Carbon Pricing Interventions in East Africa: A Rapid Evidence Assessment

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Advisory Board

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Executive Summary

Background

Carbon pricing assigns a cost to CO_2 emissions, accounting for their environmental and economic impacts, such as climate change and health risks. This policy aligns with the "polluter pays" principle, ensuring polluters bear the costs of emissions. Imposing a fee or tax reduces carbon-intensive product output and encourages a shift to cleaner energy sources. The policy's effectiveness depends on market elasticity and the reinvestment of tax revenues into renewable energy and social programmes. While carbon pricing increases the cost of emitting goods, prompting producers to minimise waste and lower production, the financial burden is shared between consumers and producers based on their sensitivity to price changes.

Methodology

The rapid evidence assessment (REA) on carbon pricing interventions in East Africa examines the effectiveness of direct and indirect carbon pricing interventions in reducing carbon emissions and their socio-economic impacts. It also explores barriers to implementing these interventions and offers practical recommendations for policymakers. We utilised a comprehensive search strategy, gathering studies from diverse sources, which resulted in 16 records being included. A meta-analysis of 12 studies was conducted, synthesising 119 effect sizes to evaluate the effectiveness of carbon tax interventions.

Key Findings

The studies, which focused on a few countries in East Africa, including Uganda, Kenya, Tanzania, and Ethiopia, revealed that carbon pricing interventions in the region effectively reduce CO_2 emissions and generate significant revenue. However, their impacts on energy consumption, income distribution, and GDP are modest and context-dependent.

Six studies examined the impact of carbon pricing on CO_2 emissions and found a large decrease, suggesting that these interventions effectively reduce greenhouse gases. Three studies explored the effect of carbon pricing interventions on revenue generation and reported large increases in revenue, indicating that these interventions can significantly boost government revenue. Two studies investigated the distributional impact of carbon pricing, revealing a moderate and positive effect, indicating that carbon pricing interventions may help reduce income inequality by having a progressive effect, benefiting lower-income groups more than higher-income groups. The impact on GDP is slightly negative, indicating limited economic growth benefits, while the effects on income and expenditure are small and positive but statistically insignificant. Five studies focused on energy consumption, showing a small negative overall effect, indicating a modest reduction in energy use.

The two process evaluations provide key insights into overcoming barriers to carbon pricing in East Africa. They emphasise the importance of targeted revenue allocation to increase public support, enhanced institutional coordination, and mobilised funding and expertise to implement carbon pricing strategies effectively.

Most of the studies reviewed were rated with medium confidence, and there was substantial variability in studies on carbon pricing. This highlights the need for standardised research methods and explicit assumptions.

Implications for policy

Studies in this review support the implementation of well-designed carbon pricing policies to drive environmental and economic change.

- Policymakers must carefully consider how carbon pricing interventions impact different income groups and design strategies to mitigate regressive distributional effects, ensuring consumers and producers are not unfairly affected, especially poor people and small scale enterprises who rely on, and may have few substitute sources of, essential goods like fuel and electricity.
    - Progressive schemes, such as equal cash transfers or transfers inversely proportional to income, help mitigate potential negative impacts on low-income groups, thereby promoting equity and widening the income distribution in favour of those who need it most.
    - Measures like targeted subsidies, carbon tax rebates, revenue redistribution, reallocation of tax revenues for renewable energy infrastructure, or investments in social programmes such as agricultural support programmes could help protect lower-income households and ensure that carbon pricing policies are equitable and socially acceptable. Addressing these is crucial for building public trust and support for carbon pricing initiatives.
    - Integrating carbon pricing into broader sustainability policies, such as medium-term plans like poverty reduction strategies (PRSPs), could accelerate progress toward net-zero targets while fostering economic resilience.

- Transparency in carbon pricing mechanisms and public engagement strategies is likely necessary to secure long-term political and social acceptance.

- Tailored policy designs that consider each country's unique socio-political and economic contexts can maximise the effectiveness of these interventions. This can usefully draw on commissioned evaluations.
    - Making policies flexible and adaptive, allowing for adjustments based on ongoing evaluations and new research insights, can provide real-world information.
    - For example, some policies implemented at the sub-national level can be randomly allocated by district or other administrative levels.
    - Where randomisation is impossible, quasi-experimental designs which use existing data sources and/or non-policy groups as comparators may be feasible.
    - This approach can provide valuable insights into the effectiveness and efficiency of the policies, which can inform necessary adjustments, such as the modifications needed to scale programmes at the national level.

Implications for research

- Future studies should focus on conducting rigorous evaluations, carefully evaluating how carbon pricing works and how effective it is in different economic and social situations. This includes looking at its impact on jobs, energy use, and other economic factors.
- More studies are needed to assess the distributional impacts of carbon pricing across different income groups and regions, focusing on identifying effective interventions to mitigate adverse effects on vulnerable populations.
- More research is needed to understand how changes in important factors, like technology costs or demand growth, could impact policy results. This research could include systematic sensitivity analysis in new studies or combine modelling evidence from several existing studies. By doing this, we can better predict how different scenarios might influence outcomes.
- Long-term research examining the effects of carbon pricing over many years could help us understand how the market behaves, how emissions are reduced, and what socio-economic impacts occur. This kind of research can reveal important patterns that inform decision-makers about the effectiveness of carbon pricing strategies.
- More process evaluations are needed, and existing ones incorporated into systematic decision-making processes (e.g., via evidence synthesis), to facilitate sharing experiences and insights on the effectiveness of carbon pricing instruments across East Africa.

Background

Carbon pricing is a policy tool designed to address the environmental and economic impacts of greenhouse gas (GHG) emissions by assigning a cost to emitting carbon dioxide (CO_2). This cost reflects the adverse effects of emissions, such as climate change, health risks, and environmental damage, which are not typically included in market prices (World Bank, 2022). By putting a fee or tax on carbon dioxide (CO_2) emissions, carbon pricing ensures that these costs are paid for by the sources of pollution. It also accounts for the long-term financial impacts of climate change and considers how marginalised groups are affected, aiming to reduce social inequalities (Nordhaus, 2017; Moore & Diaz, 2015).

Carbon pricing aligns with the "polluter pays" principle, ensuring that those responsible for emissions bear the costs of their actions (Pigou, 1920; Goulder, 2019). The adjustment in the market following a tax imposition typically shifts the supply curve upward, thereby reducing the equilibrium quantity and raising prices (Pigou, 1920) (**Appendix A**). However, the extent to which these costs are passed on depends on the elasticity of demand (responsiveness of demand to changes in price) and the structure of the supply market. For instance, in markets where the consumption of carbon-intensive goods is relatively price-inelastic, a more significant portion of the tax burden will be passed onto consumers. This is more likely to occur for goods like energy which are consumption necessities (or necessary inputs to production), where clean energy sources are not available as substitutes. The "polluter pay principle" intends for producers to bear more of the cost, which in theory can be achieved by applying a proportionate tax rate on production quantities and reducing the elasticity of supply with respect to price at higher production levels. Both the higher cost for producers and the higher price for consumers reduce the output of carbon-related products.

Conversely, suppose the demand for taxed goods is more elastic (more responsive to changes in price). This might occur if there are substitute goods available which are not subject to carbon taxes or if the taxed good is not a necessity for consumption (or input to production). In that case, consumers may significantly reduce their consumption in response to price increases, leading to a more substantial decrease in emissions and also a more significant reduction in the deadweight loss (Knittel and Sandler, 2015) – that is, a welfare gain to society and planetary health from the reduced production and consumption of the polluting product.[1] The increased equilibrium price signals the carbon costs of production and consumption (Hartmann et al., 2023; Pigou, 1927).

