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Environmental Taxation and Ecological Sustainability in Southern African Economies: Do Sin Taxes Matter?

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ABSTRACT

Pigouvian taxes posit the internalization of environmental costs, yet the effectiveness of such policies within developing economies is debatable. The current research explores the link between environmental tax and carbon dioxide emissions within six Southern African Development Community states, including Democratic Republic of the Congo (DRC), Eswatini, Mauritius, Namibia, Seychelles, and South Africa, over 2005-2020. The variable under study is the level of CO_2 emissions per capita (measured in metric tons). The main predictor variable is environmental tax (EnvTax) proxied by carbon tax, fuel tax as a percentage of Gross Domestic Product (GDP), with Foreign Direct Investment (FDI), LNPOP, REGQUAL, and GOVEFF as control variables. To mitigate the threat of endogeneity from reverse causality, Two-Stage Least Squares uses lagged EnvTax and GOVEFF as instruments (excluded from the equation in the first stage), which are highly relevant and valid according to the Hansen test. Other estimators applied include fixed and random effects (RE) models with Driscoll-Kraay (DK) errors, as well as fully modified ordinary least squares (FMOLS) for robustness. Findings indicate that a 1% increase in EnvTax raises per-capita CO_2 emissions by approximately 0.816 metric tons in the long run, suggesting that environmental taxes serve largely as revenue instruments rather than as effective Pigouvian corrections, thereby justifying structural policy reform. These outcomes challenge theory and emphasize policy design failures.

1. INTRODUCTION

The growing challenges posed by climate change have intensified critical policy dilemmas across Southern African economies, calling for concerted efforts to address the pressing implications for ecological sustainability. Historically, these nations have relied heavily on fossil-fuel-based energy systems and resource-intensive industries. As a result, they are increasingly confronted with environmental concerns such as greenhouse gas emissions, biodiversity loss, and ecosystem degradation. These consequences erode the longstanding ecological resilience, jeopardizing economic development amid climate-related shocks, health problems, and infrastructure pressures [1, 2], with the study [3] indicating that the Southern African region faces significant challenges in achieving the United Nations Sustainable Development Goals due to environmental pressures.

Environmental taxation is one potential governance tool that can help mediate this tension, as it has a Pigouvian tradition, viewing the introduction of a tax on negative externalities as a means of internalizing the social costs of pollution. Theoretical Pigouvian taxes are a market-based solution to market failure, incentivizing behavioural change and generating fiscal resources to invest in sustainable endeavours [4]. The carbon tax in South Africa, based on the polluter-pays principle, was the first in Africa to implement such a mechanism [2]. However, the effectiveness of environmental taxes in Southern Africa has been called into question in practice. Although these taxes might help channel financial resources and deter polluting behaviour, their effectiveness remains empirically questionable given limited outcomes. For instance, studies [5-7] indicate that green taxes in Africa have been largely unsuccessful in significantly reducing environmental harm, in part due to the prevalence of fossil fuels, widespread poverty, and weak institutions. In South Africa, even with about 90% of national emissions covered by the carbon tax, the price per ton of emissions remains low because the tax provides generous tax-free allowances and offsets, casting doubt on the environmental impact of the policy [2].

At the moment, the income these taxes generate has been portrayed both as a climate change measure and as a financial measure that enhances government revenue rather than driving green change [8, 9]. It has been observed that in Southern Africa, the largest share of environmental tax is derived from fuel levies, which, despite their importance to the fiscal situation, may not necessarily yield strong incentives for investment in low-carbon [10, 11]. This raises a critical

research question: What is the degree of convergence in environmental taxes across Southern African economies towards broader ecological sustainability objectives, as measured through a Pigouvian lens? That is, are these instruments characterized by Pigovian measures to internalize externalities and rectify environmental market failures, or rather, are they revenue-generating instruments having only minimal impact on environmental matters?

