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Article

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Carbon tax adoption and foreign direct investment: Evidence from Africa

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ABSTRACT

The study investigates the effect of carbon tax adoption on foreign direct investment in Africa. We set up the Dynamic Stochastic General Equilibrium (DSGE) model and estimate it with the differenced GMM techniques. The data span from 1995 to 2019 and covers 43 Sub-Saharan African countries. Data is sourced from the World Bank's World Development Indicators. The findings show that the unmitigated effect of the carbon tax on FDI is repressive. However, if the revenue from the carbon tax is recycled into the economy, the carbon tax will have a significant positive effect on FDI. Hence, the findings corroborate the double dividend theory. The results further suggest that a carbon tax of around US\$ 8.5 per tonne is reasonable to enhance inward FDI but a carbon tax either above US\$ 25 per tonne or below US\$ 3 per tonne will be detrimental to the African region. Also, the entrenched negative relationship between FDI and taxes is worsened if the additional carbon tax is levied among high tax regimes countries than their counterparts. This study opens the frontiers to the discussions on the policy implications of carbon tax introduction on the free movement of international capital. Being among the few studies to examine the effect of the carbon tax on FDI, the study makes a significant contribution to the sparse literature in the African context. The use of a stepwise approach to estimate data based on reasonable assumptions can form the basis for future research to venture into areas where data is constrained. The policy implications are that (i) carbon tax per tonne below US\$ 3 or above US\$ 25 is detrimental to FDI, and (ii) the negative effect of the carbon tax on FDI can be overturned by efficiently reinvesting the carbon tax revenue in the economy.

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1. Introduction

Environmental sustainability has emerged as a critical global concern due to the escalating challenges posed by climate change, resource depletion, and pollution. In recent years, numerous studies have shed light on the urgent need for sustainable practices and their impact on various sectors of society. However, it is crucial to provide a comprehensive depiction of the importance of such studies, ensuring a strong foundation for further research and policy development. Yiadom et al. (2023), Bashir et al. (2022), and Vassiliades et al. (2022) have investigated central government actions that can drive environmental sustainability. Specifically, Bashir et al. (2022) advocated for the introduction of environmental taxes to deepen sustainability compliance at local and national levels. In a similar study, Bashir et al. (2021) provide valuable insights into the effectiveness of environmental taxes as a policy instrument for reducing energy consumption and promoting sustainable practices.

Furthermore, a bibliometric and systematic literature review from 1999 to 2019 on environmental taxes conducted by Bashir et al. (2021) reveals that environmental tax studies in developing countries, especially Africa, are marginalized. The lack of studies is evidenced by the absence of clear policy direction toward the development and introduction of environmental taxes.

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Our study discusses a specialized type of environmental tax known as a carbon tax. This study opens the frontiers to discussions on the policy implications of carbon tax introduction on the free movement of international capital. Being among the few studies to examine the effect of the carbon tax on FDI, the study makes a significant contribution to the sparse literature in the African context. The use of a stepwise approach to estimate data based on reasonable assumptions can form the basis for future research to venture into areas where data is constrained.

A carbon tax is an effective way to reduce carbon emissions, with potential reductions of up to 32% by 2030 (Gaspar & Amaglobeli, 2021). Despite concerns about the impact on the economy, research suggests that a carbon tax can enhance economic growth. For example, Sweden has reduced carbon emissions by 25% and expanded its economy by 75% since implementing a carbon tax in 1995. South Africa recently introduced a carbon tax and has already accumulated US\$175 million in revenue, with projections of mobilizing US\$1.87 trillion for developmental projects (Yiadom et al., 2023; Ofosu-Mensah Ababio et al., 2023; Gaspar et al., 2019; World Bank, 2020). Empirical evidence also confirms that carbon taxes reduce carbon emissions (Conefrey et. al., 2013).

However, only 27 countries have implemented a carbon tax as of 2020, despite two-thirds of submitted Nationally Determined Contributions considering its use to achieve carbon emission reduction targets. Gaspar et al. (2019) suggest that countries that have implemented carbon taxes are largely not charging the recommended rates, likely due to concerns about the impact on local firms and international competitiveness for capital. Also, the current global average carbon tax of \$3 per ton is far below the recommended rates of \$50 and \$25 per ton for developed and developing countries, respectively, according to the 2015 Paris Agreement. The slow pace of the adoption of carbon tax policies requires investigation.

Africa has been particularly slow to adopt carbon taxes, with only South Africa implementing a tax of \$8 per ton in 2019. Several factors contribute to this slow implementation, including high corporate taxes and the informal nature of economies in the region, which limits the tax bracket to a few formal sector taxpayers. The introduction of a carbon tax on top of existing high taxes could have complex implications, especially for already burdened taxpayers. Policymakers in Africa need to holistically assess the wholesale recommendation of the carbon tax before implementing it.

The introduction of a carbon tax in Africa could hurt the competitiveness of the domestic economy, according to Zhang and Baranzini (2004) and Marron and Toder (2014). The former study suggests that the reduction in competitive advantage is the main reason why many countries are hesitant to implement a carbon tax. Marron and Toder (2014) study indicates that the carbon tax reduces international competitiveness and can lead to increased demand for cheaper imported goods, making it difficult for firms to expand into international markets. However, the negative impact of the carbon tax on the domestic economy can be minimized if there is a global consensus to implement the tax in every country and almost at the same rate. But due to the sovereignty of nations, achieving such a recommendation is almost impossible.

Further, Voßwinkel and Birg (2018) found that the imposition of a unilateral carbon tax could lead to firm relocation to a foreign country with a minimal or no carbon tax. Their study shows that if two countries simultaneously set carbon taxes, it reduces the chances of relocation. The theory of international tax competition explains that tax policies are the key determinants in accounting for foreign direct investment (FDI), as demonstrated by Oates (1972).