As production processes adjust to higher emissions costs, there is, in theory, a shift toward cleaner energy sources and more efficient practices (Sen & Volleyer, 2018). Whether the shift to cleaner sources occurs depends partly on the extent to which the emissions reduction can be objectively monitored and verified—see, for example, the Volkswagen diesel emissions scandal that emerged in 2015, affecting 11 million models built since 2009 worldwide. There may also be active policies to promote the transition. For example, revenue recycling reinvests tax revenue into renewable energy

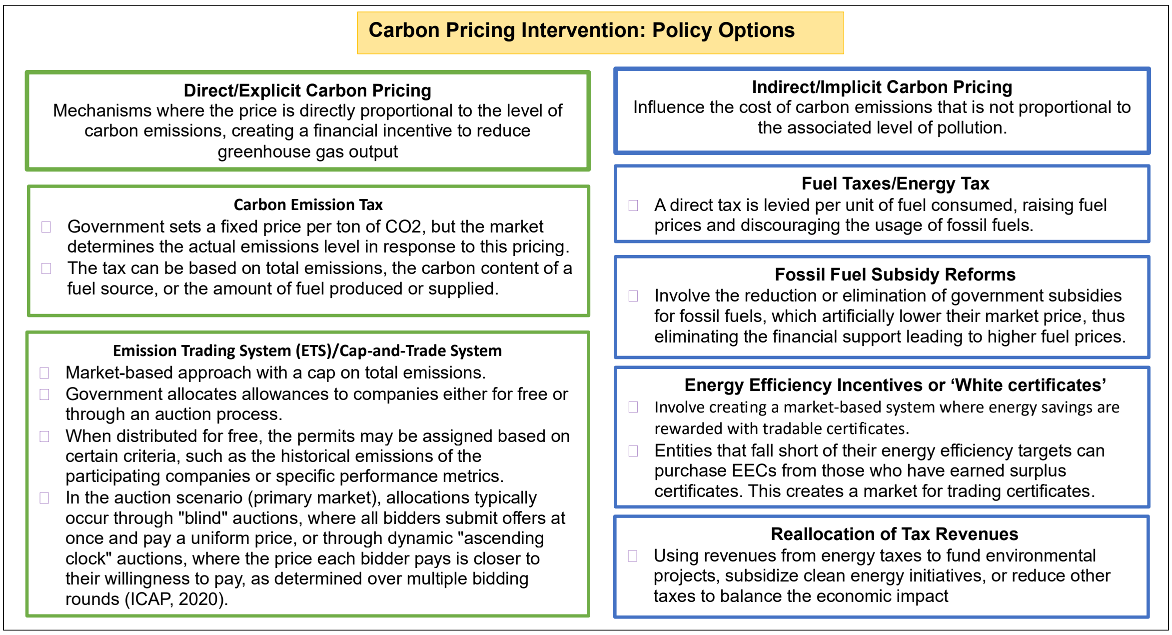
[1] Deadweight loss is a measure of the inefficiency that occurs when the equilibrium quantity is not at the socially optimal level. See Appendix A.

and efficiency programmes, creating a feedback loop that shifts practices and lowers long-term costs (Borge-Diez et al., 2024).

The effectiveness of carbon pricing in fostering economic efficiency is balanced with concerns about affordability and equity (**Appendix A**). For example, demand will be more elastic (responsive to price) for goods expenditures that represent a greater share of total income. Hence poorer people may experience greater adjustment costs, if they are forced to shift their consumption patterns away from the taxed goods, than richer people, who may still be able to afford and willing to pay to consume the goods. Therefore, revenue generated from carbon taxes can be reinvested in social programmes, further alleviating potential adverse impacts on vulnerable populations, or provided back to households as compensatory income tax rebates.

Carbon pricing interventions adopt various forms, primarily categorised into direct and indirect approaches (**Figure 1**). Direct carbon pricing includes instruments like carbon taxes and cap-and-trade systems, where a clear price is assigned to carbon emissions, sending a strong economic signal. Indirect mechanisms, such as fuel taxes or the removal of fossil fuel subsidies, influence behaviour without explicitly setting a price on carbon, yet they still drive change in carbon-intensive activities (Goulder, 2019; Sterner, 2012; World Bank, 2024).

Figure 1 Carbon pricing interventions



The diagram presents various policy options for carbon pricing interventions. It includes a **Carbon Emission Tax**, where governments set a fixed price per ton of CO_2, allowing the market to determine actual emission levels. This tax can be based on total emissions, carbon content, or the amount of fuel produced. The **Emission Trading System (ETS)/Cap-and-Trade System** is a market-based approach with a cap on total emissions, where allowances are allocated to companies either for free or through auctions. Allocation criteria may include historical emissions or performance metrics, with auctions conducted via "blind" or "ascending clock" methods.
Additionally, the **Fuel Taxes/Energy Tax** imposes a direct tax on fuel consumption, raising prices to discourage fossil fuel use. **Fossil Fuel Subsidy Reforms** aim to reduce or eliminate government subsidies for fossil fuels, preventing market price distortion. The **Energy Efficiency Incentives or 'White certificates'** involve a market-based system where energy savings are rewarded with tradable certificates, allowing entities to trade surplus certificates. Lastly, the **Reallocation of Tax**

Revenues involves using revenues from energy taxes to fund environmental projects, subsidize clean energy initiatives, or reduce other taxes to balance the economic impact.

Rationale

The existing literature on carbon pricing, including works by Green (2021) and Döbbeling-Hildebrandt et al. (2024) and Kohlscheen et al. (2024), predominantly evaluates the effectiveness of carbon pricing in reducing emissions, with a focus on high-income countries and does not examine broader socio-economic outcomes or the specific challenges faced in different regions. Tamasiga et al. (2024) explore socio-economic outcomes and energy poverty but do not include East African cases, while Cuevas et al. (2024) investigate health co-benefits from a global perspective, including some low- and middle-income countries (L&MICS), but do not specifically address the East African context. Price's (2020) report offers insights into developing countries such as South Africa but lacks a substantive discussion of East Africa.

A small amount of literature from Africa discusses the general applicability of carbon pricing (Valencia et al., 2024 & Ankel-Peters et al., 2025). Two global studies, Missbach et al. (2024) and Dorband et al. (2019), offer a comprehensive analysis using a harmonised dataset from household budget surveys across 88 countries, including some from East Africa. Dorband et al. (2019) assess the expected incidence of moderate carbon price increases for different income groups in 87 primarily low- and middle-income countries. While these papers include some data from East Africa, emphasising harmonised datasets can lead to generalised findings, potentially missing critical regional dynamics. Tsegay (2023) notes that institutional capacity is a significant challenge in East Africa, with many countries lacking the necessary infrastructure and expertise to implement and manage comprehensive carbon pricing mechanisms effectively.

This Rapid Evidence Assessment (REA) uniquely incorporates direct and indirect carbon pricing measures, addressing a gap in the existing literature, which often narrows its focus to direct pricing alone or does not specify this distinction. This comprehensive approach aims to provide a more nuanced understanding of how carbon pricing can be effectively applied in East Africa, ensuring that environmental and socio-economic goals are met. By examining the distributional impacts and identifying barriers to implementation, the study provides evidence-based recommendations for designing and implementing carbon pricing mechanisms while identifying existing research gaps.

Objectives

We aim to answer the following primary research questions.

Research question 1: "What is the effectiveness of direct (e.g., carbon taxes) and indirect (e.g., fuel taxes and subsidies) carbon pricing interventions implemented in East Africa to date, and what evidence exists on their impact on carbon emissions and socio-economic outcomes?", incorporating:

- What is the effectiveness of carbon pricing interventions in East Africa?
- What are the distributional impacts of carbon pricing interventions?

Research question 2: "What are the key policy objectives of carbon pricing initiatives, and what are the barriers and facilitators encountered during implementing these initiatives in East Africa?", incorporating:

- What barriers are encountered during the implementation of these initiatives in East Africa?
- What factors facilitate the successful implementation of carbon pricing policies in East Africa?

Methods

The study protocol elaborates on the criteria for reviewing the studies and is published (Saran et al., 2025).

Types of Populations

The populations of interest for this assessment include different socioeconomic groups (Davenport et al., 2018) in East African countries.

Types of Studies

Eligible studies included impact evaluations, modelling studies, process evaluations and economic and financial evaluations.

Types of Interventions

Interventions needed to have some pricing mechanisms included. Both direct and indirect carbon pricing interventions were eligible (**Figure 1**).

Exclusion Criteria

We excluded studies focused on interventions like using solar power, fuel wood, or subsidising non-carbon sources to reduce carbon emissions.

Comparator

Comparators were business-as-usual (BAU), different carbon pricing interventions, no intervention, synthetic controls, before/after carbon pricing implementation, and with versus without model simulations of outcomes with and without a carbon pricing policy.

Type of Outcomes

Eligible outcomes included CO_2/GHG emissions, energy consumption, GDP impact, revenue generation, income and savings, employment, and distributional impacts.

Results

SEARCH RESULTS

Sixty-eight studies were identified from previous reviews, and 293 records were identified from extensive database searches. Furthermore, 1,111 records were screened and identified from websites (209) and machine learning searches (902). After 103 duplicates were removed, 1,391 records were screened at the title and abstract stage. Of these, 1288 records were excluded, leaving 103 records for full-text screening. During the full-text screening, 77 records were excluded, resulting in 26 records for data extraction (**Appendix B**).

The 16 records included for data extraction were categorised as follows: quasi-experimental design (QED) studies (n=1), modelling studies (n=10), before-versus-after (n=2), process evaluations (n=2), and economic evaluation (n=1). We did not find any RCTS.

Appendix C presents a table of included studies that describes each study's key characteristics. This table provides information on the study design, population, intervention and outcome categories, providing a comprehensive overview of the research conducted in the region.