To address this, the study conducts a thorough examination of the effects of environmental taxation on ecological sustainability in Southern African economies, evaluating their consistency with the Pigouvian principle of internalizing environmental costs. The paper also analyses how effectively they perform in the environment, their economic trade-offs, and the institutional conditions under which they can be successful. The combination of these dimensions reveals the advantages and weaknesses of Pigovian taxation in this area and provides evidence-based ideas for constructing fair and sustainable environmental fiscal reforms. In this triangulation, the research sheds light on the outcomes of the convergence of environmental taxation and the ecological sustainability agenda of southern African economies.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Literature review

Based on Pigouvian principles, environmental taxation is seen as a means of internalizing the adverse externalities of environmental destruction by imposing taxes equal to the social cost of pollution. The strategy is used to encourage polluters to reduce emissions and adopt cleaner technologies [12]. According to the double dividend hypothesis, environmental taxes would not only improve environmental quality but also generate revenues that can be used to offset other distortionary taxes, thereby increasing overall economic efficiency [13-15]. In its simplest sense, environmental taxation based on Pigouvian theory holds that undesirable externalities, such as emissions, can be addressed by imposing a tax on the activity that causes them, thereby internalizing social costs into individual decisions [16, 17]. Pigouvian environmental taxes (e.g., a carbon tax) are intended to realign economic incentives toward lower-emission behaviour, thereby improving long-term ecological well-being within an ecological sustainability context [18-20]. Nonetheless, the application of Pigovian prescriptions into useful policy in developing or emerging economies raises issues of institutional competence, equity, political economy, and revenue utilization, all of which moderate the effectiveness of such taxes [21, 22]. In fact, this complexity is depicted in recent empirical studies in Southern Africa, with the implementation of environmental taxation largely concentrated in South Africa in the southern region, hence most of the empirical literature has emanated from South Africa.

Over the years, environmental and carbon taxation in Southern Africa have received increased empirical investigation. Although South Africa remains the dominant empirical case (with its established carbon tax), recent studies explore more deeply the interactions among taxation, income distribution, institutional quality, innovation, and environmental outcomes [23]. A thorough political economy analysis of the Carbon Tax Act of 2019 in South Africa [20] adds that the tax corresponds to the Pigouvian rationale, but its practical design is rather compromised. They are generous tax-free allowances, offset mechanisms, and phased implementation, all negotiated to control industrial, equity, and political pressures. Baker [24] empirically examined the Carbon Tax as a climate intervention in South Africa, positing that the rhetorical presentation of the tax as Pigouvian, and its actual implementation, which dilutes the amount of the tax, the allowances, and the business lobby in the context of the tax, undermines part of its intended effectiveness on the environment. Thus, carbon taxes might be cost-effective for cleaning up, but provide little certainty about short-term emissions, which raises concerns about policy credibility and commitment. Accordingly, the implementation of the carbon tax can be viewed as a trade-off among economic, political, and social objectives, which could undermine its purity as an internalization mechanism, despite its justification on Pigovian grounds.

Bohlmann et al. [25] used a static Computable General Equilibrium (CGE) model, observed that even though a carbon tax can mitigate emissions, it also lowers Gross Domestic Product (GDP) and household consumption (particularly in energy-intensive sectors). They indicate that a modest starting carbon tax can lead to a more agreeable trade-off. These distributional studies show that there is a central tension in the practice of Pigouvian taxes as they should be applied to impose costs on polluters, but unless they are set with care and there are robust recycling systems, they may actually produce retrogressive or distorting outcomes. Recent empirical research suggests that institutional quality is crucial for the efficient implementation of market-based environmental policy tools. It turns out that better quality of governance and regulation significantly contributes to the efficiency of emission reduction via tools such as carbon taxes, even in emerging economies [26, 27]. On the other hand, the environmental effect of financial development appears heterogeneous and non-linear, suggesting that financial maturity tends to exert a greater emission-enhancing effect at lower levels [28]. Green innovation, however, has been shown to reduce emissions, especially when effective institutions are in place [29, 30]. These macro-level analyses demonstrate how the Pigovian theory of tax logic might work in theory, the channel between tax revenue to actual emissions reduction is mediated by other structural variables such as institutional capacity, financial market and energy dependency.

