should be examined more comprehensively. While the EKC hypothesis addresses the link between income levels and environmental quality, it may overlook the impact of institutional structures and policy factors. In this context, recent studies increasingly highlight the role of institutional structures in environmental degradation. Accordingly, this study aims to provide a comprehensive analysis of environmental sustainability by approaching the EKC hypothesis from the perspective of institutional quality. To determine the effects of institutional quality on environmental degradation, the study employs the Driscoll-Kraay estimation method. The analysis is conducted on a sample of SADC countries for the period 1990-2021. The findings indicate that institutional quality has a statistically significant and positive effect on environmental degradation; however, beyond a certain threshold, this effect reverses. Additionally, the impact of economic growth on environmental degradation is examined within the EKC framework, revealing that while per capita income initially increases environmental degradation, exceeding a certain income level leads to improvements in environmental quality. The findings confirm the validity of the EKC hypothesis in SADC countries and suggest that strong institutional structures can play a supportive role in promoting environmental sustainability.

Keywords: Environmental Kuznets Curve, Institutional Quality, Environmental Degradation, Rule of Law, Sustainable Development
JEL Classifications: Q56, Q58, O43

1. INTRODUCTION

The Environmental Kuznets Curve (EKC) hypothesis is a significant theoretical framework explaining the relationship between economic growth and environmental pollution. According to the hypothesis, as per capita income increases, environmental pollution initially rises but eventually decreases after reaching a certain income level (Grossman and Krueger, 1995; Panayotou, 1993). This inverted U-shaped relationship provides a dual perspective for evaluating the environmental impacts of economic growth. The literature includes numerous studies that confirm the EKC hypothesis, such as Mahmood et al. (2023), Nguea (2024), and Mahmood and Saqib (2025).

However, criticisms of the fundamental assumptions of the hypothesis indicate the need for a more comprehensive examination of this relationship. The EKC approach, while addressing the link between income levels and environmental quality, may neglect the effects of institutional structures and policy factors alongside growth dynamics (Deacon, 1999; Stern, 2004). For instance, Deacon (1999) emphasizes that most empirical models exclude governance structures, which hinders the effective evaluation of environmental protection policies, particularly in developing countries. According to Deacon (1999), empirical models in the EKC literature generally examine pollution in relation to income, income squared, and other variables. This limitation prevents a reliable prediction of the types of political reforms that could support environmental protection in developing countries or the environmental effects of democratization trends observed in recent years. Excluding governance structures as an explanatory variable in cross-country empirical models may lead to biased results and incorrect inferences regarding the impact of economic growth on the environment. Governance structures should be included in the model, as non-democratic regimes tend to be less effective in providing public goods such as pollution control compared to democracies.

Similarly, Stern (2004) argues that the EKC hypothesis' attempt to explain all changes in the economic development process solely through income levels fails to sufficiently capture the underlying dynamics of environmental degradation. In his study, Stern (2004) asserts that the EKC hypothesis is based on weak statistical foundations. He contends that the simplified reduced-form EKC model does not adequately explain the underlying dynamics of environmental degradation, as it attempts to account for all changes in the economic development process solely through income levels. Within this scope, the study highlights the role of structural factors and technological change in reducing emissions. Therefore, Stern suggests that new modeling approaches and panel data analyses should be employed to better understand the EKC.

The EKC approach, which examines the relationship between growth and the environment, has been developed over time by addressing different dynamics within this context. While the EKC hypothesis defines the relationship between income growth and environmental quality, it remains unclear whether income level alone is a determining factor or whether the rate of growth makes a difference. Additionally, to what extent does the difference between the nature and size of the economic structure, the impact of environmental expenditures and regulations, and the role of institutional quality matter? These questions expand the scope of the EKC. This approach underscores the necessity of examining the growth-environment relationship from a more detailed perspective. Although rapid economic growth and increasing population density beyond a certain point may moderately increase the environmental cost of economic growth, better policies can easily offset these effects and make economic growth more environmentally friendly and sustainable. In this way, the EKC can be flattened, ensuring environmental sustainability without surpassing any ecological thresholds (Panayotou, 1997: 483).

Torras and Boyce (1998) also highlight the importance of environmental policies and institutional quality in preventing environmental degradation, arguing that EKC analyses should focus not only on economic indicators but also on institutional factors. Their study supports the EKC hypothesis by suggesting that once income levels surpass a certain threshold, they have a pollution-reducing effect. However, they emphasize that this relationship is strongly shaped by institutional structures.