Additionally, Xu and Wu (2021), Boachie Yiadom and Mensah (2021) and Boly et al. (2020) examined the effect of tax policy on inward FDI and reported that a cut in corporate taxes indeed increases the net inflow of FDI and can influence the FDI receipts of neighboring countries in the short and long term. Although no study has specifically examined the relationship between the carbon tax and FDI, this present study relies on the international tax competition theory and posits that carbon tax adoption could dwindle FDI in the host country. We make this claim based on the strong relationship between FDI and taxes (Mensah et al., 2021; Gao & Liu, 2021; Xu & Wu, 2021; Damgaard et al., 2019; Oates, 1972). Damgaard et al. (2019) have shown that countries with low corporate taxes attract high FDI and that foreign firms, in particular, are sensitive to additional taxes. Subsequently, this study suspects a similar behavior between FDI and carbon tax.

The relevance of this study is not only because it is the first to examine the effect of the carbon tax on FDI but also contributes to the sparse literature in the African context. Carbon tax introduction and its effect in the African region are almost missing in the vast literature reviewed for the present study. But Africa possesses unique characteristics in the carbon tax and climate change mitigation debate that need considerable attention. It will be interesting to know how a capital-trapped economy with a high corporate tax rate will implement a policy perceived to be damaging to the local economy and may deter foreign capital as well. In this paper, we examine the effect of the carbon tax introduction on foreign direct investment in Africa. We argue that imposing a carbon tax may deter foreign investors; hence, the study recommends a pragmatic approach of reinvesting the carbon tax revenue efficiently into the economy. The carbon tax reinvestment assumption hinges on the double dividend theory as suggested by Pearce (1991) Yang, Jiang, and Pan (2020), Freire-González and Ho (2019), and Radulescu et al. (2017) empirically verified the double dividend theory and concluded that plowing back carbon tax revenue minimizes the negative effect of the carbon tax on the economy.

In addition, this study fills in the carbon tax and international capital omissions in the literature. The debate on the carbon tax is skewed towards its deterrent nature and the ability to cut down carbon emissions without analyzing the implications of additional taxes on local economies. It is surprising to note that despite the deterrent nature of the carbon tax and the possibility of raising revenue for local and international governments, policymakers are hesitant to implement it. This study thinks that if carbon tax externalities are not addressed, its implementation will continue to be stalled.

The objectives of this study are threefold and are grounded on the international tax competition theory and the double dividend theory. These objectives include:

- i. To examine the impact of the carbon tax on FDI.
- ii. To estimate an ideal carbon tax rate that will be friendly to FDI.
- iii. To investigate the impact of carbon tax revenue on the relationship between carbon tax and FDI

Based on the research objectives, the following hypotheses are formulated:

Ho₁: carbon tax has no impact on FDI.

Ho₂: there is no ideal carbon tax that will be friendly to FDI.

Ho₃: carbon tax revenue has an impact on the relationship between carbon tax and FDI.

The paper is divided into five sections. [Section 1](#) introduces the study and discusses why countries are hesitant to implement carbon taxes. [Sections 2](#) and [3](#) provide literature and empirical modeling. [Section 4](#) discusses the results, while [Section 5](#) includes conclusions and recommendations.

2. Literature review

Environmental sustainability is a pressing global concern, and numerous studies have explored different aspects of this topic. This literature review examines several key articles that shed light on the environmental impacts of structural transition, foreign direct investment (FDI), environmental taxation, carbon taxes, and the role of FDI in environmental sustainability. Xie et al. (2018) assess the role of FDI in environmental sustainability using a spatial semiparametric panel approach. Their research sheds light on the spatial variations in the relationship between FDI and environmental sustainability. Shaari et al. (2023) examine the determinants of FDI in ASEAN + 3 countries, focusing on the role of environmental degradation. Their study emphasizes the need for effective environmental policies to attract sustainable FDI and mitigate environmental degradation. Yue et al. (2023) investigate the relationship between FDI and environmental performance, exploring the shadow prices of pollutants. Their findings provide insights into the potential positive impact of FDI on environmental sustainability.

In recent times, environmental taxation has emerged as a policy tool to incentivize sustainable practices and mitigate environmental degradation. This literature review examines key studies that investigate the impacts of environmental taxes on energy consumption, energy intensity, and

renewable energy consumption. Nchofoung et al. (2023) explore the link between green taxation and the adoption of renewable energy technologies on a global scale. Their study provides evidence of the positive influence of green taxation policies in promoting the uptake of renewable energy sources.

Bashir et al. (2021) provide empirical evidence on the heterogeneous impacts of environmental taxes on energy consumption and energy intensity in OECD countries. Their study highlights the variations in the effectiveness of environmental taxes across different countries, shedding light on the complexities and nuances of implementing such policies.

In a related study, Bashir et al. (2022) explore the role of environmental taxes and regulations in promoting renewable energy consumption in developed economies. Through empirical analysis, they demonstrate the positive impact of these policy instruments on renewable energy consumption, emphasizing the importance of supportive regulatory frameworks.

Furthermore, Bashir et al. (2021) conducted a bibliometric and systematic literature review on environmental tax publications. Their analysis provides insights into the existing body of knowledge on environmental taxation, identifying key themes, methodologies, and research gaps. This review serves as a valuable resource for researchers and policymakers in navigating the literature on environmental taxes.

2.1. Carbon tax, productivity, and capital movement

A carbon tax is a tax levied on coal, oil products, natural gas, and any product that requires the burning of carbon-based fuels in proportion to their carbon emission content (World Bank, 2020). The use of carbon tax as a carbon emission mitigation tool is reinforced by the 'polluter pays principle' (Pigou, 1952; OECD, 1993). The polluter pays principle attempts to place the environmental responsibility of carbon emissions at the doorstep of the primary emitters and those who benefit from it. In the absence of a polluter pays policy, market failure is entrenched, and the least emitters of harmful gases become the most affected (World Bank, 2020). Therefore, the deterrent nature of carbon tax fully addresses the requirement of the polluter pays principle.