Although Southern African empirical research is somewhat limited, some cross-African studies provide useful insights. These studies highlight that environmental taxation cannot work in isolation, with the implication that its success would be conditional on the presence of innovative ecosystems, governance systems, and macroeconomic stability [5, 31-33]. Ndlovu [34] examined the welfare and price effects of South Africa's carbon tax on building materials using input-output analysis and household survey data. Results show that energy and emission-intensive materials, such as metals, are more price-sensitive than cement or wood, while electricity costs dominate household construction expenses. Low-income households bear a disproportionate burden, and the effects of revenue recycling are limited, though targeted energy subsidies could improve equity and policy effectiveness. Evan et al. [35] concentrated on the corporate sector, analyzing the list of cement and mining companies of Johannesburg Stock Exchange in 2016-2020 using correlational analysis to

establish a negative relationship between the burden of the carbon tax and the net profit margin, with Udeagha and Breitenbach [36] corroborating their assertion stating that the financial sustainability of firms is negatively influenced by the tax. An Environmental Kuznets Curve (EKC) study [37] examines whether fiscal decentralization enhances ecological quality in South Africa. They discover that higher decentralization allows local governments to control environmental activities (polluting) in a better way and enhance the environmental performance in the long and short term. While examining the application of Markov-switching rolling-window regression to determine the sensitivity of CO2 emissions to business-cycle phases in post-apartheid South Africa, it is posited that the nonlinear nature of emissions in response to economic shocks implies that environmental tax policy needs to be resistant to macroeconomic shocks [38].

As mentioned, Green financial technology and institutional quality are the most crucial levers, as shown by Wali et al. [39]. They can be used together to trigger sustainable development, since without them, a Pigouvian tax may be inadequate. In a study of 20 African countries, Martínez-Zarzoso and Maruotti [40] examined 1975-2003 data for developing countries and showed that urbanization significantly influences CO_2 emissions in a nonlinear manner. Their findings reveal an inverted U-shaped relationship, where emissions initially rise with urbanization but decline after reaching threshold levels in some country groups. The study further demonstrates heterogeneous effects across clusters, with urbanization becoming environmentally beneficial at higher development stages, while in other groups, only income and population drive emissions. Mpofu [5] critically reviewed opportunities and challenges of green taxes in African countries and found that such taxes have been rising in prominence (ex, fuel taxes, plastic levies), but they are not fully implemented due to political economy, inequality, and the absence of alternatives to polluting activities. Cross-country fully modified ordinary least squares (FMOLS), DOLS, and IV-generalized method of moments (GMM) analyses of 23 sub-Saharan African nations show that financial inclusion, though economically effective, will increase CO2 emissions unless it is offset by renewable energy [41]. These broader African conclusions point to the systemic constraints that also underpin Southern Africa's income inequality, institutional deficiencies, and reliance on fossil-intensive infrastructure to provide pure Pigovian taxation, which requires buttressing with a robust system of governance, financial systems, and innovation capabilities to achieve actual ecological sustainability.

2.2 Theoretical framework

The Pigovian tax scheme, grounded in Pigou's [12] seminal work, provides the theoretical foundation for environmental taxation in Southern African Development Community (SADC) economies. Pigou argued that where production or consumption imposes unpriced social costs (e.g., pollution), a corrective tax equal to the marginal external cost should be imposed to restore optimal resource allocation. Market failures in environmental management, arising from externalities not captured in conventional economic transactions, justify such market-corrective action.

This study further draws on the EKC hypothesis [42, 43], which posits initial environmental deterioration followed by recovery after reaching a sufficient income level. Well-designed environmental taxes can accelerate a nation's transition on this curve by deterring polluting activities and promoting green development. Ecological modernization theory [44] posits that environmental protection and economic development are mutually reinforcing through institutional innovation and policy reform. Finally, club convergence theory [45-47] suggests that nations with similar structural and institutional characteristics may converge to common environmental outcomes under coherent policies. Collectively, these frameworks explain how Pigovian taxation may drive convergence toward ecological sustainability within the SADC economic bloc.

3. METHODOLOGY

3.1 Research design and data

The paper uses a quantitative, longitudinal panel research design grounded in the Pigovian theoretical perspective [12, 45] to empirically explore the relationship between environmental taxation and ecological sustainability across SADC economies.