According to Dasgupta et al. (2000), the structural interpretation of EKC results obtained from reduced-form models remains largely hypothetical. The primary reason for this is the lack of data that would allow for a detailed examination of the sources of change in the marginal relationship between development and pollution. It is clearly stated that indicators explicitly measuring environmental policies are needed for further progress in structurally modeling the income-environment relationship.

Panayotou (1997) presents one of the pioneering studies integrating institutional quality into the EKC hypothesis. His study examines the role of environmental policies and institutional structures in the income-environment relationship, demonstrating that better policies and institutions can enhance environmental quality. Countries with the same income levels may exhibit different environmental performances depending on institutional factors such as education level, rule of law, and bureaucratic quality. This finding reveals that environmental sustainability is shaped not only by economic growth but also by institutional structures and policies. His study makes a significant contribution to the literature by incorporating explicit policy evaluations into the income-environment relationship and exploring its determinants. It represents a step toward a better understanding of this relationship and its potential as a policy tool.

Studies on the EKC are crucial for identifying environmental policies that can promote better economic growth without compromising environmental quality. In this context, another study emphasizing the need for an appropriate institutional structure to achieve higher economic growth rates without leading to environmental degradation is that of Lau et al. (2018). According to Lau et al. (2018), developing local institutions is essential to explain why countries grow with better environmental quality; in other words, improvements in institutional quality can lead to reductions in CO2 emissions.

Carlsson and Lundström (2000) examine the impact of economic freedom—an essential component of institutional structures—on environmental quality through various mechanisms. They argue that the direction of this relationship depends on the effects of economic freedom on environmental factors. Direct effects, such as more efficient resource use, may positively contribute to the environment, while indirect effects, often mediated through economic growth, may be detrimental. The study proposes four hypotheses to explain the relationship between economic freedom and environmental quality: Regulatory Effect-Economic freedom may influence environmental quality by either promoting or restricting environmental regulations. Efficiency Effect-Competitive and efficient markets can contribute positively to the environment. Stability Effect-Macroeconomic stability encourages long-term environmental investments. Credit Effect-Financial constraints may disproportionately affect lower-income groups, linking environmental decisions to the consumption and investment preferences of these groups. The authors note that the overall outcome of these effects depends on the types of regulations, market structures, and economic conditions.

The primary objective of this study is to provide a more comprehensive analysis of environmental sustainability by approaching the EKC hypothesis from an institutional quality perspective. In this framework, the study aims to reveal the long-term effects of institutional factors on environmental quality and to develop an innovative approach to environmental sustainability. Unlike traditional EKC studies that focus on per capita income, this study places institutional quality at the center of the analysis, offering a different perspective. Institutional quality is considered a critical factor that can have both direct and indirect effects on environmental sustainability. For instance, in the early stages, weak regulations or policies that prioritize economic growth may lead to increased environmental degradation. However, as institutional quality improves and effective environmental policies are implemented, this degradation may decrease.

In this study, the Rule of Law Index from the V-Dem Institute is used as an indicator of institutional quality. This index provides a comprehensive measurement as it includes various institutional subcomponents such as judicial independence, regulatory quality, and control of corruption. Additionally, alongside the squared term of economic growth, the squared term of the institutional variable is also incorporated into the model to analyze potential nonlinear effects in the growth-environment relationship.

The literature on the EKC hypothesis from an institutional quality perspective remains limited. This study fills this gap by analyzing the dynamics between institutional quality and environmental sustainability, covering both the present and future periods. In this context, the Rule of Law Index is included in the model alongside the squared economic growth variable. To ensure robustness against heteroskedasticity and autocorrelation problems, Driscoll-Kraay standard errors are employed.

Conducted within the context of African countries, this study aims to provide a new understanding of the relationship between institutional quality and environmental degradation. Specifically, it seeks to analyze the impact of institutional improvements on environmental degradation in countries with low institutional quality, thereby making this relationship more explicit. In doing so, it emphasizes the importance of institutional reforms in ensuring environmental sustainability during economic development processes. The study's findings contribute to the development of policy recommendations that can reduce environmental degradation while maintaining sustainable economic growth. This contribution to the literature is expected to help design more effective environmental policies by considering institutional factors.