More also, it has been confirmed in the literature that carbon tax is effective at reducing carbon emissions (Fu et al., 2021; Jia & Lin, 2020; Meng, Siriwardana, & McNeill, 2013). However, it is feared that carbon tax could reverse domestic economic developments (Evans, et. al, 2021; Xu & Wu, 2021; Voßwinkel & Birg, 2018; Marron & Toder, 2014; Zhao, 2011; Zhang & Baranzini, 2004). The perceived negative effect of the carbon tax on the local economy is stalling its global adoption.

Meng et al. (2013) have conducted studies using computable general equilibrium modeling (CGE) to examine the impact of a carbon tax on the environment and economy of Australia and selected Chinese provinces, respectively. Both studies have found that the carbon tax reduces carbon emissions but causes economic contractions. The effect of the tax on business operations increases operational costs, cuts down profit, and culminates in low capital for reinvestment, with greater incidence falling on capital than labor (Conefrey et al., 2013). Unequal levying of a carbon tax can retard sectoral competitiveness and make firms less productive, leading to the reluctance or refusal of countries to adopt carbon taxes, as evidenced by the United States' withdrawal from the Paris Agreement (Xie et al., 2018; Zhao, 2011).

Evans et al. (2021) and Marron and Toder (2014) suggest that a carbon tax can influence the productivity of local firms and how they compete both within and outside the borders of the domestic economy. The effect of carbon tax introduction will require firms to invest in new clean energy technologies, influencing economies of scale in the short run due to the possible changes in the cost of production, and at the structural level, it can change the industrial cycle by altering patterns in economic activities. The aggregated effect of these significant adjustments on the economy depends on how the transitions are managed, and a deliberate government policy is pivotal.

However, while previous studies have extensively researched the effect of the carbon tax on various economic indicators, the effect of the carbon tax on FDI is missing in the available literature (Xu & Wu, 2021). Thus, this study enriches the literature by examining how foreign capital (FDI) reacts to carbon taxes. Additionally, Conefrey et al. (2013) found that capital pays a greater part of the carbon tax than labor.

2.2. Theoretical foundation for carbon tax

The theory of international tax competition suggests that governments use taxes to encourage the inflow of economic resources and discourage their relocation. Research by Gao and Liu (2021) and Xu and Wu (2021) reveals a negative relationship between tax burden and FDI. Developing countries are more sensitive to tax rates, and FDI tends to locate in countries with lower tax rates. Marginal tax rate variations within an economic block contribute to the direction of inward FDI. The OECD has ranked the tax environment highly among the five key determinants of inward FDI. Boly et al. (2020) found that a cut in corporate taxes increases the net inflow of FDI and can influence the FDI receipts of neighboring countries in the short and long term. Thus, the effect of the carbon tax on the domestic economy should consider the theory of international tax competition and its influence on FDI.

While previous research has focused on the impact of corporate income tax on FDI, the present study narrows the argument to carbon tax. Unlike other taxes, the carbon tax has unique environmental implications, which make its design and administration distinct. A specific tax meant to stop pollution can impact a country's economic outlook and potentially deter FDI due to the free movement of capital. Therefore, a comprehensive assessment of the effect of carbon taxes is necessary, and remedial measures should be put in place.

Another gap in the existing literature is the lack of research on carbon tax dynamics in Africa, despite the region's unique characteristics, including reliance on foreign capital to finance developmental programs (Agbloyor et al., 2016). While Africa emits the least carbon dioxide globally, it has the potential to become one of the highest emitters if capital constraints are removed. Leke and Signé (2019) estimate that US\$1 trillion in capital investment can transform Africa into a manufacturing hub, which has implications for carbon emissions. Since most African countries are capital-trapped, FDI may be necessary to fill the capital gap, and examining the relationship between carbon tax and FDI will inform how FDI receipts contribute to carbon emissions. It is well documented that FDI is sensitive to the general tax environment, and carbon tax is no exception (Agbloyor et al., 2016).

Studies have shown that to achieve the full benefits of a carbon tax, complementary policies such as tax cuts and reliefs must be implemented to minimize the negative effects on the economy (Freire-González & Ho, 2019; Marron & Toder, 2014; Mathur & Morris, 2012; Yang et al., 2020). Revenue from carbon taxes can also be recycled into strategic sectors of the economy. However, designing a real-world carbon tax that deters emitters and promotes macroeconomic development is challenging, and tax rate, collection, and revenue use are key considerations (Marron & Toder, 2014). Carbon taxes may disproportionately affect low-income households due to their regressive nature (Mathur & Morris, 2012). To address this, Marron and Toder (2014) recommend a restructuring of the tax system to give tax credits or payroll tax cuts and support firms through corporate income tax reductions and subsidies. Carbon tax revenue can be used to create alternative sources of livelihood for affected households.

The double dividend theory supports using carbon tax revenue to offset the negative effect on the economy. Empirical and theoretical studies confirm the practicality and effectiveness of double dividends (Freire-González & Ho, 2019; Pearce, 1991; Radulescu et al., 2017; Repetto, Dower, & Geoghegan, 1992; Yang, Jiang, & Pan, 2020). Yang, Jiang, and Pan (2020) found evidence of the employment double dividend in China, while Freire-González and Ho (2019) confirmed that recycling carbon tax revenue by cutting taxes on labor, capital, and value addition can reduce the cost of carbon tax implementation and mitigate CO₂ emissions. Not recycling carbon tax revenue, however, can result in high carbon tax costs to the economy.

3. Method and data

3.1. Theoretical model

The DSGE approach captures macroeconomic shocks with opportunities to solve intertemporal optimization problems (Blanchard & Perotti, 2002; Ramey, 2016). The DSGE incorporates macroeconomic decisions by assuming preferences, regime changes, and resource constraints (Fernández-Villaverde et al., 2016). Its flexibility to track and forecast macroeconomic dynamics over time makes it appropriate for

policy experimentation (Fernández-Villaverde et al., 2016). The study employs the DSGE approach to examine the effect of carbon tax imposition on FDI and local output.

We start building the empirical model by considering a Cobb-Douglas production function grounded on Leeper et al. (2013).