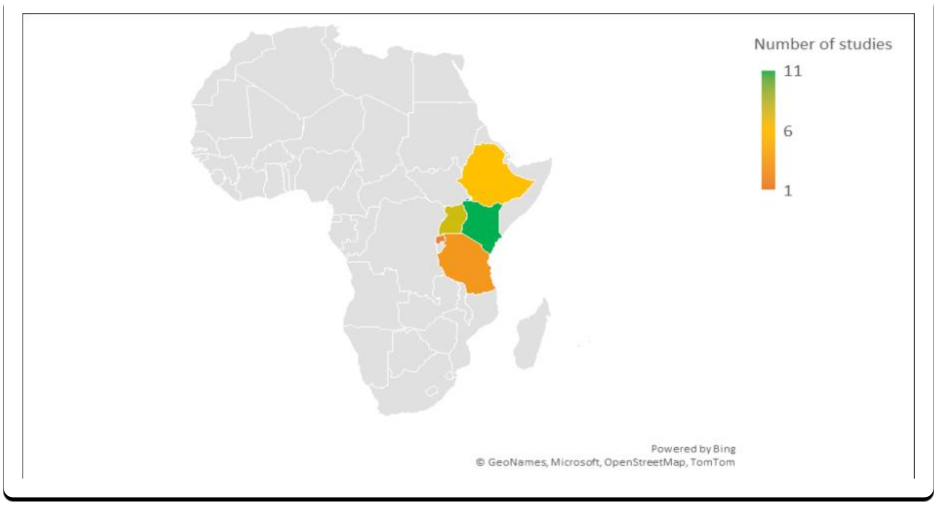
CHARACTERISTICS OF EVIDENCE

Population and Setting

The analysis of carbon pricing studies in East Africa comprises sixteen studies that illustrate a diverse geographic distribution of research focusing on various countries and populations (**Figure 2**).

In Uganda, four studies (24%) have been conducted, examining various aspects of carbon pricing, including its economic and environmental impacts on households in the Greater Kampala Metropolitan Area (Aggarwal et al., 2024; Ismail et al., 2023; Kimuli et al., 2022 & Kimuli et al., 2023). Six studies (35%) are from Kenya that explore the effects of carbon pricing on urban households in cities like Nairobi and Mombasa, utilising modelling studies and quasi-experimental designs (Al-Guthmy & Yan, 2020; Carvallo et al., 2017; Mutua et al., 2017; Mutua et al., 2012; Semboja, 1994; and Zhu, 2023). Tanzania is represented by two studies (12%) focusing on households across different income quintiles, particularly lower-income groups (Asare & Schuerer, 2024 and Shimba et al., 2024). Ethiopia contributes four studies (25%), addressing both rural and urban households and the implications of carbon pricing on grain producers and consumers (Fuje, 2019; Fuje, 2020; Telaye et al., 2019; and Timilsina & Sebsibie, 2023). Additionally, one study (5%) encompasses multiple East African countries, including Ethiopia, Kenya, Rwanda, Tanzania, and Uganda, providing a broader perspective on the regional impacts of carbon pricing policies (Harring et al., 2024).

Figure 2 Distribution of studies across East African Countries



The map illustrates the distribution of studies across East African countries with a colour gradient indicating the number of studies. The countries highlighted are Kenya, Uganda, Tanzania, and Ethiopia. The gradient ranges from green, representing the highest number of studies (11), to orange, indicating fewer studies (1). Kenya shows the highest concentration in green, while other countries like Tanzania and Ethiopia are marked in shades of orange and yellow, signifying fewer studies. The map provides a visual representation of research distribution in this region.

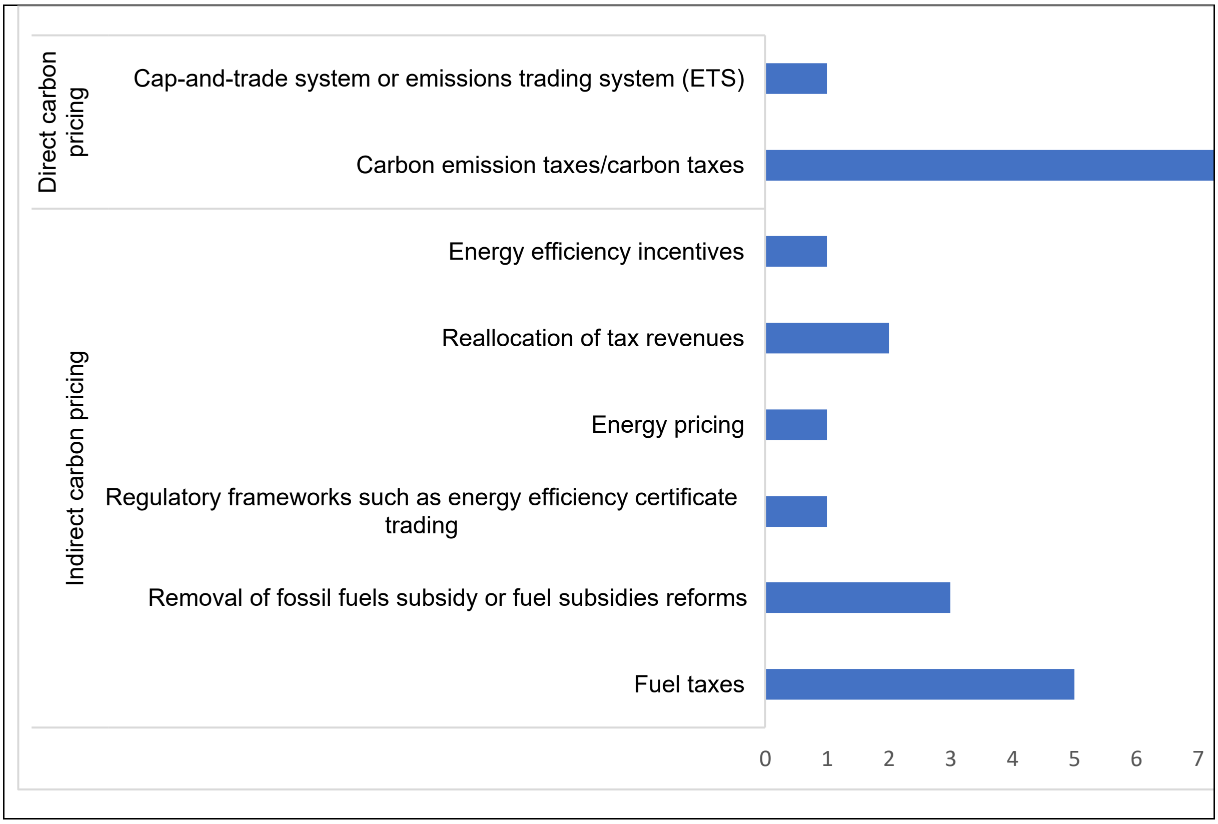
Interventions

We identified seven (41%) studies on direct carbon pricing, eight (47%) studies on indirect carbon pricing interventions, and two (12%) studies that assessed both direct and indirect carbon pricing **(Figure 3).**

Of the seven direct carbon pricing interventions, six specifically targeted carbon taxes (Aggarwal et al., 2024; Carvallo et al., 2024; Ismail, 2023; Kimuli et al., 2023; Shimba, 2024; and Telaya et al., 2019) and one explored personal carbon trading (Timilsina & Sebsibie, 2023).

Nine studies focused on indirect carbon pricing interventions, with four studies assessing the impact of fuel taxes (Harring et al., 2024; Kiambati, 2023; Mutua, 2012; Zhu, 2023). Three studies explored the removal of fossil fuel subsidies (Fuje, 2019; Harring et al., 2024; Kimuli et al., 2023), looking into the impacts of subsidy removal in Ethiopia. Semboja (1994) analyses an energy pricing intervention involving tariff adjustments to promote efficient usage and renewable technology investment. Two studies, Telaya et al. (2019) and Timilsina & Sebsibie (2023), specifically analysed the reallocation of tax revenues, exploring various revenue recycling schemes to evaluate their impact on equity and economic efficiency.

Figure 3 Distribution of studies by intervention categories



Outcomes

We identified six studies assessing the effectiveness of carbon pricing interventions on CO_2 emissions, all of which demonstrated a moderate to significant reduction in emissions (Ismail et al., 2023; Kimuli et al., 2022; Kimuli et al., 2023; Telaya et al., 2019; Timilsina and Sebsibie, 2023; Zhu, 2023) (**Figure 4**).