The study is structured into five sections. The second section presents a literature review on the EKC hypothesis and the relationship between institutional quality and environmental pollution. The third section discusses the data and methodology, while the fourth section presents the analysis findings. The final section evaluates the findings and provides policy recommendations. Figure 1 shows the overall structure of the study.

2. LITERATURE REVIEW

The EKC represents an inverted U-shaped hypothesis explaining the relationship between economic growth and environmental degradation. Grossman and Krueger (1995) popularized the EKC by proposing that environmental degradation initially increases with rising income levels but begins to decline after reaching a certain income threshold. The mathematical expression they suggested to test the EKC hypothesis is as follows:

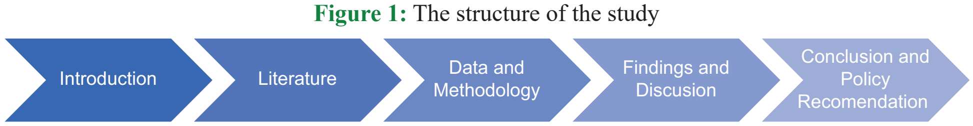
$$Y_{it} = \beta_1 G_{it} + \beta_2 G_{it}^2 + \varepsilon_{it} \quad (1)$$

In this formula, Y_{it} represents the environmental degradation indicator (e.g., air and water pollution), G_{it} denotes per capita GDP, and ε_{it} is the error term. Grossman and Krueger (1995) explain the formation of the EKC through three key mechanisms. First, the scale effect suggests that, in the early stages of economic growth, increased production and consumption lead to higher resource use and environmental degradation. Next, the composition effect implies that, over time, economic structures shift toward less environmentally harmful sectors, slowing environmental degradation. Finally, the technology effect highlights that, upon reaching a certain income level, investments in environmentally friendly technologies increase, leading to pollution control and enhanced environmental sustainability.

Following Grossman and Krueger's (1995) mechanisms, various approaches have been developed to expand the scope of the EKC hypothesis. For instance, scholars have debated whether environmental degradation is driven primarily by economic size or by structural changes, policy frameworks, and institutional quality. Panayotou (1997) addressed these questions by incorporating policy variables and economic growth rates into EKC analyses. He also developed a model that decomposes income effects into scale, composition, and abatement effects. This transformation made the EKC a tool for analyzing how structural changes, policies, and institutions influence environmental externalities during economic development. Later, Stern (2004) contributed theoretical insights by questioning the linearity of the EKC hypothesis. Stern (2004) argued that the mechanisms of the EKC do not solely depend on income levels; factors such as institutional quality, policies, international trade, and social awareness also play significant roles.

Panayotou (1997) emphasized that the environmental impacts of economic growth are shaped by policies and market conditions, which, in turn, significantly affect the reversibility of environmental damage when ecological thresholds are exceeded (Appendix: Figure a). For example, in tropical regions, deforestation coupled with topsoil loss can lead to an irreversible process. Effective policies—such as removing harmful subsidies, strengthening property rights, and implementing pollution taxes—can reduce the environmental cost of economic growth, flatten the

Figure 1: The structure of the study



income-environment curve, and lead to an earlier turning point. Additionally, institutional frameworks can enhance environmental monitoring capacity, facilitating the alignment of societal changes with environmental improvements. Panayotou (1997) specifically highlighted that better policies have a substantial positive impact on environmental quality, particularly in pollution reduction, as evidenced by lower SO_2 levels (Appendix: Figure b).

In this context, Panayotou's (1997) pioneering study adopted a more structural and analytical approach to the income-environment relationship by incorporating both policy variables and economic growth rates. Using panel data analysis covering 30 developed and developing countries for the period 1982-1994, the findings suggest that the quality of policies and institutions can significantly reduce environmental degradation at low-income levels and accelerate improvements at higher income levels. In other words, better policies—such as stronger property rights, improved contract enforcement, and effective environmental regulations—can flatten the EKC, mitigating the environmental cost of economic growth.

Torras and Boyce (1998) examined the impact of institutional factors, such as political rights and civil liberties, on environmental pollution in a sample of low-income countries for the period 1977-1991. Their results indicate that political rights and civil liberties play a crucial role in reducing environmental pollution. Accordingly, countries with stronger democratic institutions tend to have lower levels of environmental pollution. Additionally, when institutional factors such as political freedoms and civil rights were included in regression models, the income effect of the EKC hypothesis was found to weaken.