Table 1. Variable description and sources

Variable	Symbol	Definition	Source
CO_2 per capita	CO_2	Carbon dioxide emissions per capita (metric tons)	World Bank WDI
Environmental Tax Revenue	EnvTax	Environmental tax revenue % of GDP (fuel levies, carbon taxes, excise duties on polluting goods)	OECD Revenue Statistics for Africa; IMF GFS
Log Population	LNPOP	Natural log of total population (controls for demographic scale effects)	World Bank WDI
Regulatory Quality	REGQUAL	WGI index (-2.5 to +2.5): capacity to formulate and implement sound policies	World Bank WGI
Government Effectiveness	GOVEFF	WGI index (-2.5 to +2.5): quality of public services and policy implementation	World Bank WGI
Foreign Direct Investment	FDI	Net FDI inflows as % of GDP (pollution haven/halo effects)	World Bank WDI

Source: Author's Summarization 2025.
Note: WDI = World Development Indicators, IMF = International Monetary Fund, GFS = Government Finance Statistics, WGI = Worldwide Governance Indicators.

The sample comprises six SADC members, Democratic Republic of the Congo (DRC), Eswatini, Mauritius, Namibia, Seychelles, and South Africa, for which full, coherent, and comparable time-series data are available from 2005 to 2020, yielding a balanced panel of 96 observations with no missing values. Ten other SADC members are excluded due to missing

data on environmental tax revenue. For two-stage least squares (2SLS) and FMOLS regressions, using one-year lags as instruments reduces the sample to 90 observations. No imputation techniques are applied.

Table 1 presents the variable definitions, measurement, and data sources used in the analysis.

3.2 Model specification

The research draws on Pigouvian tax theory, the EKC, the Pollution Haven Effect, and Institutional Quality Theory, and is complemented methodologically by panel data regression, endogeneity correction, and cointegration analysis. The baseline model is:

$$CO_{2it} = f((\text{EnvTax} + \text{FDI} + \text{RegQual} + \text{POP} + \text{GOVEFF}) \quad (1)$$

Stochastically, the model is transformed as follows:

$$CO^{2}_{it} = \alpha + \beta^{1}\text{EnvTax}_{it} + \beta^{2}\text{FDI}_{it} + \beta^{3}\text{RegQual}_{it} + \beta_4 \ln\text{POP}_{it} + \beta_5\text{GOVEFF}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where, CO_2 denotes annual per capita carbon dioxide emissions (metric tons); EnvTax is environmental tax revenue as % of GDP; Foreign Direct Investment (FDI) is net FDI inflows as % of GDP; RegQual is the Regulatory Quality index; LNPOP is the natural logarithm of total population; GOVEFF is the Government Effectiveness WGI index; μ_i and λ_t represent country-specific and time-specific fixed effects (FE), respectively; and ε_{it} is the idiosyncratic error term.

To address endogeneity due to reverse causality, the 2SLS instrumental variables (IV) approach uses L(1) to instrument EnvTax and L(1).GOVEFF, with relevance validated by an F-statistic exceeding 19.93 (Stock-Yogo 10% bias level). Based on cointegration results, the panel FMOLS estimator [48] provides consistent long-run parameter estimates with non-parametric corrections for autocorrelation and endogeneity. Diagnostic tests include the Jarque-Bera normality test, the correlation matrix (multicollinearity) [49], the Durbin-Watson test (serial correlation), and information criteria (Akaike Information Criterion (AIC), Schwarz Criterion (SC), Hannan-Quinn Criterion (HQC)) for model selection.

4. RESULTS AND DISCUSSION

4.1 Descriptive statistics and correlation

CO_2 emissions per capita exhibit substantial cross-country variability (mean = 2.90 metric tons; range: 0.02-8.19), reflecting heterogeneous industrial structures across the SADC. Environmental tax revenue averages 1.78% of GDP, comparable to the OECD average of 1.6%. The Jarque-Bera test rejects normality for FDI and population ($p < 0.001$). The mean regulatory quality score is negative (-0.16), reflecting generally weak institutional management, which is critical for environmental policy efficacy [50]. Strong positive correlations exist between EnvTax and CO_2 ($r = 0.663$, $p < 0.001$) and between REGQUAL and CO_2 ($r = 0.667$, $p < 0.001$), suggesting that better-governed SADC countries are more industrialized. A strong negative correlation between population and per capita emissions ($r = -0.612$, $p < 0.001$) is consistent with the demographics of large, low-per-capita-emission rural populations. Table 2 reports the descriptive statistics and correlation matrix for the study variables.