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha} \quad (1a)$$

Where; 'Y' is output, 'K' is capital, 'L' is labour, and, α and $(1 - \alpha)$ are shares of capital and labour in output respectively.

Divide through by 'L' to derive the intensive form of (1)

$$\frac{Y_t}{L} = \frac{A_t K_t^\alpha L_t^{1-\alpha}}{L} \quad (1b)$$

For simplicity, we write this function in intensive form and normalize technology (A_t), leading to (2). Normalization of A_t is on the assumption that technology or technical progress is constant to focus on the variable of interest for the study, and in this case capital (K).

$$y_t = k_t^\alpha \quad (2)$$

The interest of this study is to estimate the effect of carbon tax introduction on capital (K). Hence, we assume that the government charges carbon taxes at ' τ ' per ton of carbon emitted. The effect of a carbon tax on the economy can be viewed from two points of view. It can be pushed forward to affect output prices. Given that household income is constant, there will be a cut in demand, and output will be affected. Conversely, the carbon tax can be pushed back to the factors of production: capital and labour (labour is omitted for convenience). We can estimate the carbon tax shock ' $\varepsilon_{\tau,t}$ ' on capital. Based on the Cobb-Douglas function, Ramey (2016) deduced the capital accumulation rule as:

$$k_t = \alpha k_{t-1} + \varepsilon_{\tau,t} \quad (3)$$

Where $\varepsilon_{\tau,t}$ is the carbon tax shock. Our empirical model is estimated based on equation (3) with a few modifications. In Equation (3), capital is reduced to FDI to examine the effect of a carbon tax on FDI. In (4) we introduce the lag of the dependent variable y_{t-1} based on Barro and Sala-i-Martin's (2003) economic convergence hypothesis, which suggests that poor countries will grow at a rate faster than rich countries, and therefore current economic developments depend on previous values.

3.2. Estimation strategy

The choice of empirical strategies significantly affects the outcomes and recommendations when examining the relationship between environmental risk and finance. The literature remains divided on the most suitable estimation strategies. Dziwornu et al. (2023), Yiadom and Abdul-Mumuni (2022), Yiadom et al. (2022), and Stern (2004) reviewed 79 studies and found that time-series studies favor ARDL and the Granger causality approach, while panel studies are undecided between fixed/random effects and GMM. This study supports the GMM approach, specifically instrumental variable system GMM, due to its ability to include the lagged dependent variable as a regressor.

In economic and financial modeling, the concept of 'history matters' holds significance. Consequently, the present value of FDI is not solely dependent on exogenous variables but also on the previous value of FDI received. Models that exclude the lagged dependent variable may be less efficient. Fixed or random effect models can yield biased and inconsistent estimates. The GMM approach addresses this by allowing for the inclusion of additional instruments. The instrumental variable GMM approach, introduced by Arellano and Bond (1991), resolves endogeneity issues and other estimation challenges. It improves efficiency and handles unobserved heterogeneity, omitted variable bias, and measurement errors.

The GMM approach has challenges, including uncertainty in selecting appropriate instruments, leading to weak instruments and small-sample bias. However, the Hansen/Sargan test helps assess instrument validity. The GMM has two variants: differenced GMM and system GMM. The choice depends on the estimation technique that improves the stability of the lagged dependent variable coefficient. The

appropriate model is selected using the Bond et al. (2001) model acceptance criteria, along with the Andrews-Lu information selection criteria (AIC, BIC, and HQIC) for model suitability.

To estimate the DSGE models, the GMM approach developed by Arellano and Bonds is used. According to Yiadom et al. (2024), Ababio et al. (2023), Fernández-Villaverde et al. (2016), and Ramey (2016), this method is considered efficient as it addresses the endogeneity issue typically found in OLS. The potential correlation between the lag-dependent variable in Equation (3) and the error term may cause persistent endogeneity if not addressed. The GMM approach provides additional instruments to address this type of problem, which the usual OLS may not be able to solve.

The empirical model is specified below:

$$fdi_{it} = \delta fdi_{it-1} + \gamma indexct_{it} + \omega indexctrev_{it} + \rho Control_{it} + \varepsilon_{it} \quad (4)$$

Where; ‘*i*’ and ‘*t*’ denote a country and time respectively.

fdi_{it} represents foreign direct investment,

fdi_{it-1} is the lag of foreign direct investment and is included based on convergence theory (Barro & Sala-i-Martin, 2003).

$indexct$ is the carbon tax index included based on the polluter pays hypothesis (Pigou, 1952),

$indexctrev$ is a measure of carbon tax revenue based on the double dividend hypothesis (Pearce, 1991).

$control$ is a set of exogenous explanatory variables selected based on their wide acceptance in the literature (Gao & Liu, 2021; Xu & Wu, 2021; Zhang & Baranzini, 2004). These variables include gross domestic per capita (gdp), net international trade (trade), education (edu), rule of law (rule), and domestic investment (inv). Detailed descriptions and computations of all the variables are explained in Table 1.

3.3. Measurement of carbon tax and carbon tax revenue

Presently, it is only South Africa that has implemented a carbon tax in Africa; Cote d’Ivoire and Senegal are considering introducing it in the future (World Bank, 2020). Therefore, data on the carbon tax is not available. But it can be estimated based on reasonable assumptions.

We assume three possible carbon tax rates that African countries can charge.

- i. The World Bank’s minimum carbon tax recommendation of \$25/ton for developing countries. Relative to the existing global average carbon tax, there is little motivation for African countries to

Table 1. Variable definitions, summary statistics, and computations.