Six studies assessed the impact on income and expenditure; four studies demonstrated a positive effect on income and expenditure (Aggarwal et al.,202; Asare & Schurer, 2024; Fuje, 2019; Kimuli et al., 2022; Timilsina & Sebsibie, 2023; Zhu, 2023). However, in Fuje (2019), 76% of the households experienced significant income reductions after the fuel subsidy removal. Similarly, Zhu (2023) highlighted the unintended consequences of carbon pricing on income and expenditure, with losses ranging from 2.1-4.0%.

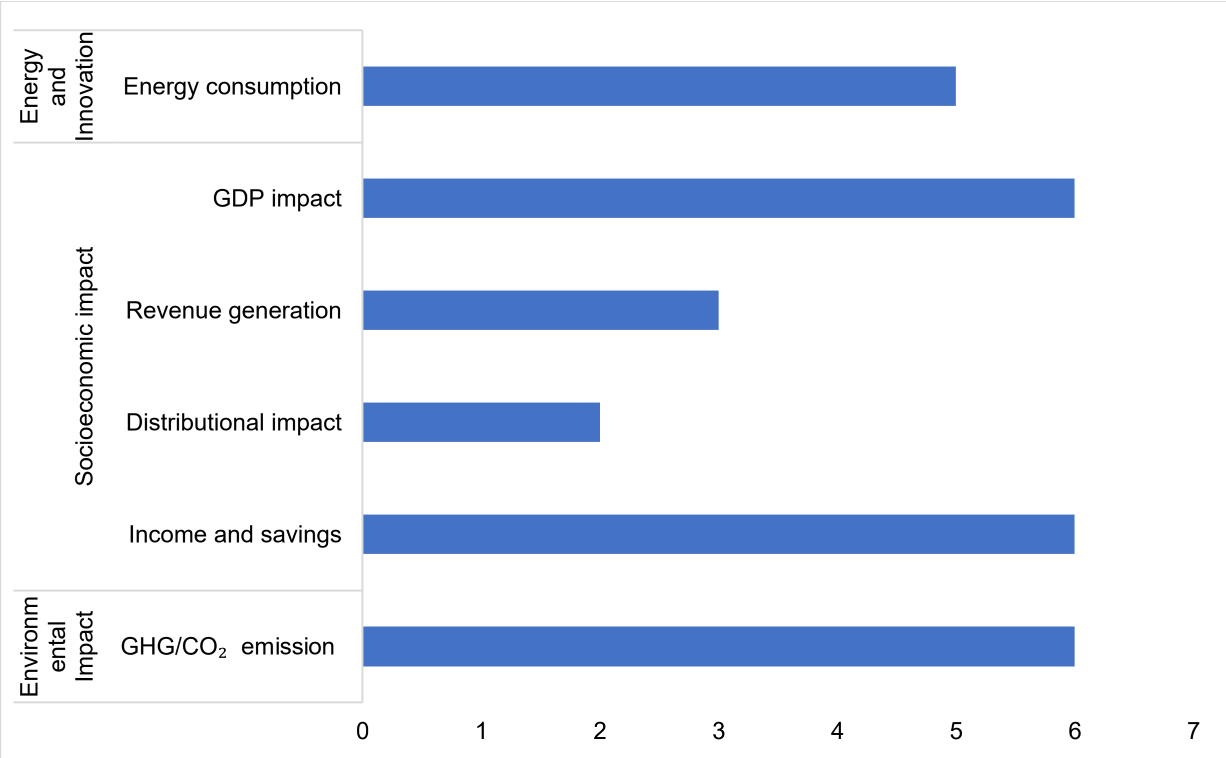
Five studies examined the impact on energy consumption outcomes, indicating the amount of energy used or shift from fossil fuels to renewable energy (Aggarwal et al., 2024; Kimuli et al., 2022; Kimuli et al., 2023; Semboja, 1994; Telaya et al., 2019).

Three studies assessed the impact on revenue generation, with all the studies showing a moderate to large positive impact (Ismail et al., 2023; Kimuli et al., 2022; Semboja, 1994).

Two studies assessed the distributional impact of carbon pricing interventions across income groups. Al-Guthmy and Yan (2020) examined how different income groups are impacted by various carbon quota allocation methods within personal carbon trading (PCT). Their findings indicate that Equal per-capita (EpCA) and Needs-Based

Allocation (NbA) promote a progressive effect, benefiting lower-income groups. Conversely, Equal per-vehicle (Epva) is less equitable**,** favouring higher emitters and potentially leading to disparities in carbon distribution. Mutua, 2012 examined fuel taxes as a method of carbon pricing in Kenya, revealed that such pricing mechanisms tend to be progressive.

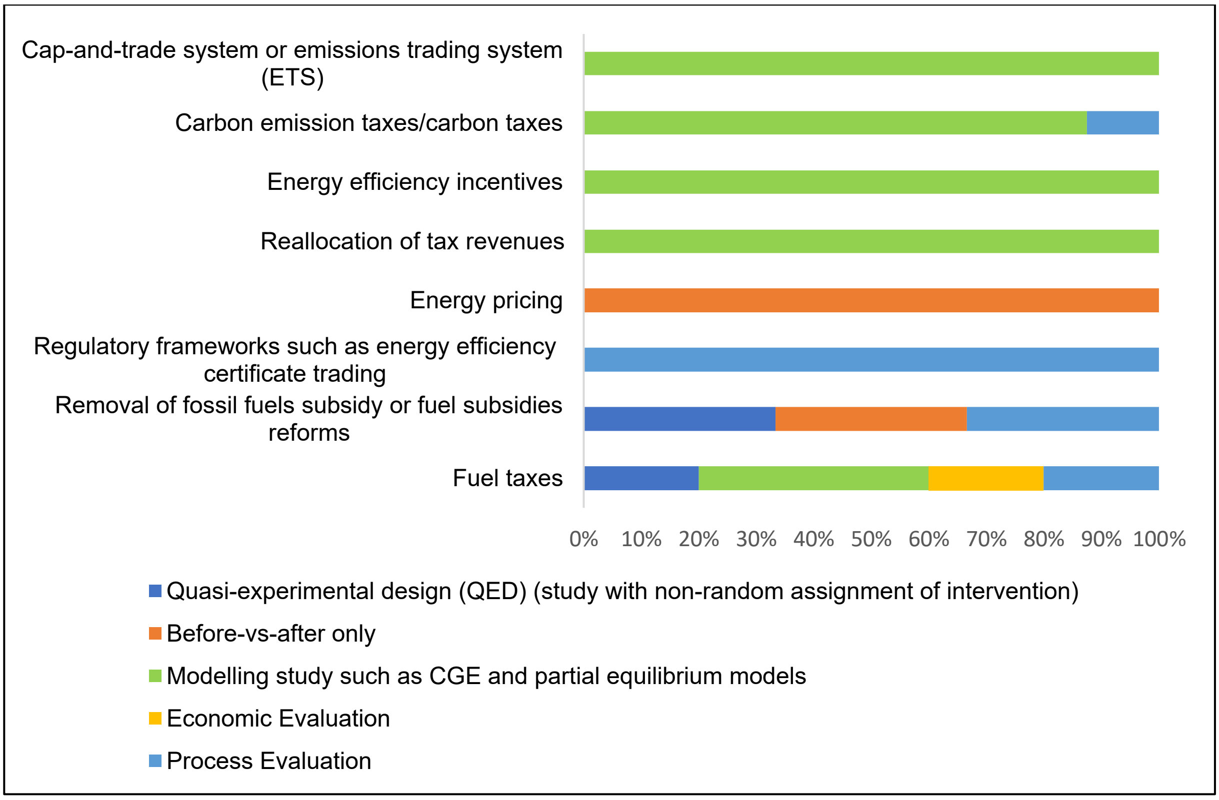
Figure 4 Distribution of studies by outcome categories



Study Design

Among the studies on direct carbon pricing, eight (90%) are classified as modelling studies, specifically utilising CGE and partial equilibrium models (Aggarwal et al., 2024; Al-Guthmy & Yan, 2020; Carvallo et al., 2017; Ismail et al., 2023; Kimuli et al., 2022; Kimuli, 2023; Telaye et al., 2019; Timilsina & Sebsibie, 2023), with one study categorised as a process evaluation (Shimba et al., 2024). In contrast, the studies on indirect carbon pricing include five (50%) modelling studies employing CGE and partial equilibrium methods (Asare & Schuerer, 2024; Mutua, 2009; Telaye et al., 2019; Timilsina & Sebsibie, 2019; Zhu, 2023); two (20%) studies using a before-vs-after design (Fuje, 2019; Semboja, 1994), one (10%) quasi-experimental study, and one (10%) process evaluation (Fuje, 2020) and one (10%) process evaluation (Harring et al., 2024) The modelling studies demonstrate a diverse range of approaches, with a significant emphasis on carbon emission taxes (**Figure 5**).