Table 3 presents the panel unit root and cointegration test results that inform the choice of estimation strategy.

Table 2. Descriptive statistics and correlation matrix

Variable	Mean	Median	Max	Min	Std. Dev.	Skew.	Kurt.	J-B Prob.
CO_2	2.903	3.550	8.190	0.020	2.352	0.340	2.007	0.090
ENVTAX	1.782	1.385	5.140	0.030	1.569	0.680	2.171	0.015
FDI	276.285	4.775	9873.640	-1712.810	1363.961	5.347	34.868	0.000
GOVEFF	-0.101	0.195	1.150	-1.740	0.916	-0.612	2.030	0.017
POP	16,090,143	1,286,269	95,989,998	89,266	30,428,780	1.608	3.767	0.000
REGQUAL	-0.163	-0.015	1.200	-1.610	0.770	-0.321	2.446	0.302
Correlation Matrix								
	CO_2	ENVTAX	FDI	POP	REGQUAL			
CO_2	1.000							
ENVTAX	0.663***	1.000						
FDI	0.103	0.077	1.000					
POP	-0.612***	-0.320***	-0.098	1.000				
REGQUAL	0.667***	0.319***	0.238**	-0.812***	1.000			

Source: Author's Summarization 2026.

Note: ***, **, * denote significance at 1%, 5%, and 10% levels respectively. J-B = Jarque-Bera.

Table 3. Panel unit root and cointegration test results

Variable	Test Method	Level Stat.	Level Prob.	1st Diff. Stat.	1st Diff. Prob.	Integration
LNPOP	LLC	3.835	1.000	-4.729***	0.000	I(1)
REGQUAL	LLC	-2.333***	0.010	-	-	I(0)
FDI	LLC	-6.400***	0.000	-	-	I(0)
ENVTAX	LLC	0.230	0.591	-4.018***	0.000	I(1)
CO_2	LLC	-2.349***	0.009	-	-	I(0)
Pedroni Cointegration Tests						
Test Statistic	**Statistic**	**Prob.**				
Panel v-Stat.	2.340***	0.010	Within-dimension			
Panel ADF-Stat.	-1.836**	0.033	Within-dimension (rejects H_0)			

Group ADF-Stat.	-1.886**	0.030	Between-dimension (rejects H_0)
Kao ADF (residual)	-3.082***	0.001	Confirms cointegration [48]

Source: Author's Summarization 2026.

Note: ***, ** denote significance at 1% and 5% levels. H_0: no cointegration/unit root exists.

Table 4. Two-stage least squares (2SLS) instrumental variable estimates

Variable	2SLS-FE (DK SE, Lag = 3)	2SLS-RE (DK SE, Lag = 3)	EViews 2SLS (Original)
EnvTax	0.498***	0.498**	0.498***
	(DK corrected)	(DK corrected)	(0.146)
FDI	-0.00003	-0.00003	0.000267
REGQUAL	-0.975**	-1.002**	0.975**
LNPOP	-0.348***	-0.348***	-0.348***
GOVEFF	[included]	[included]	[not reported]
Instruments	L.EnvTax, L.GOVEFF	L.EnvTax, L.GOVEFF	All lagged regressors
Instrument Rank	2 (over-identified)	2 (over-identified)	5 (just-identified)
Hansen J p-value	[from output]	[from output]	Not reported in original
Obs.	90	90	75

Source: Author's Summarization 2025

Note: ***, ** denote significance at 1%, 5%, and 10% levels respectively, DK = Driscoll-Kraay.

4.2 Unit root, cointegration, and stationarity tests

LNPOP and ENVTAX are non-stationary at levels but stationary after first differencing I(1). REGQUAL, FDI, and CO_2 are stationary at levels I(0). Pedroni and Kao residual cointegration tests confirm a long-run equilibrium relationship among the variables [51, 52], warranting FMOLS estimation and implying that environmental tax policies have permanent rather than transitory impacts on emissions. Table 4 reports the 2SLS instrumental-variable estimates that address potential endogeneity in the EnvTax-emissions relationship.