Variable	Indicator Name	Mean	SD	Source/Computation
fdi	Foreign direct investment, (the value of net inflows calculated as a % of GDP)	3.98	8.264	WDI
gdp	GDP per capita (log)	4.65	7.165	WDI
trade	Trade (value of net trade calculated as a % of GDP)	1.798	0.199	WDI
edu	Education: number of secondary school enrollment, (log)	32.613	18.26	WDI
rule	Rule of law index ranging from 1 (low) to 6 (high)	2.684	0.69	WDI
inv	Domestic investment (calculated as a % of GDP)	22.239	9.734	WDI
maxct	Maximum carbon tax	5.512	2.5	Tax rate multiplied by \$25/ton
minct	minimum carbon tax	0.441	0.2	Tax rate multiplied by \$3/ton
mltct	most likely carbon tax	1.874	0.85	Tax rate multiplied by \$8.5/ton
indexct	Index of carbon	0.9	1.732	Generated using principal component analysis (PCA) from the three proxies of the carbon tax (maxct, minct, mltct).
maxctrev	Maximum carbon tax revenue (log)	9.305	1.84	Maxct multiplied by CO2 emission
mlctrev	Minimum carbon tax revenue (log)	6.779	1.84	Minct multiplied by CO2 emission
minctrev	Most likely carbon tax revenue (log)	6.779	1.84	Mltct multiplied by CO2 emission
indexctrev	Index of carbon tax revenue	1.5	1.732	Generated using principal component analysis (PCA) from the three proxies of carbon tax revenue.

(Source: Authors’ computations).

charge carbon tax beyond this value. Hence, the World Bank's recommended carbon tax becomes the maximum carbon tax (*maxct*)

- ii. Global carbon tax average of \$3/ton (World Bank, 2020). This is assumed to be the minimum carbon tax (*minct*)
- iii. South African current tax of \$8.5/ton. South Africa introduced its carbon tax in 2019 at \$8/ton but increased it later to \$8.5/ton. The \$8.5/ton is the most likely carbon tax (*mlct*) African countries may desire to charge, following the South African example.

All three possible carbon taxes are examined in different models. This strategy will not only minimize multicollinearity problems but also be instructive to advise policy on the implications of various carbon tax values on the dependent variables.

Further, to ensure that carbon tax is heterogeneous (varying across time and country), we assumed that each country will charge a carbon tax as a function of the corporate tax rate and the three-carbon tax values: \$25, \$3, and \$8.5. This approach also facilitates the building of the panel dataset. The carbon tax revenue is computed by multiplying the carbon tax value by the tons of carbon emitted.

3.4. Data Source and description

The data span from 1995 to 2019 covers 43 Sub-Saharan African countries. The data is sourced from the World Bank's World Development Indicators. The 43 countries were selected purely based on data availability. To standardize the data, variables that are neither in percentage terms nor index form are included at their logarithm levels (Table 1). GDP per capita, education, and the three measures of carbon tax revenue are all in logarithmic terms. Table 1 contains the summary statistics.

4. Results and discussions

Before estimating the empirical model in Equation (4) using GMM, preliminary checks were carried out. The Breusch-Pagan/Cook-Weisberg test showed heteroscedasticity in the residuals, and the Levin-Lin-Chu unit-root test showed evidence of serial correlation in the series (see Table A5 and Table A6 in the Appendix). To correct for these effects, robust standard errors were used. The GMM approach is particularly useful in this study because of the large number of panel units (Arellano & Bonds, 1991).

Also, the GMM estimation technique is robust enough to deal with the endogeneity problem, which is usually associated with macroeconomic variables (FDI, GDP, trade, investment, etc.), especially when estimated with static models (Bond & Windmeijer, 2005). But the issue of moment condition proliferation is a concern for GMM estimates. The Hansen test for overidentifying restrictions is used to validate the number of instruments employed in this study (see Table 2). Further, the use of lags as regressors in the GMM estimations can entrench the serial correlation problem identified by the Levin-Lin-Chu unit-root test. The study uses the Arellano and Bonds test for second-order serial correlation in the GMM estimates. The second-order autocorrelation (AR2) results presented in Table 2 show that the estimates are free from serial correlation.

The computation of the carbon tax revenue (*indexctrev*) depends on the value of the carbon tax (*indexct*) and this may lead to multicollinearity if included in a single regression. So, the study tested for the presence of multicollinearity using the pairwise correlation matrix and the variable inflation factor (VIF). The results in Table A3 and Table A4 in the Appendix show no concern for multicollinearity.

The results from the empirical estimations are included in Tables A2 and A3. Table 2 examines the effect of the carbon tax and carbon tax revenue on FDI. Table 2 also contains the results of the model selection processes. Based on the recommendations of Bond et al. (2001), the two-step differenced GMM shown in column (4) of Table 2 is selected as the most efficient model in estimating the empirical models. The lagged dependent variable *l.fdi* in column (4) lies in between the upper and lower bounds and also has the lowest values of the Akaike (AIC), Bayesian (BIC), and Hannan-Quinn (HQIC) as per the Andrews-Lu model and moment selection criteria. Again, the differenced GMM estimates produce efficient gains with relatively small standard errors as compared to the results from the pooled OLS, the fixed effect, and the system GMM (Table 2, column 4).

Table 2. Effect of carbon tax index and carbon tax revenue index on FDI.

Variables	(1) Pooled OLS: Upper Bound	(2) Fixed Effect: Lower Bound	(3) Two-Step System GMM	(4) Baseline Two-Step Difference GMM	(5) Baseline With Carbon tax revenue
l.fdi	0.471*** (0.032)	0.312*** (0.034)	0.173*** (0.0495)	0.342*** (0.017)	0.344*** (0.0209)
indexct	−0.0767 (0.0874)	0.0165 (0.193)	−3.148* (1.664)	−0.377** (0.164)	0.581* (0.307)
gdp	0.0129 (0.0367)	0.0195 (0.0379)	0.171*** (0.0501)	0.036*** (0.011)	0.00202 (0.0162)
trade	1.869 (1.294)	−2.118 (2.566)	28.28 (23.95)	−1.005 (1.581)	1.724 (1.956)
edu	0.00480 (0.0127)	0.100*** (0.0349)	−0.101 (0.102)	0.0796*** (0.023)	0.132** (0.0595)
rule	0.514 (0.349)	1.121* (0.643)	7.604** (3.422)	1.079*** (0.268)	1.280*** (0.412)
inv	0.120*** (0.0255)	0.194*** (0.0357)	0.202** (0.100)	0.160*** (0.016)	0.196*** (0.0207)
indexctrev					−2.893*** (0.630)
Constant	−6.006** (2.556)	−6.232 (5.684)	−70.00 (48.66)	−	−
Year dummies	yes	yes	yes	yes	Yes
Observations	1,032	1,032	1,032	1,032	1,032
Number of Countries	43	43	43	43	43
Number of Instruments	—	—	24	24	26
R-squared	0.347	0.288	—	—	—
AR(1)	—	—	0.062	0.024	0.208
AR(2)	—	—	0.427	0.481	0.405
Hansen	—	—	0.224	0.371	0.385
Andrews-Lu model and moment selection criteria					
Akaike (AIC)			−0.0012	−0.0018	—
Bayesian (BIC)			−0.0025	−0.0033	—
Hannan-Quinn (HQIC)			−0.0017	−0.0024	—