Another pioneering study by Deacon (1999) incorporated political regime variables (democracy) into EKC analyses. The findings suggest that countries with fewer democratic rights tend to have lower environmental quality. Carlsson and Lundstrom (2000) explored the effects of political and economic freedom on CO_2 emissions. Their sample included 77 countries for the period 1977-1996. The study found that political freedom had no significant effect on CO_2 emissions in either low- or high-income countries. However, the direct effects of economic freedom on emissions were mostly negative for low-income countries and positive for high-income countries. Nonetheless, the indirect effects of economic freedom on CO_2 emissions were generally positive, indicating that economic freedom indirectly increases emissions.

Dasgupta et al. (2000) examined the relationship between environmental policy and performance in 31 countries using a quantitative analysis of reports prepared for the United Nations Conference on Environment and Development. They found that developing countries with relatively secure property rights, effective legal and judicial systems, and efficient public administration had more advanced environmental regulations.

Damania et al. (2003) expanded the Environmental Kuznets Curve (EKC) by incorporating institutional quality indicators to analyze economic and environmental relationships. Using a sample of developed and developing countries from 1982 to 1992, they employed corruption as an indicator of institutional structure and found that corruption weakens the stringency of environmental policies. Fredriksson and Millimet (2004) examined the relationship between electoral rules and environmental quality in a sample of 86 democratic countries. Their results indicate that governments in proportional representation systems implement stricter environmental policies than those in majoritarian systems.

Bhattarai and Hammig (2004) investigated the relationship between deforestation rates and income in 63 countries from tropical regions of Latin America, Africa, and Asia between 1980 and 1995. Their study focused on the role of institutions and macroeconomic policies in the deforestation process. The findings highlight governance quality as a significant determinant in protecting forest resources.

Leitão (2010) analyzed the effect of corruption on the income level at the turning point of the sulfur emissions-income relationship using a panel of countries with varying development levels and degrees of corruption. The findings support the EKC hypothesis for sulfur emissions and indicate that as corruption levels increase, the per capita income level at the turning point also rises.

Another study investigating the relationship between the environment and institutions is Castiglione et al. (2011), which explores how the rule of law affects the turning point income level of the EKC in European countries. Their findings reveal a negative relationship between pollution and the rule of law, indicating that when the rule of law is strong, the EKC's turning point occurs at a lower per capita income level, thereby reducing emissions.

Lau et al. (2018) examined the EKC hypothesis in a sample of 100 developed and developing countries while considering the role of institutional quality. Using the generalized method of moments (GMM) estimators, their analysis found an inverted U-shaped relationship between economic growth and carbon dioxide (CO_2) emissions only in developed countries, while no such relationship was observed in developing countries. Additionally, anti-corruption efforts were found to play a critical role in reducing CO_2 emissions in high-income countries. The rule of law positively impacted the environment in all countries except low-income nations. Overall, their findings confirm the importance of institutional quality in reducing CO_2 emissions.

Iwińska et al. (2019) investigated the relationship between democracy and environmental quality, questioning the effectiveness of democratic regimes in environmental protection across countries with different income levels during 2006-2014. Their results show a positive correlation between higher democracy levels and environmental quality. However, when data were categorized based on government effectiveness and perceptions of corruption, this relationship became less clear. These findings emphasize the need to consider mediating factors and their effects when assessing the democracy-environment quality relationship.

Bétila (2023) examined the mediating role of renewable energy consumption in the relationship between economic freedom and carbon emissions in 138 countries from 1995 to 2018. The results indicate that economic freedom has both direct and indirect negative effects on carbon emissions, with renewable energy consumption acting as a mediator in this relationship.

Bjørnskov (2024) explored the relationship between economic freedom and environmental damage. Using greenhouse gas emissions and per capita GDP data for 155 countries from 1975 to 2015, the study tested the impact of economic freedom on emissions. The results suggest that economic freedom reduces greenhouse gas emissions while also shifting the peak of the Kuznets Curve to the left.

The studies in the literature examine the relationship between institutional structure and environmental quality through different institutional indicators, leading to various results. Since there is no single measure of institutional structure, different variables such as corruption, democracy, the rule of law, economic freedom, and governance quality have been used. Generally, it is observed that strong institutions improve environmental quality by tightening environmental policies. However, some studies show that the relationship between institutional structure and environmental quality is not absolute, as corruption and low governance quality weaken the effectiveness of environmental policies. Therefore, it can be said that there is no consensus in the literature regarding institutional structure and environmental sustainability.