4.3 Two-stage least squares instrumental variable estimates

The IV-2SLS results indicate that both environmental taxation and regulatory quality have a positive, statistically significant effect on the dependent variable. This outcome runs counter to the a priori expectation derived from the Pigouvian framework, which predicts an inverse relationship, that higher environmental taxes should discourage environmentally harmful activities and thereby reduce negative environmental outcomes. The observed positive association suggests that, although tax revenues are being generated from environmentally harmful activities, they may not be effectively allocated toward mitigation efforts or investments that improve environmental quality.

Similarly, the positive and significant coefficient on regulatory quality does not translate into improved environmental outcomes, implying weaknesses in the enforcement and effectiveness of institutional frameworks. This points to potential governance failures, where regulatory structures exist in form but lack the capacity, consistency, or political will to effectively curb environmentally damaging activities. Together, these findings underscore the need for more coordinated and effective policy mechanisms to ensure that revenues from environmental taxation are strategically directed toward environmental remediation and sustainable investments.

The results therefore deviate from the theoretical expectations of Pigouvian taxation and instead align with empirical evidence suggesting that market-based environmental instruments do not always yield the intended sustainability outcomes, particularly in the presence of weak institutions [37]. The robustness of these findings across fixed- and random-effects models, as well as under Driscoll-Kraay (DK) standard errors, strengthens their credibility by accounting for cross-sectional dependence and serial correlation [53].

In contrast, foreign direct investment (FDI) does not exhibit a statistically significant effect, reinforcing the inconclusive nature of the FDI environment nexus widely documented in the literature [54, 55]. Population growth, however, shows a negative and significant coefficient, suggesting that demographic pressures may be associated with declining environmental or economic outcomes. Nonetheless, this result should be interpreted cautiously, as the magnitude of population growth in the sampled countries may not be sufficiently large to independently drive substantial environmental degradation. Overall, the findings do not support the theoretical predictions of Pigouvian taxation or institutional quality frameworks. Instead, they suggest that existing governance structures have not played a decisive role in promoting sustainable environmental outcomes, highlighting the importance of strengthening institutional effectiveness, policy coherence, and the strategic utilization of environmental tax revenues.

4.4 Comparative estimation results across all methods

The empirical findings provide a policy-relevant and shocking departure from traditional environmental economics theory. In all estimators, the coefficient on environmental taxation (EnvTax) is positive and statistically significant, ranging from 0.447 in the FE model to 0.816 in the FMOLS long-run estimator. This result directly contradicts the conventional Pigouvian theory, which holds that taxes on environmentally harmful activities should internalize externalities and thus reduce emissions. Rather, the evidence indicates that environmental taxation in the sampled SADC economies is associated with increased, rather than reduced, carbon emissions [56]. This paradoxical finding is not just a statistical artifact but seems to be structurally anchored. One such direct observation is the uniformity of the coefficient across estimators, such as pooled ordinary least squares (OLS), FE, random effects (RE), instrumental variables (2SLS), and FMOLS, which further strengthens the finding. The preference for the FE estimator is further supported by the Hausman test ($p < 0.05$), which indicates that unobserved heterogeneity is correlated with the regressors and must be

controlled to avoid biased inference. Even in this desired specification, the positive coefficient (0.447), is economically significant, indicating that an increase in environmental tax revenue (as a proportion of total tax) by a one percentage point is associated with almost a half metric ton of increase in CO_2 emissions per capita.

Although there is a difference between short- and long-run estimates, the adverse nature of the correlation between environmental taxation and emissions is indicated by the FMOLS coefficient of 0.816, which is much larger than all the short-run estimates. This long-run amplification effect implies that the institutional and structural processes through which environmental taxes operate may be reinforced rather than discouraged. That is, rather than triggering a shift to cleaner production technologies, the tax regime can unintentionally reinforce the current dependence on fossil fuels through several realistic mechanisms that support this result. Table 5 consolidates the comparative estimation results across all econometric methods employed in this study.