Robust Standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

(Source: Authors' computations).

4.1. The effect of carbon tax and carbon tax revenue on FDI

In Table 2, we proxied carbon tax with the carbon tax index generated through the principal component analysis process. This helps in assessing the singular effect of the carbon tax on FDI. In Table 3, the carbon tax is decomposed into three different classifications and introduced into the empirical model separately. This approach offers the opportunity to examine the effect of different carbon tax policies on FDI.

Column (4) of Table 2 shows that the unmitigated effect of the carbon tax on FDI is repressive. This finding is new due to the scarcity of studies in this area. However, there is compelling evidence that FDI responds negatively to the general tax environment in the host economy (Gao & Liu, 2021; OECD, 2008; Xu & Wu, 2021). The negative effect of taxes on FDI is the reason why FDI is located in countries with lower tax rates (Damgaard et al., 2019). It is no surprise that the introduction of additional taxes like the carbon tax can also drive away foreign investors if a tax-mitigating policy is not implemented alongside it. One such policy is the recycling of carbon tax revenue into the economy.

There are various channels through which carbon tax revenue can be recycled, as advanced by the double dividend hypothesis (Repetto, Dower, & Geoghegan, 1992; Pearce, 1991). But the use of carbon tax revenue to offset payroll taxes and/or corporate taxes are the two channels that stand out (Freire-González & Ho, 2019; Radulescu et al., 2017; Yang, Jiang, & Pan, 2020). The use of carbon tax revenue to reduce corporate tax will be directly beneficial to foreign investors as compared to payroll tax cuts. This insight is highlighted in our results in column (5) of Table 2. The effect of the carbon tax on FDI changed from negative to positive after the introduction of the carbon tax revenue into column (5).

The carbon tax revenue (indexctrev) can absorb the negative shock from the carbon tax even to the extent that the tax now becomes a positive driver for FDI. This situation intuitively makes sense because the carbon tax is a specific tax levied to regulate carbon emissions, and not every firm will be obliged to pay it. But if the carbon tax revenue is recycled into the economy (say through a corporate tax cut), it will benefit every firm, thereby influencing FDI positively. These findings corroborate Yang, Jiang, and Pan

Table 3. Effect of different carbon tax values on FDI.

Variables	(6) fdi	(7) fdi	(8) fdi	(9) fdi	(10) fdi	(11) Fdi
L.fdi	0.342*** (0.0167)	0.344*** (0.0209)	0.339*** (0.0166)	0.348*** (0.0243)	0.339*** (0.0165)	0.349*** (0.0238)
mlct	-0.758** (0.333)	1.192* (0.621)				
mlctrev		-2.731*** (0.590)				
maxct			-0.231** (0.0962)	0.385 (0.252)		
maxctrev				-2.409*** (0.560)		
minct					-2.828** (1.200)	4.966 (3.067)
minctrev						-2.442*** (0.558)
gdp	0.0360*** (0.0105)	0.00220 (0.0162)	0.0373*** (0.0101)	0.0139 (0.0130)	0.0374*** (0.0101)	0.0139 (0.0128)
trade	-1.037 (1.583)	1.719 (1.954)	-1.122 (1.618)	-0.893 (2.105)	-1.113 (1.618)	-0.992 (2.118)
edu	0.0793*** (0.0228)	0.133** (0.0595)	0.0810*** (0.0241)	0.0787 (0.0537)	0.0808*** (0.0241)	0.0791 (0.0516)
rule	1.072*** (0.267)	1.279*** (0.410)	1.107*** (0.268)	1.606*** (0.450)	1.102*** (0.268)	1.605*** (0.432)
inv	0.161*** (0.0158)	0.196*** (0.0207)	0.159*** (0.0154)	0.203*** (0.0173)	0.159*** (0.0155)	0.203*** (0.0173)
Year dummies	yes	yes	yes	yes	yes	Yes
Observations	1,032	1,032	1,032	1,032	1,032	1,032
No. of Countries	43	43	43	43	43	43
No. of Instruments	25	28	28	28	28	28
AR(1)	0.098	0.082	0.112	0.115	0.158	0.163
AR(2)	0.549	0.519	0.465	0.548	0.510	0.564
Hansen	0.327	0.347	0.335	0.268	0.315	0.250

Robust Standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

(Source: Authors' computations).

(2020) and Freire-González and Ho (2019) that carbon tax revenue indeed mediates the negative effect of the carbon tax on macro variables, hence affirming the presence of the double dividend theory.

Taking the results in columns (4) and (5) together minimizes the fears of African economies about the carbon tax spillover on international capital. But factors such as the rule of law (rule), human capital development (edu), and sustained domestic investment (inv) are crucial in ensuring that the revenue from carbon taxes is used judiciously to advertise the negative effect of carbon taxes (see column 5).