Figure 5 Distribution of studies based on study design and carbon pricing intervention



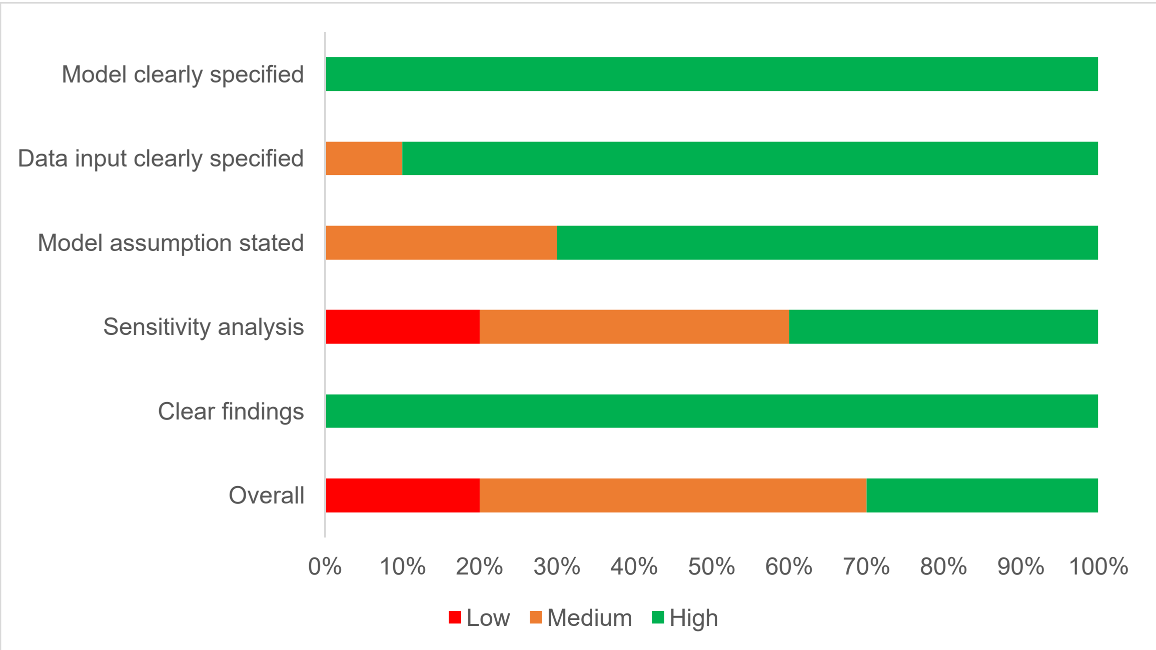
Cap-and-trade system or emissions trading system (ETS)
Carbon emission taxes/carbon taxes
Energy efficiency incentives
Reallocation of tax revenues
Energy pricing
Regulatory frameworks such as energy efficiency certificate trading
Removal of fossil fuels subsidy or fuel subsidies reforms
Fuel taxes
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Quasi-experimental design (QED) (study with non-random assignment of intervention)
Before-vs-after only
Modelling study such as CGE and partial equilibrium models
Economic Evaluation
Process Evaluation

Modelling Studies

The critical appraisal of the ten modelling studies on carbon pricing interventions revealed a high level of confidence in many assessment items. Most studies were rated high for the clarity of their model frameworks and the relevance of their data inputs. Specifically, all studies demonstrated a well-defined modelling framework suitable for assessing carbon pricing impacts, with robust data documentation. However, several studies exhibited medium confidence regarding the assumptions made, as they were often stated without sufficient justification or sensitivity analysis. Additionally, while most models were validated and calibrated with relevant data, some studies did not adequately address uncertainty in their predictions (**Appendix D**).

The overall findings indicated that while the three studies received high confidence ratings, five studies received medium confidence, and two studies were rated as low confidence. There were notable gaps in the justification of assumptions and comprehensive uncertainty analysis, leading to a mixed confidence level across the board (**Figure 6**).

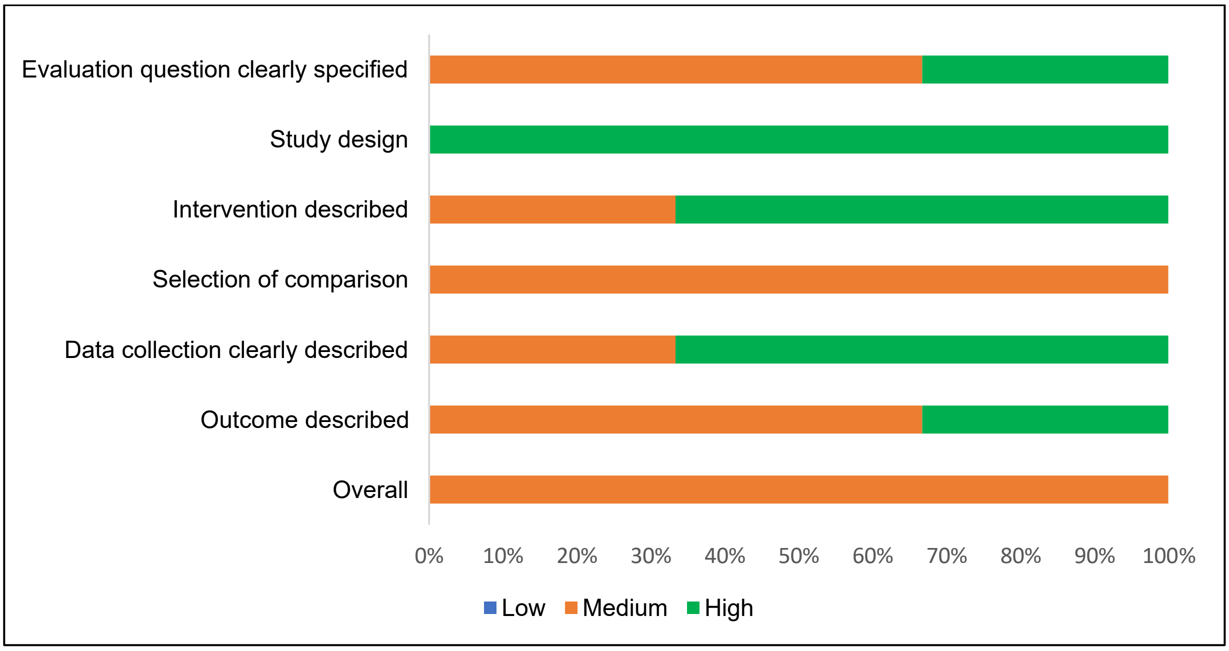
Figure 6 Confidence assessment in modelling studies



Impact Evaluations

We conducted a critical assessment of studies related to carbon pricing interventions using a framework that evaluated six domains, with five of these (evaluation questions, study design, intervention clarity, comparison group selection, and data quality) deemed essential for determining the effectiveness of the interventions (**Appendix E**). Overall, the studies exhibited a mix of medium to high confidence levels, primarily due to partial descriptions and documentation in certain areas, such as group selection methods and data sources. Notably, while most studies provided clear definitions and reliable data sources, the lack of comprehensive justification for comparability and the absence of power calculations limited the overall confidence ratings, with all studies assessed as medium confidence (**Figure 7).**

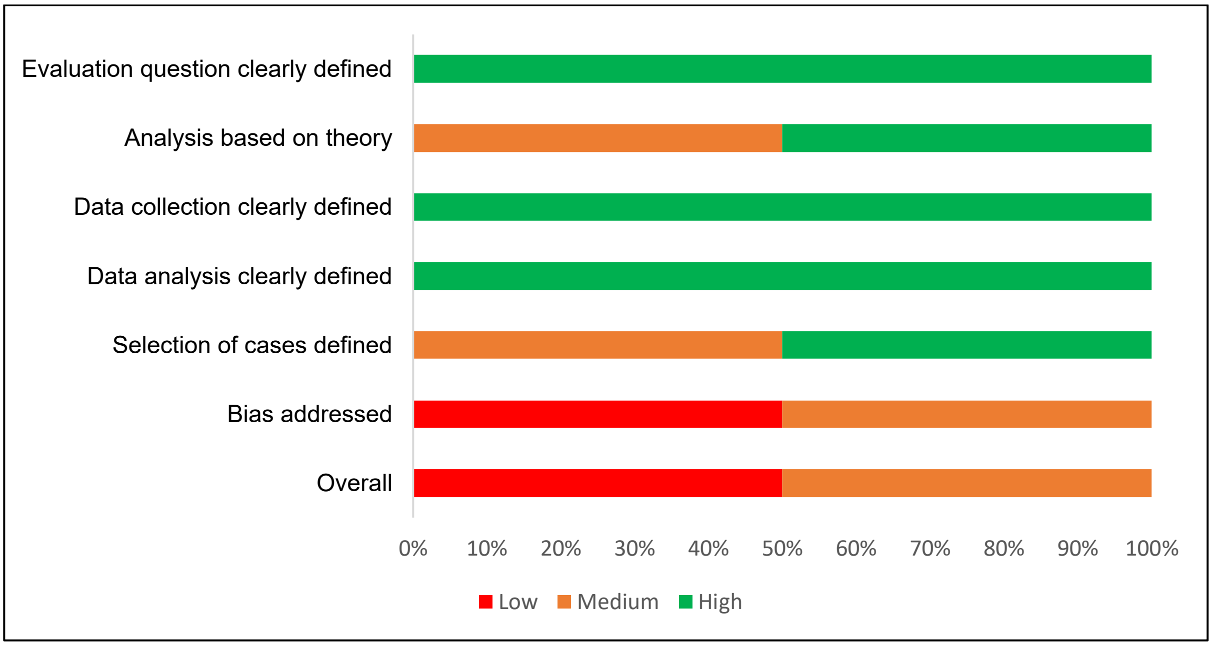
Figure 7 Confidence assessment in impact evaluations