3. DATA AND METHODOLOGY

3.1. Data

This study has analysed the nexus between institutional quality and environmental degradation in the Southern African Development Community (SADC) countries in the framework of the EKC hypothesis. The study is constrained by the data limitations of the countries, and consequently is limited to the period 1990-2021. The analysis of the study has employed carbon dioxide emissions (CO_2) as an environmental degradation variable and the rule of law index (IQ) as an indicator of institutional quality. On the other hand, Gross Domestic Product (GDP) per capita, the proportion of renewable energy in total energy consumption (REC) and the natural resource utilisation rate (RENT) has been used as control variables in the analysis. IQ variable has obtained from the V-Dem database, while the other variables have been obtained from the World Bank-WDI database. The detailed descriptive information about the variables is shown in Table 1.

The Driscoll-Kraay estimation method based on robust standard errors has been employed to examine the impact of IQ on environmental degradation. The econometric model for the panel data analysis is presented in equation (2).

$$lnCO2_{it} = \alpha_0 + \alpha_1 lnIQ_{it} + \alpha_2 lnIQ_{it}^2 + \alpha_3 lnGDP_{it} + \alpha_4 lnGDP_{it}^2 + \alpha_5 lnREC_{it} + \alpha_6 lnRENT_{it} + \varepsilon_{it} \quad (2)$$

In equation (2), countries have been denoted by *i* and the period has been denoted by *t*. *ln* represents the natural logarithm, α_0 indicates the constant term, $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6$ denote the long-run parameter coefficients and ε_{it} refers the error term.

3.2. Methodology

There are several important issues to be considered on series and models before panel data estimations. Firstly, it should be ensured that the series are stationary. However, before the stationarity analysis, the type of stationarity test should be determined by conducting cross-sectional dependence (CSD) test for the series and the model. If the findings show that the series have CSD, then second generation unit root tests should apply the series. The flowchart of the methodology has been presented in Figure 2.

In order to test CSD in the study, the LM test developed by Breusch and Pagan (1980) which can be used in the case of $T > N$ has been applied and the formulation of the test has been shown in equation (3).

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^2 \sim X^2_{\frac{N(N-1)}{2}} \quad (3)$$

Where $\hat{\rho}_{ij}$ is the correlation coefficient among the residuals from the OLS estimation of each equation. The LM test shows the χ^2 distribution for $T \rightarrow \infty$ when N is constant, with the null hypothesis that there is no correlation between the residuals.

Likewise, in the case of $T > N$ and $T \rightarrow \infty$, CD_{LM} test can be applied as well. However, this test assumes $T \rightarrow N$ instead of is constant and asymptotically standard distribution (Pesaran, 2021).

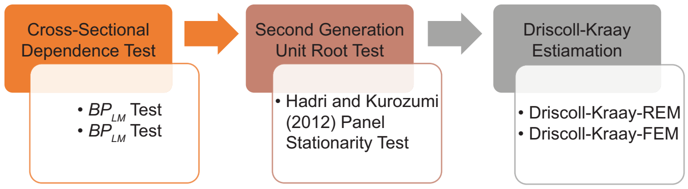
$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(T\hat{\rho}_{ij}^2 - 1\right) \sim N(0,1) \quad (4)$$

After testing CSD in the study, the next step in the methodology is to check stationarity of the variables and Hadri and Kurozumi (2012) panel unit root test has been used for this purpose. This test is one of the second-generation tests and allows CSD with the null hypothesis that there is no unit root in the series, and rejecting of the null hypothesis means that series are non-stationary (Hadri

Table 1: The descriptions of the variables and sources

Variables	Symbol	Unit of measurement	Source
Carbon dioxide emissions	CO_2	Mt CO_2e	World Bank-WDI (2024)
Intuitional quality	IQ	Rule of law index	V-Dem (2024) – processed by Our World in Data
Economic growth	GDP	GDP per capita (constant 2015 US$)	World Bank-WDI (2024)
Renewable energy consumption	REC	Renewable energy consumption (% of total final energy consumption)	World Bank-WDI (2024)
Natural resources rents	RENT	Total natural resources rents (% of GDP)	World Bank-WDI (2024)

Figure 2: The flowchart of the methodology



and Kurozumi, 2012). Two different methods, SPC and LA, have been used in the test. SPC method is based on the AR(p) process developed by Sul et al. (2005) while LA method is based on the AR(p+1) process proposed by Choi (1993) and Toda and Yamamoto (1995).