The results from the decomposition of the carbon tax into most likely (mlct), maximum (maxct), and minimum (minct) are presented in Table 3. The results in columns (6, 8), and (10) show that all three variants of carbon taxes significantly hurt FDI. This implies that any amount of additional tax in the form of a carbon tax will hurt FDI. These findings again affirm the deep-rooted negative relationship between taxes and FDI. The OECD (2021) has pointed out that Africa has the highest average corporate tax rate as compared to the rest of the world; based on these high-level corporate taxes in the region, it is only expected that foreign investment will roll back at the introduction of additional taxes.

The fact that a carbon tax may deter inward FDI does not imply that it should not be introduced at all. Given the devastating effect of FDI on the environment, as highlighted in the past by Boachie-Yiadom and Mensah (2021) and Omri et al. (2014) necessitate a carbon tax to reinforce the polluting pay policy. To ensure that FDI pays for destroying the environment and, at the same time, encourages inward FDI in the presence of a carbon tax, complementary policies are needed. The results in column (7) reveal that if the most likely carbon tax of \$8.5 is introduced, the carbon tax will significantly increase inward FDI. But the positive effect of running from the carbon tax can only be achieved if the revenue from the taxes is ploughed back into the economy.

This is because, without the ploughback of the carbon tax revenue, the carbon tax will unilaterally have a significant negative effect on the FDI, as shown in column (6). The recycling of carbon tax revenue sounds almost automatic, and once revenue is mobilized, it will surely be reinvested into the economy. But this automatic recycling assumption cannot be realistic given Africa's history with public funds.

Public funds in Africa are occasioned by diversions from their original intentions (IMF, 2015). Moreover, the endemic nature of corruption in Africa and the use of taxes to service public debt will compete with the recycling of revenue from carbon taxes (Mensah, Bokpin, & Boachie-Yiadom, 2018).

Consequently, there is a need for a deliberate policy to ensure that the carbon tax revenue is invested in its intended purposes. However, to minimize the likelihood of this diversion, corporate tax cuts can be introduced alongside the carbon tax so that the carbon tax revenue cushions the reduction in the corporate tax. The results in Columns (9) and (11) show that the carbon tax charged at either \$25/ton (maxct) or \$3/ton (minct) will not have any effect on the level of inward FDI to Africa, even if the carbon tax revenue is recycled. There are two lessons from these findings. First, if the carbon tax is set either too high or too low, its relevance will not be missed. When the carbon tax is too high, it will drive away FDI, and the revenue mobilized from the carbon tax revenue may not be able to make up for the shortfall in FDI.

Conversely, if the carbon tax is too low, carbon tax revenue will also be low and environmental costs from the FDI cannot be repaired by the carbon tax revenue. Second, the findings in columns (9) and (11) validate why South Africa introduced a carbon tax of \$8.5/ton. The \$25/ton and the \$3/ton almost set cap and floor respectively for the fixing of the carbon tax for Africa and following the South African example seems rational given the results in Columns (7, 9), and (11).

4.2. Robustness check

To ensure the consistency of the results, the study samples were divided into two, and the objectives were reexamined with the new samples. To do this, the observations from the study were reclassified into low and high tax regimes. Given the entrenched negative relationship between FDI and taxes, we do not expect carbon tax to behave in the same way in the two regimes. The results from this exercise are presented in Tables A1 and Table A2 in the Appendix. Table A1 contains the results of the effect of the carbon tax and carbon tax revenue on FDI among low-tax regime economies. Results in columns (12, 14, 16, 18), corroborate the findings in Tables A2 and A3 that carbon tax has a significant and negative effect on FDI but if the revenue from the carbon tax is controlled for by recycling it into the economy, carbon tax begins to promote FDI [refer to column (13, 15, 17), and (19)].

Conversely, examining the effect of the carbon tax and carbon tax revenue among high tax regime economies produce contrasting results as presented in Table A2. The negative significant effect of the carbon tax on FDI is persistent throughout columns (20–25), and (26). These findings suggest that the negative effect of a carbon tax cannot be overturned by recycling carbon tax revenue. High tax regime economies are fragile for further taxes and the introduction of a carbon tax could be devastating to foreign investment. The post-estimation checks confirm that the estimates in Tables A1 and A2 do not suffer from instrument proliferation and autocorrelation as confirmed by the Hansen test and the AR(2) test respectively.

5. Conclusions

This study opens the frontiers for more discussion on the effect of the carbon tax on macroeconomic indicators. We have examined the effect of carbon tax introduction on FDI in Africa. We were particularly alarmed by the slow pace of the introduction of the carbon tax in Africa. A carbon tax can deter dirty industries from polluting the environment and at the same time generate revenue to augment public revenue. Despite these benefits, only South Africa has introduced a carbon tax across the sub-region. The lack of enthusiasm among African countries to implement carbon tax necessitated this research, perhaps, the effect of carbon tax transcends beyond the carbon emission reduction mantra. We set up the DSGE model and estimate it with the differenced GMM techniques.

The findings are that the unmitigated effect of the carbon tax on FDI is repressive. However, if the revenue from the carbon tax is controlled, the carbon tax will have a significant positive effect on FDI. We introduce three variants of a carbon tax: \$25/ton, \$8.5/ton, and \$3/ton. Our findings suggest that if the revenue generated from a carbon tax of \$8.5/ton is recycled, FDI will respond favorably to the introduction of the carbon tax. The study did not find justification for a carbon tax of \$25/ton and \$3/ton. Furthermore, as a robustness check, we use two different subsamples grouped into low and high tax regimes to retest our suspicions. We find support for the double dividend theory and that recycling

carbon tax revenue mitigates the negative effect of the carbon tax on FDI among countries with low taxes. However, high-tax countries cannot overturn the negative spillover from the carbon tax to FDI. Meanwhile, the current study has few limitations. The carbon tax has not been fully introduced in Africa, therefore data is a challenge. Although reasonable assumptions were made to generate the carbon tax data used in the study, future studies should consider using alternative measures of carbon taxes.