Process Evaluations

The process evaluations for the studies by Harring et al. (2024) and Shimba et al. (2024) exhibit varying confidence levels across different variables. Harring (2024) received high confidence ratings in all critical areas, including clear evaluation questions, a well-defined theory of change, and a comprehensive description of methods and case selection. However, it noted medium confidence regarding potential sources of bias, which were mentioned but not adequately addressed (**Figure 8**). In contrast, Shimba et al. (2024) achieved high confidence in evaluation questions, methods, and intervention clarity, but only medium confidence in the theory of change due to the presentation of fewer elements, and low confidence in addressing bias, as there was no discussion on this aspect (**Appendix F**). While Harring's evaluation is robust, Shimba's evaluation shows significant gaps, particularly in bias assessment and theoretical framework justification.

Figure 8 Confidence assessment in process evaluations



Economic Evaluations

The included economic evaluations address several important dimensions relevant to the evaluation, including clarifying the research question, considering equity objectives (i.e. addressing disparities across subgroups), and addressing uncertainties through sensitivity analyses. While the study makes a commendable effort to incorporate equity considerations, further refinement in the articulation of perspective, justification of comparator relevance, detailed measurement and valuation of outcomes across subgroups, and a more comprehensive treatment of uncertainty would increase confidence in the robustness and policy relevance of the analysis.

Synthesis of Findings

EFFECTIVENESS STUDIES

This section presents findings from the synthesis of effect sizes in these studies. We employ meta-analysis to generate pooled effects that reflect the weighted average effect across the studies. This approach also measures statistical heterogeneity, indicating the representativeness and generalisability of the pooled effect across various contexts in which the interventions have been evaluated. The meta-analysis included 12 studies and 119 effect sizes, primarily examining the effectiveness of carbon tax interventions on CO_2 emissions and energy consumption. Descriptive information about these studies is contained in **Table 1. Appendix F** also presents a narrative summary of the included studies.

Effect Size Conversion and Standardisation Methodology

Our analysis encountered multiple types of effect sizes, including percentages, beta coefficients, and indices. Standardising these different metrics was necessary to ensure consistency and comparability. We converted all effect sizes to correlation coefficients ('r'), as this metric is integral to calculating Cohen's d. The correlation coefficient provided a uniform scale (-1 to +1) for effect sizes reported in different metrics.
For standardisation, we converted the correlation coefficients into Cohen's d using the following formula:

$$\text{Cohen's } d = \frac{2 \times ES_r}{\sqrt{1 - ES_r^2}}$$

We further computed the standard error (SE) for Cohen's d, which is later used in the meta-analysis.

In this context, we are considering the absolute values of d. Large effect sizes are indicated by $|d| \geq 0.5$, moderate effect sizes fall within the range $0.2 \leq |d| < 0.5$, and small effect sizes are within the range $0 \leq |d| < 0.2$. Effect sizes have been transformed so that $d > 0$ consistently reflects a desirable outcome and $d < 0$ reflects an undesirable outcome.

Table 1 Descriptive information of studies included in meta-analysis

Study author	Intervention	Comparison	Outcome	Confidence
Aggarwal et al., 2024 Uganda	Carbon tax (US$40/ton on Ugandan households)	Business as usual (BAU)	Energy consumption	High
			Energy demand	

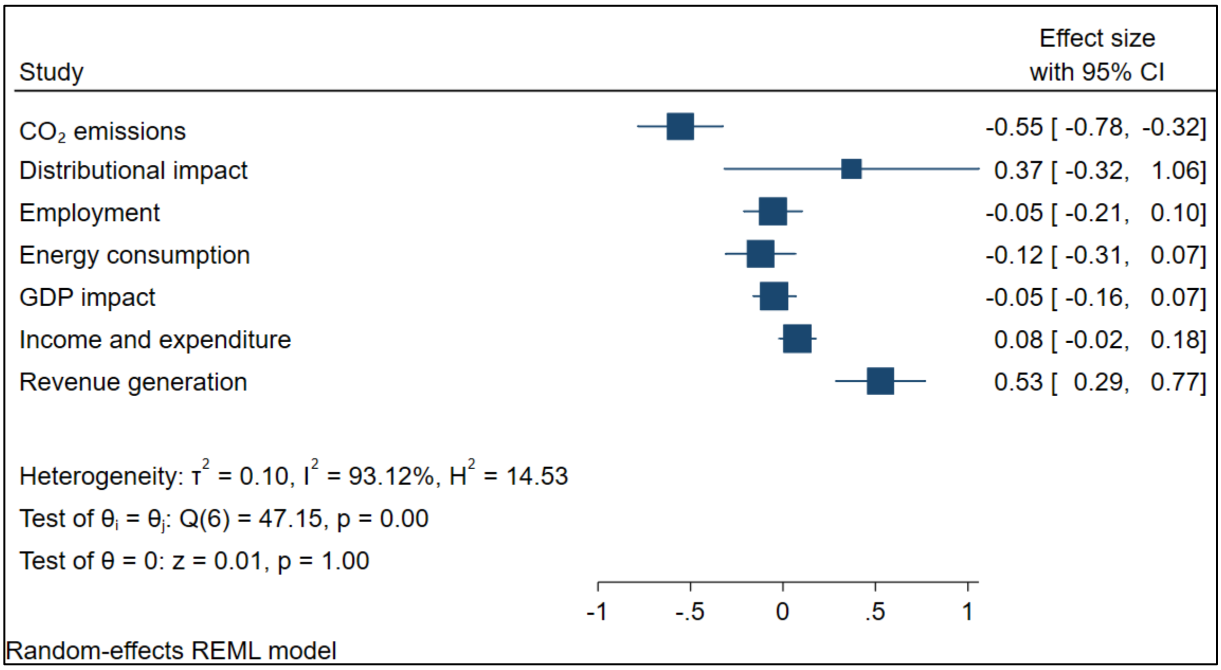
Study author	Intervention	Comparison	Outcome	Confidence
Al-Guthmy and Yan, 2020	Personal Carbon Trading	Three quota allocation: Equal per-capita, equal per-vehicle and needs-based allocation methods	Distributional impact on income	Low
Asare & Schuerer, 2024 Tanzania	Carbon tax and fuel tax, energy efficiency incentives	Business as usual (BAU)	Income and expenditure	Low
Ismail et al., 2023 Uganda	Carbon tax (100$/ton)	Alternative treatment (Energy scenarios- Kabejja (20% CO_2 abatement and Iutta (95% CO_2 abatement)	CO_2 emission reduction GDP	High
Kiambati, 2023 Kenya	Energy pricing	Business as usual (BAU)	Employment	Medium
Kimuli (2022) Uganda	Carbon tax (100$/ton)	Alternative treatment (Energy system modelling scenarios- Kabejja (20% CO_2 abatement and Iutta (95% CO_2 abatement))	CO_2 emission reduction (-0.84%)	Medium
Kimuli (2023) Uganda	Carbon tax (100$/ton)	Alternative treatment (Energy system modelling scenarios)	CO_2 emission reduction (-0.80%) Energy consumption	Medium
Mutua (2009)	Fuel tax	Business as usual (BAU)	Distributional impact on income	Low
Semboja (1994)	Energy pricing	Business as usual (BAU)	Energy consumption	Medium

Study author	Intervention	Comparison	Outcome	Confidence
Kenya				
Telaye (2019) Ethiopia	Carbon tax (starting at US$5 per ton of CO_2 (in 2018) and rising to US$30 per ton by 2030)	Business as usual (BAU)	CO_2 emission (-0.38%) Employment	Medium
Timilsina (2023) Ethiopia	Carbon tax ($20/tCO_2$)	Business as usual (BAU)	CO_2 emission (-0.38%)	High
Zhu (2023) Kenya	Fuel tax	Alternative treatment (different tax scenarios-0.5% energy tax and a 20% energy tax.)	CO_2 emission (-0.55%)	Medium

The meta-analysis was done at the outcome sub-domain level, providing a more nuanced interpretation of the findings by outcome.