The following next step is to decide the estimator of the study. The estimator developed by Driscoll and Kraay (1998) has been used for robust standard errors estimation. Driscoll and Kraay (1998) method can be applied to avoid biased results and to estimate based on robust standard errors in the case of heteroskedasticity, autocorrelation and CSD problems in the models. Driscoll-Kraay estimation based on both fixed effects and random effects is performed and to determine which of the estimator has more consistent result, Hausman (1978) test with the null hypothesis that there is no correlation between unit effects and explanatory variables has been applied. The null hypothesis is rejected, so the fixed effects model (FEM) is consistent.

4. FINDINGS AND DISCUSSION

First of all, CSD of the series and the model is checked and the results have presented in Table 2.

The results in Table 2 show that all variables and the model have CSD at 1% significant level. Thus, it is necessary to apply one of the second-generation unit root tests to check stationarity of the series and this test should be biased to CSD in order to estimate the model. For this reason, Hadri and Kurozumi (2012) test have been employed and the findings have been demonstrated in Table 3.

The results of Hadri and Kurozumi (2012) panel stationarity test in Table 3 demonstrate that the null hypothesis, no unit root in the series, cannot be rejected. These results indicate that the series in the study are stationary at their level values.

Having determined that the series used in the study are stationary at their level values, Driscoll-Kraay estimation, which is robust to heteroskedasticity, autocorrelation and CSD problems, has been performed and the outcomes have been demonstrated in Table 4.

The results in Table 4 indicates that both REM and FEM have consistent results and the findings of the two models support each other by suggesting that the findings are robust. On the other hand, the Wald and F test results, which test the overall significance of the models, show that the models used in the study are significant. The value of Hausman test, which is used to decide which model to use, indicates that FEM model is more appropriate for the study. Hence, the results of Driscoll-Kraay-FEM estimator have been considered for the remainder of the study for analysis.

Table 2: CSD test results

Variables and model	BP_{LM}	CD_{LM}
$lnCO_2$	212.259***	5.955***
lnIQ	182.409***	4.028***
lnIQ2	214.442***	6.096***
lnGDP	179.858***	3.864***
lnGDP2	172.902***	3.415***
lnREC	169.495***	3.195***
lnRENT	303.267***	11.830***
Model	188.400***	7.901***

***Represents the rejection of null hypothesis at 1% significance levels
CSD: Cross-sectional dependence

Table 3: Hadri and Kurozumi (2012) panel Stationarity test

Variables	Test	Stat.	Prob.
$lnCO_2$	ZA_spac	0.0238	0.4905
	ZA_la	−2.6883	0.9964
lnIQ	ZA_spac	0.8041	0.2107
	ZA_la	0.1599	0.4365
lnIQ2	ZA_spac	−0.7006	0.7582
	ZA_la	0.1911	0.4242
lnGDP	ZA_spac	0.0656	0.4738
	ZA_la	−0.3424	0.6340
lnGDP2	ZA_spac	0.4789	0.3160
	ZA_la	−0.5566	0.7111
lnREC	ZA_spac	−2.7748	0.9972
	ZA_la	−1.8647	0.9689
lnRENT	ZA_spac	−1.7834	0.9627
	ZA_la	−3.6555	0.9999

Table 4: Driscoll Kraay random effects model (REM) and fixed effects model (FEM) estimation results