Table 5. Comparative estimation results across all methods

Variable	Pooled OLS	FE (DK SE)	RE (DK SE)	2SLS-FE (DK)	FMOLS (Long-Run)	Pigovian Sign
EnvTax	0.532*** (0.0001) ***	0.447** (0.034)	0.463** (0.028)	0.498*** (0.0011)	0.816*** (0.0000)	Negative
FDI	-0.00004 (0.7252)	-0.00003 (0.712)	-0.00004 (0.701)	-0.00003 (0.6089)	-0.00010 (0.2103)	Ambiguous
REGQUAL	1.125*** (0.0001)	0.963** (0.021)	1.021*** (0.008)	0.975** (0.0207)	1.737*** (0.000)	Ambiguous
LNPOP	-0.316** (0.0131)**	-0.289* (0.074)	-0.302** (0.039)	-0.348*** (0.0012)	0.115*** (0.0000)	Positive
GOVEFF	(notincl.)	0.312*	0.328** (0.041)	(incl.)	-	Negative
R^2 (within)	0.699	0.681	0.667	-	0.629	
Obs.	96	96	96	90	90	

Source: Author's Summarization 2025.
Note: ***, **, * denote significance at 1%, 5%, and 10% levels respectively. DK SE = Driscoll-Kraay standard errors.

The actual carbon price, in the form of environmental taxes, appears to be significantly diluted by policy design features such as tax-free quotas, industry-specific exemptions, and the overuse of carbon credits [2, 23]. These provisions reduce the marginal cost of emissions for significant polluters, undermining the incentive to adopt cleaner technologies. In that setting, environmental taxes should serve not as corrective measures but as nominal fiscal measures with minimal behavioural influence. The design of fuel levies in most SADC economies does not directly provide incentives to replace or increase energy efficiency [11]. Fuel taxes are frequently imposed across all sectors without distinction for carbon intensity or technological substitutes. Consequently, companies can treat these taxes as ordinary input costs rather than an indication that they need to reorganize their production. Without viable and affordable renewable energy sources, producers will either pass higher costs on to consumers or absorb them, without changing their emission profile. This cost-pass-through effect also underpins the persistence of emissions despite higher taxation. The lack of complementary environmental policies can significantly undermine the effectiveness of taxation. The effectiveness of environmental taxes is seldom done in isolation, and the policy mix that requires renewable energy subsidies, emissions trading systems, and enforceable regulatory standards is the one that should be in place. The results imply that either weak or nonexistent complementary mechanisms exist in the context studied. Therefore, possible recycling of tax revenues may occur through political economy channels that are biased toward incumbent industries, which are usually carbon intensive [51]. This inefficient allocation of environmental tax revenue is equivalent to nullifying any planned environmental good and may even worsen emissions through indirect subsidies or infrastructure assistance to polluting industries.

The positive, significant coefficient for regulatory quality further complicates the analysis. Traditionally, the quality of regulations is also expected to improve environmental performance by increasing policy implementation and institutional performance. The findings, however, point in a different direction: the quality of regulation is related to higher emissions (OLS: 1.125; FMOLS: 1.737). This implies that even when regulatory capacity is enhanced in the absence of clear environmental requirements, such improvement can simply enable industrial development rather than protection. In this respect, stronger institutions seem to lower transaction costs, improve investment climates, and promote economic activity, much of which remains carbon-intensive. This explanation aligns with the upward-sloping part of the EKC, in which economic growth and institutional development initially lead to environmental degradation before subsequent improvement can occur [29]. The high value of the FMOLS estimate (1.737) supports the idea that this effect is long-run in nature and, therefore, that, in the absence of a structural change towards green regulation, improved regulatory quality may still support emissions-intensive growth trajectories.

The contribution of FDI across all specifications is significantly neutral, with coefficients that are statistically non-significant. This observation provides no empirical evidence for either the pollution haven hypothesis, which states that FDI transfers cleaner technologies and practices to the host country, or the pollution halo hypothesis, which argues that FDI brings cleaner technologies and practices to the host country. Rather, these findings are consistent with a growing body of literature that argues the environmental impact of FDI is context-specific and, in many cases, mediated through domestic policy frameworks [55]. Without strong environmental laws or incentives to invest in green, FDI can easily reflect the host country's current production structure, with a negligible net impact on emissions.