Overall, there is a significant and large effect on CO_2 emissions reduction (d = -0.55, 95% CI: -0.78, -0.32) and a significant and large effect on revenue generation (d = 0.53, 95% CI: 0.29, 0.77). This suggests that carbon pricing effectively reduces emissions and generates financial resources. While there is a notable decrease in energy consumption, indicating a modest reduction in energy use (d = -0.12, 95% CI: -0.31, 0.07), this effect is not statistically significant. The analysis found a moderate positive effect (d= 0.37, 95% CI: -0.32, 1.06, 2 estimates) on distributional impact, suggesting a progressive impact, though this was statistically insignificant. The effect on GDP is slightly negative (d= -0.05, 95% CI: -0.16, 0.07, 5 estimates), indicating limited economic growth benefits, while the effects on income and expenditure are small and positive but statistically insignificant (d= 0.08, 95% CI= -0.02, 0.18; 6 estimates) (**Figure 9**).

Figure 9 Forest plot of CO_2 emission, distributional impact, employment, energy consumption, GDP, income and expenditure and revenue generation outcomes

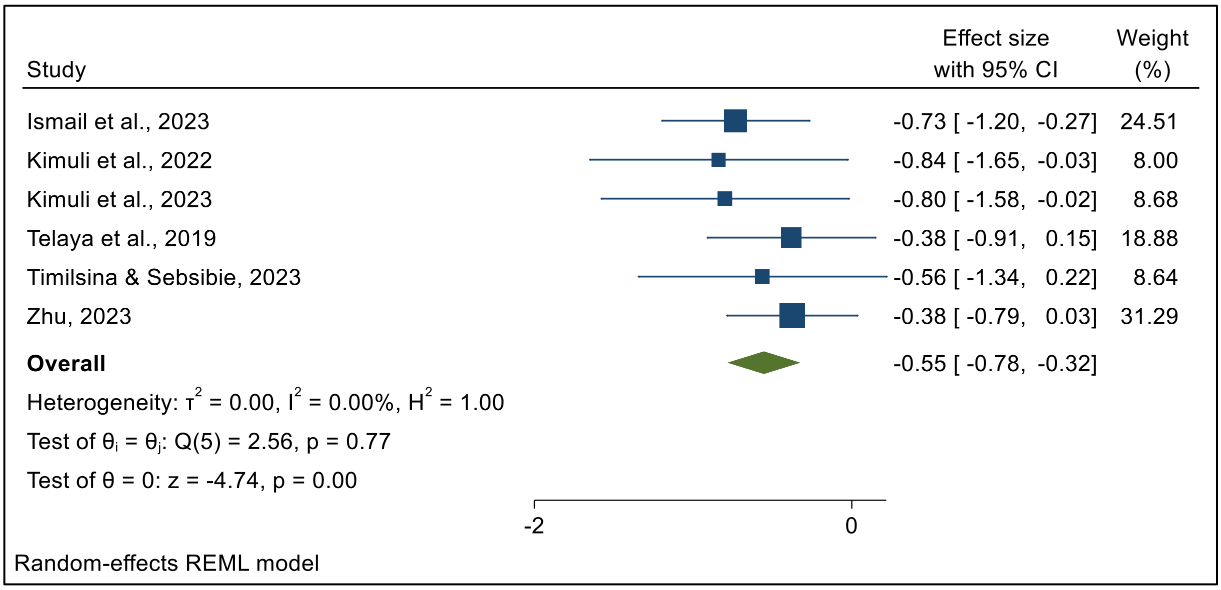


Emissions Reductions

Six studies modelled the impact of carbon pricing interventions on CO_2 emission reductions. The overall effect size is large and negative, suggesting a reduction in CO_2 emissions as a result of these interventions (d= -0.55, 95% CI= -0.78, -0.32; 6 estimates) (**Figure 10**). Five of these studies focused on the effects of a carbon tax, while one evaluated the impact of a fuel tax on CO_2 emissions. The lack of heterogeneity suggests consistency across the studies, supporting the reliability of these findings.

Overall, the findings highlight the effectiveness of these interventions in achieving significant reductions in greenhouse gas emissions.

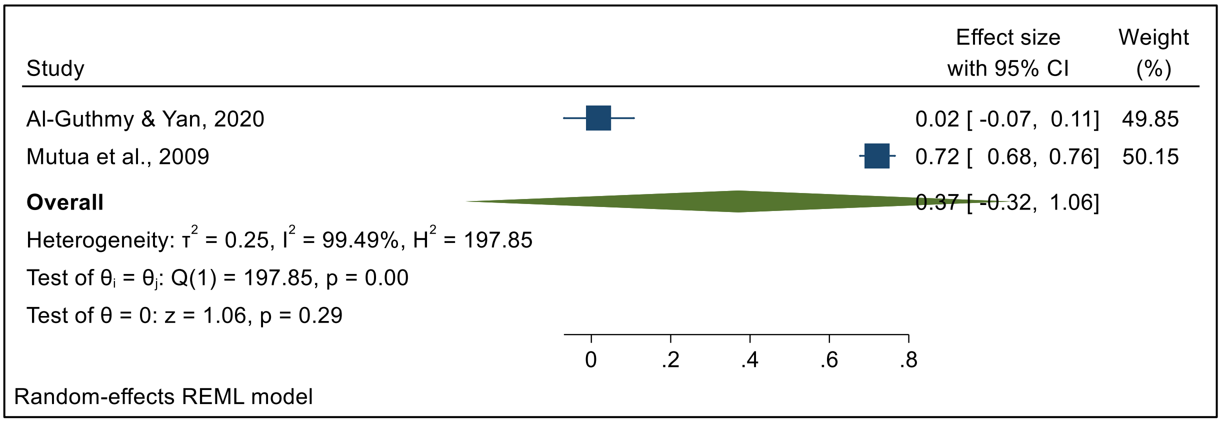
Figure 10 Detailed forest plot of emission reduction outcome



Distributional Impact

The overall effect size is moderate and positive (d= 0.37, 95% CI: -0.32, 1.06, 2 estimates), suggesting a progressive impact across income groups. This suggests that the intervention contributes to an equitable redistribution of resources, potentially benefiting lower-income groups while maintaining overall economic balance. The observed effect was found to be statistically insignificant (**Figure 11**). Additionally, substantial heterogeneity was noted, indicating that the effects vary across contexts and study conditions.

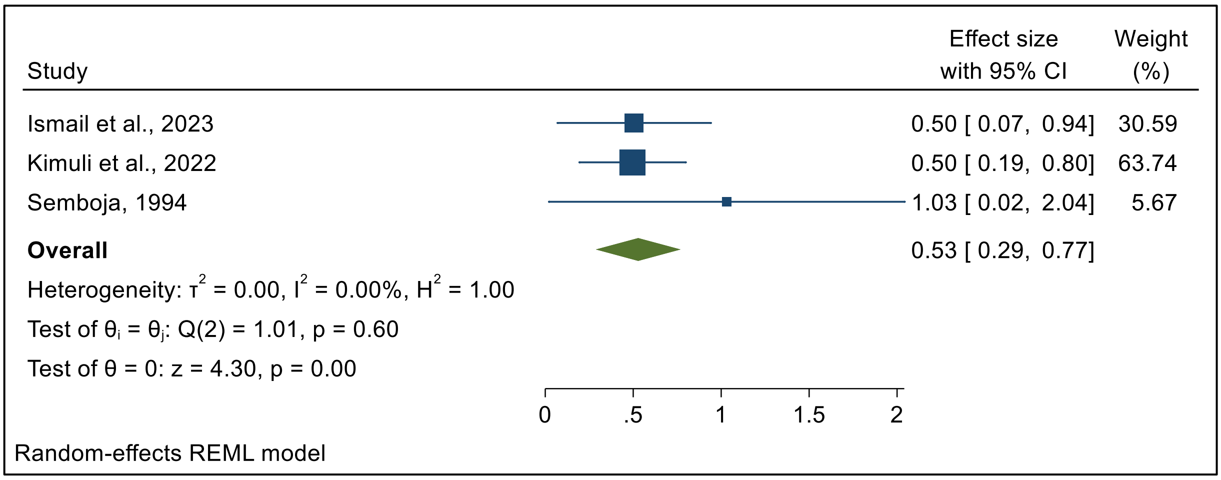
Figure 11 Detailed forest plot of distributional impact



Revenue Generation

Three studies modelled the impact of carbon pricing interventions on revenue generation. The overall effect size is large and positive, suggesting an increase in revenue generation due to these interventions (d = 0.53, 95% CI: 0.29, 0.77, 3 estimates). The lack of heterogeneity suggests consistency across the studies, supporting the reliability of these findings. (**Figure 12**).