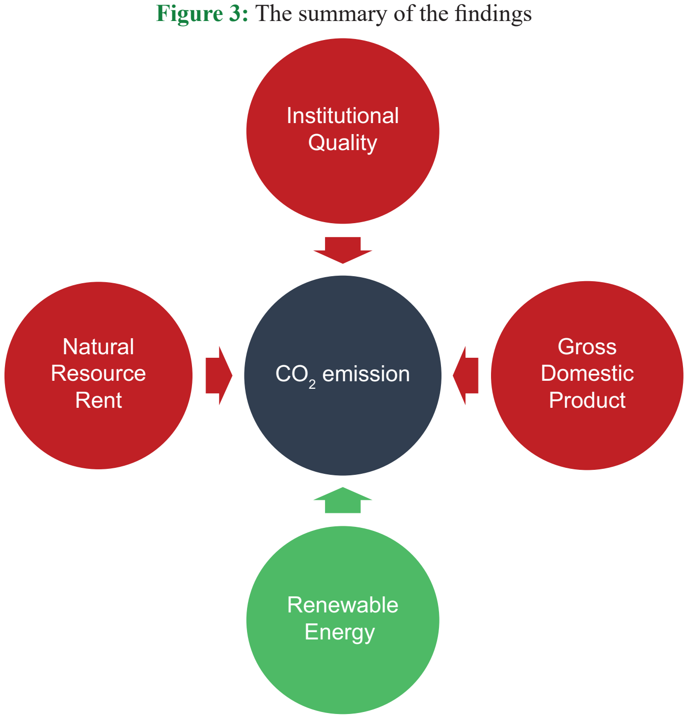
Variables	Driscoll-Kraay-REM	Driscoll-Kraay-FEM
lnIQ	0.939**	0.954**
lnIQ2	−0.154**	−0.155***
lnGDP	4.608***	4.625***
$lnGDP_2$	−0.232***	−0.232***
lnREC	−0.704***	−0.716***
lnRENT	0.103**	0.093*
Cons	−18.664***	−18.762***
Observ.	512	512
Unit	16	16
Wald stat.	460.45***	-
F test	-	148.54***
Hausman test	27.83***	

***, **, * indicate 1%, 5% and 10% significance level

According to Driscoll-Kraay estimation result based on FEM in Table 4, institutional quality (IQ) has a statistically significant and positive effect on environmental degradation (CO_2), and the square of institutional quality (IQ^2) has a statistically significant and negative effect on environmental degradation. These findings reveal that institutional quality in SADC countries increases environmental degradation until a certain level but decreases environmental degradation after a certain threshold. Our findings are consistent with the results of Panayotou (1997) and Carlsson and Lundstrom (2000). Boussaidi and Hakimi (2025) have suggested to improve institutional quality to reduce negative effect of financial inclusion and to increase environmental quality in Middle East and North Africa (MENA) countries. Similar suggestion has been made by Qayyum et al. (2024) to reduce environmental degradation in Southern Common Market (MERCOSUR) economies. However, our findings have shown that institutional quality mitigate environmental quality in SADC countries. There can be several reasons for this dilemma, however, having very weak institutions can be the first one. To strengthen the quality of institutions in the region, the European Union has provided €50 million in funding and has encouraged investment (Southern African Development Community, 2025). Institutional quality is one of the driver of the economic growth in the region (Hussen, 2023). Hence, strong co-movement of economic growth and institutional quality can mitigate environmental quality in the region. The negative sign of the $lnIQ^2$ has supported this idea. Due to the low institutional quality in the region, until the institutional quality is ensured, the investments to be made will harm the environment, but after the fundamental investments necessary for ensuring and monitoring the institutional quality are made, the increase in institutional quality will increase the environmental quality. This would graphically draw an inverted U-shape as in the EKC hypothesis.

On the other hand, GDP variable has a statistically significant and positive effect on environmental degradation, while GDP^2 variable has a statistically significant and negative effect on environmental degradation. The values of GDP and GDP^2 variables included in the model within the framework of the EKC hypothesis show that the EKC hypothesis is valid in SADC countries. Our results support the findings of Grossman and Krueger (1995). The region specially during 2021 and 2022 has focused on industrialisation and market integration capacity to improve economic activity (Southern African Development Community, 2022). Prioritising industrialisation in economic growth will strengthen the link between environmental degradation and economic growth. However, once industrialisation has reached a certain size, the development of the service industry will begin and will be the determinant of growth. After that, economic growth will stop causing environmental damage and will improve environmental quality. The negative sign of implies this relationship.

Figure 3: The summary of the findings



Regarding the effects of renewable energy (REC) and natural resource utilisation (RENT), which are included as control variables in the study, on the environment, renewable energy has a statistically significant and negative effect while natural resource utilisation has a positive effect. The findings obtained from renewable energy and natural resource utilisation are consistent with the theoretical expectations. A summary of the overall findings of the study is shown in Figure 3.

5. CONCLUSION

This study aims to provide a comprehensive analysis of environmental sustainability by examining the EKC hypothesis from the perspective of institutional quality. While the EKC hypothesis primarily evaluates the relationship between economic growth and environmental degradation through income levels, this study investigates the effects of institutional structures on environmental sustainability. The impact of institutional quality on environmental degradation is analyzed using panel data techniques for SADC countries over the period 1990-2021.