5.1. Policy suggestions

Based on the findings of the study, a short-term policy implication is that African countries should consider implementing a carbon tax at a rate similar to South Africa's \$8.5 per ton. This can effectively deter polluting industries from harming the environment while generating revenue that can be reinvested to mitigate the negative effects of the carbon tax. By recycling the revenue, countries can achieve both the polluter pay policy and the double dividend policy, thereby encouraging foreign direct investment (FDI) while addressing environmental concerns.

In the long term, African countries must recognize the importance of carbon tax implementation and expedite its introduction. The slow pace of carbon tax adoption across the region is a cause for concern, considering its potential benefits. To attract FDI and promote sustainable economic growth, countries should strive to implement effective carbon tax policies. This would require comprehensive data collection and analysis to accurately determine appropriate tax rates and evaluate the impact of the carbon tax on macroeconomic indicators. Future studies should focus on refining measurement methods for carbon taxes and assessing alternative measures that can enhance the effectiveness of carbon tax policies.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Table A1. Effect of carbon tax and carbon tax revenue on FDI among Low tax regime countries.

VARIABLES	(12) fdi	(13) fdi	(14) fdi	(15) fdi	(16) fdi	(17) fdi	(18) fdi	(19) fdi
L.fdi	0.379*** (0.00592)	0.249*** (0.00608)	0.379*** (0.00592)	0.249*** (0.00601)	0.379*** (0.00592)	0.249*** (0.00610)	0.379*** (0.00592)	0.248*** (0.00613)
indexct	−0.423*** (0.0898)	3.146*** (0.412)						
indexctrev		−5.952*** (0.223)						
mlct			−0.862*** (0.183)	6.406*** (0.831)				
mlctrev				−5.601*** (0.210)				
maxct					−0.293*** (0.0622)	2.170*** (0.285)		
maxctrev						−5.590*** (0.209)		
minct							−3.663*** (0.778)	27.41*** (3.593)
minctrev								−5.615*** (0.220)
Controls	yes	yes	yes	yes	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	539	539	539	539	539	539	539	539
Number of i	35	35	35	35	35	35	35	35
No. of Instruments	29	30	29	30	29	30	29	30
AR(1)	0.267	0.266	0.267	0.267	0.267	0.266	0.267	0.266
AR(2)	0.318	0.333	0.318	0.333	0.318	0.332	0.318	0.332
Hansen	0.287	0.207	0.287	0.208	0.287	0.209	0.287	0.204

Robust Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2. Effect of carbon tax and carbon tax revenue on FDI among High tax regime countries.

VARIABLES	(20) fdi	(21) fdi	(22) fdi	(23) fdi	(24) fdi	(25) fdi	(26) fdi	(27) fdi
L.fdi	0.228*** (0.00132)	0.219*** (0.00581)	0.228*** (0.00132)	0.219*** (0.00581)	0.228*** (0.00132)	0.217*** (0.00347)	0.228*** (0.00133)	0.219*** (0.00584)
indexct	−0.903*** (0.00749)	−0.927*** (0.0248)						
indexctrev		0.113*** (0.0252)						
mlct			−1.840*** (0.0153)	−1.889*** (0.0505)				
mlctrev				0.108*** (0.0237)				
maxct					−0.626*** (0.00520)	−0.641*** (0.0173)		
maxctrev						0.118*** (0.0122)		
minct							−7.817*** (0.0646)	−8.027*** (0.216)
minctrev								0.105*** (0.0238)
Controls	yes	yes	yes	yes	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	373	373	373	373	373	373	373	373
Number of i	30	30	30	30	30	30	30	30
No. of Instruments	29	30	29	30	29	30	29	30
AR(1)	0.119	0.120	0.119	0.120	0.119	0.120	0.119	0.120
AR(2)	0.273	0.282	0.273	0.282	0.273	0.288	0.273	0.282
Hansen	0.326	0.397	0.326	0.397	0.326	0.392	0.324	0.395

Robust Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A3. Pairwise correlations matrix results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) fdi	1.000							
(2) gdp	0.314	1.000						
(3) trade	0.188	−0.058	1.000					
(4) edu	0.069	−0.036	0.369	1.000				
(5) rule	0.156	0.172	−0.051	0.139	1.000			
(6) inv	0.295	0.126	0.409	0.077	0.290	1.000		
(7) indexct	−0.004	0.009	0.006	0.215	0.292	0.019	1.000	
(8) indexctrev	−0.067	−0.014	0.061	0.179	0.150	0.134	0.671	1.000

(Source: Authors' computations).

Table A4. Variance inflation factor (VIF) test for Multicollinearity.

Variable	VIF	1/VIF
indexct	2.05	0.488900
indexctrev	1.91	0.524361
trade	1.51	0.664428
inv	1.47	0.682188
rule	1.32	0.756266
edu	1.27	0.789073
gdp	1.05	0.952674
Mean VIF	1.51	

(Source: Authors' computations).

Table A5. Breusch-Pagan/Cook-Weisberg test for heteroskedasticity.

Dependent variable	Assumption	F.statistics	p-value
fdi	Constant variance	21.40	0.0000

(Source: Authors' computations).

Table A6. Levin-Lin-Chu unit-root test.

Variable	Statistics		p-value
	Unadjusted	Adjusted	
fdi	−14.7709	−7.2305	0.0000
gdp	−19.0461	−8.7226	0.0000
l.fdi	−14.6870	−7.3529	0.0000
l.gdp	−19.0035	−8.8871	0.0000
indexct	−0.0909	0.0385	0.4846
indexctrev	−6.7437	−3.2833	0.0005
trade	−9.1467	−1.2629	0.1033
edu	0.3144	0.3428	0.6341
rule	−7.7e + 03	−8.4e + 03	0.0000
inv	−9.2828	−2.1475	0.0159
mlct	0.3551	0.4739	0.6822
maxct	0.2026	0.2325	0.5919
minct	0.1567	0.1778	0.5706
mlctrev	−6.7749	−3.3206	0.0004
maxctrev	−6.7433	−3.2757	0.0005
minctrev	−6.7128	−3.2485	0.0006

(Source: Authors' computations).