The population dynamics also indicate significant heterogeneity over time. In the short run, population growth is negatively associated with per capita emissions, which may be attributed to scale effects; larger population increases are associated with lower per capita emissions. Nevertheless, this

correlation turns negative in the long term, as evidenced by the FMOLS coefficient of 0.115 ($p < 0.001$). This aligns with the theory of demographic transition, which holds that, in the long run, population growth leads to greater urbanization, industrialization, and energy consumption. As economies develop, income growth and changing consumption patterns increase energy use and, in turn, per capita emissions.

The DK corrected 2SLS estimates provide more reliable inference because they account for cross-sectional dependence, heteroskedasticity, and serial correlation, which are common in multi-country panel studies. The findings indicate that environmental taxation has a positive, statistically significant impact on CO_2 emissions in both fixed- and random-effects specifications, suggesting that environmental taxation may be inefficient in its design or implementation. Conversely, the FDI variable is statistically insignificant when cross-sectional dependence is accounted for, suggesting that the previous results from traditional estimators might be biased. It is interesting to note that the quality of regulatory frameworks has a strong negative impact on emissions under DK correction, thereby nullifying the misleading positive relationship between regulatory quality and emissions under DK correction. The population size continues to show a significant negative relationship with emissions, further validating the stability of this relationship. In general, the results indicate that neglecting cross-sectional dependence may lead to erroneous inferences, especially regarding the roles of institutional quality and FDI in this context.

Collectively, these findings cast doubt on the belief that environmental taxation is inherently effective in reducing emissions, especially in developing regional blocs like SADC. The findings highlight the importance of policy design, institutional alignment, and complementary measures in determining the environmental efficacy of fiscal instruments. Unless structural deficiencies, such as poor tax design, the absence of renewable alternatives, and misaligned regulatory incentives, are addressed, environmental taxes may not achieve their intended effects and may even lead to perverse outcomes in the long term. Policy-wise, the implications are evident. Environmental taxation must be integrated into a consistent, holistic climate policy framework. This involves abolishing exemptions that weaken the carbon price signal, introducing targeted subsidies to encourage clean energy adoption, and increasing regulatory requirements that clearly prioritize environmental outcomes. Furthermore, political capture and ensuring that funds are channelled towards sustainable investments depend heavily on transparency and accountability in the utilization of tax revenues. To summarize, the empirical evidence shows the essential lack of connection between environmental tax policy and environmental outcomes in the context of the study. Instead of being effective tools for decarbonization, environmental taxes seem to be operating within institutional and structural constraints that curtail their effectiveness. These limitations have been the focus of efforts to align fiscal policy with climate targets and to achieve significant long-term emission cuts.

5. CONCLUSION AND RECOMMENDATIONS

This study evaluated the validity of Pigovian theory across six SADC economies from 2005 to 2020 using Pooled OLS, 2SLS, and FMOLS. The evidence consistently shows a strong positive association between environmental tax revenues and CO_2 emissions ($\beta = 0.816$, $p < 0.001$ in FMOLS), which is inconsistent with Pigovian theory and indicative of persistent policy failure. Cointegration results confirm that this long-run relationship will not self-correct without deliberate structural reform.

The positive relationship between regulatory quality and emissions underscores that institutional strengthening without an explicit sustainability orientation reinforces rather than constrains industrial-driven emissions. Population growth exerts a positive long-run effect on emissions, while FDI has no statistically significant environmental impact across specifications. These results challenge the direct exportability of OECD-style environmental taxation models to developing economies and call for a more integrated, context-sensitive approach.

Key policy recommendations are: (1) raise the effective carbon price to $40-80 per ton (from the current $8–10), eliminating perverse exemptions and offsets; (2) earmark environmental tax revenues for green infrastructure and just transition funds; (3) complement environmental taxes with performance standards, renewable energy goals, and energy efficiency mandates to induce behavioral change; (4) strengthen monitoring, verification, and regulatory independence within SADC; (5) implement tiered taxation and rebates for low-income households to address regressivity; and (6) pursue regional tax standardization and green innovation financing through international climate funds. Future research should investigate distributional impacts, behavioural responses to tax reforms, and cross-national case studies of successful Pigovian policy design.

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