As part of the empirical analysis, first of all, CSD has been conducted on the series and model, confirming the presence of CSD in both the model and all included variables. Subsequently, a stationarity test that accounts for CSD has been performed, indicating that the series are stationary at their level values. Finally, the Driscoll-Kraay technique, which provides robust standard errors, has been employed to estimate the effects of institutional quality on environmental degradation. The panel data analysis findings reveal that institutional quality initially increases environmental degradation in SADC countries but reduces it beyond a certain threshold. The square of institutional quality (IQ^2) has a negative and significant coefficient, confirming the pollution-reducing effect of strong institutional structures. This suggests that in regions where institutional structures are weak, environmental degradation increases, but as governance mechanisms strengthen, environmental sustainability can be achieved.

The study also evaluates the environmental effects of economic growth within the EKC framework, revealing that GDP initially increases environmental degradation, but once a certain income threshold is exceeded, environmental quality improves. Furthermore, while renewable energy consumption negatively affects environmental degradation, natural resource utilization has a positive impact.

These results indicate the presence of an inverted U-shaped relationship between both institutional quality and economic growth with environmental degradation. In other words, while institutional quality and economic growth may initially contribute to environmental degradation, beyond a certain level, this trend reverses, leading to improvements in environmental conditions. Such an inverted U-shaped relationship suggests that at low levels of institutional quality and economic growth, environmental regulations and sustainability measures may be inadequate, resulting in greater environmental harm. However, as institutional quality and economic growth improve, mechanisms that protect the environment and promote sustainable development begin to take effect.

As institutional quality improves, stronger legal frameworks, accountability, and effective regulatory structures enhance the implementation of policies aimed at reducing environmental degradation. Similarly, as economic growth increases, more resources can be allocated to environmental investments and green technologies. Consequently, once institutional quality and economic growth reach a certain level, environmental degradation tends to decline as more sustainable economic and environmental policies are implemented.

The findings also indicate that economic growth alone is not sufficient for environmental sustainability; effective institutional structures are also necessary. In other words, ensuring environmental sustainability requires not only economic growth but also institutional reforms and effective environmental policies. Based on these results, significant policy recommendations can be proposed for policymakers.

First, strengthening institutional quality should be prioritized by promoting the rule of law, accountability, and regulatory improvements. The rule of law and high-quality regulations play a crucial role in enforcing environmental policies. Additionally, more transparent and accountable mechanisms should be established to ensure the effective implementation of environmental policies. While economic freedom can enhance the effectiveness of environmental regulations, it may also encourage pro-growth policies that negatively impact the environment, making it essential to strike the right balance.

In line with sustainable development goals, green economy incentives should be promoted to support environmentally friendly investments, renewable energy, and low-carbon production processes. Political freedom and democratic structures can enhance public participation in environmental policies, creating a positive impact on sustainability. Lastly, political stability is essential for ensuring the continuity and effective implementation of environmental policies. Establishing common environmental policies and increasing knowledge-sharing among SADC countries can lead to more effective solutions in addressing environmental challenges.

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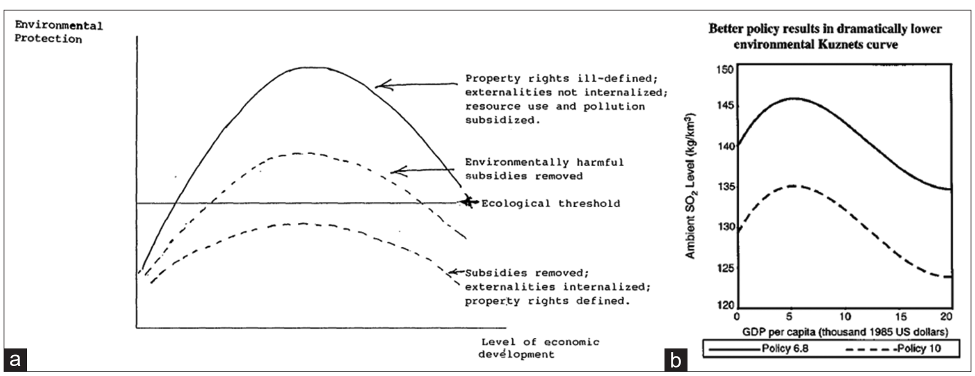
APPENDIX

Appendix: (a) The income-environment relationship under different policy and institutional scenarios. (b) Reduced-form environmental Kuznets curve: The role of policy



Source: Panayotou, 1997