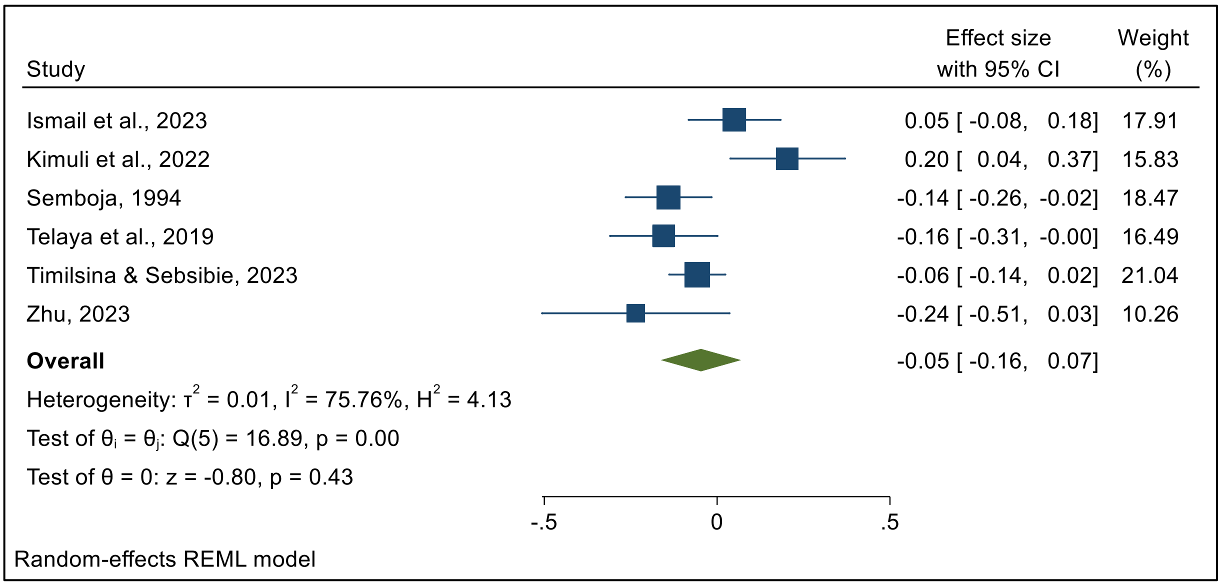
Figure 12 Detailed forest plot of revenue generation outcome



GDP Impact

Five studies modelled the impact of carbon pricing interventions on GDP. The results indicate a small negative effect (d= -0.05, 95% CI: -0.16, 0.07, 5 estimates), suggesting that these interventions do not improve GDP performance. The observed effect was found to be statistically insignificant (**Figure 13**). Substantial heterogeneity was noted, indicating that the effects vary across contexts and study conditions.

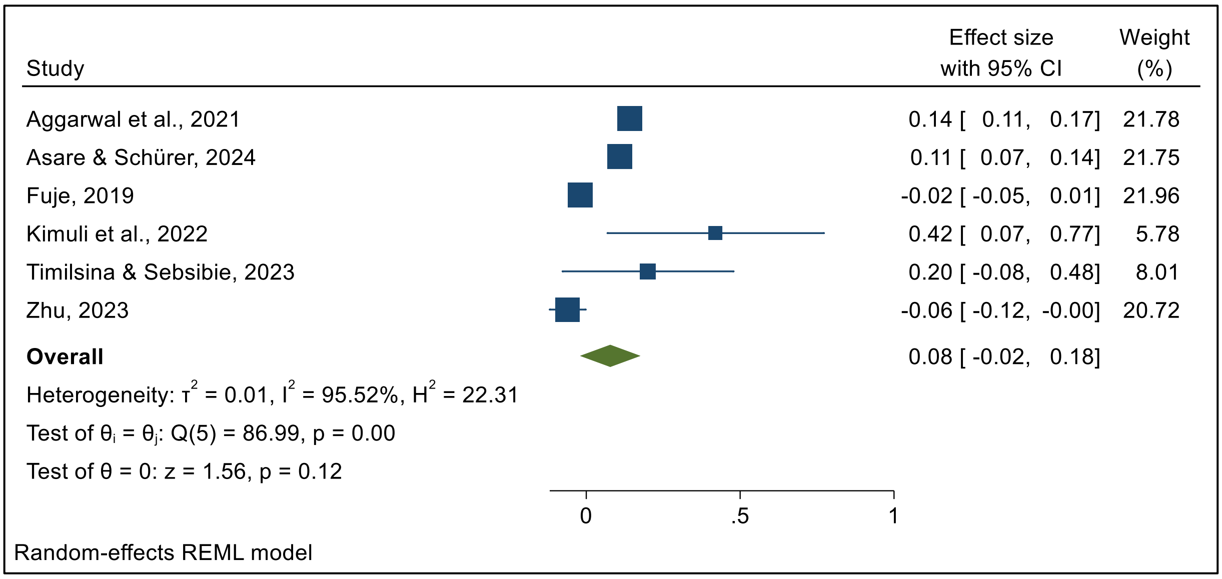
Figure 13 Detailed forest plot of impact on intervention on GDP



Income and expenditure

Six studies modelled the impact of carbon pricing interventions on income and expenditure. The results indicate a small and positive effect, suggesting that these interventions have the potential to modestly increase income and expenditure (d= 0.04, 95% CI= -0.18, 0.26; 6 estimates). However, the observed effect was statistically insignificant (**Figure 14**). Substantial heterogeneity was noted, indicating that the effects vary across contexts and study conditions.

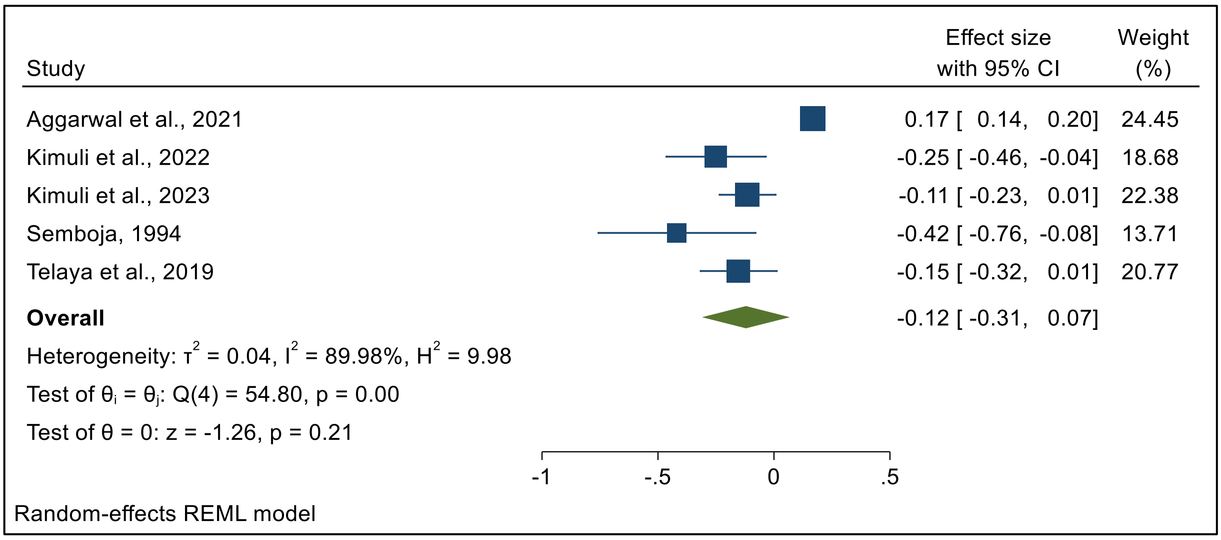
Figure 14 Detailed forest plot of income and expenditure outcome



Energy Consumption

Five studies modelled the impact of carbon pricing interventions on energy consumption. The overall effect size is small and negative, indicating that these interventions reduce energy consumption (d= -0.12, 95% CI: -0.31, 0.07, 5 estimates) (**Figure 15**). This negative effect suggests that carbon pricing interventions can effectively discourage energy use by increasing the cost of carbon-intensive activities. However, the effect was statistically insignificant, implying that the reduction in energy consumption is not consistently observed across all studies and contexts. Additionally, substantial heterogeneity was noted, indicating that the impact of carbon pricing on energy consumption varies significantly depending on factors such as the specific design of the policy, the elasticity of energy demand, and the availability of alternative energy sources.

Figure 15 Detailed forest plot of energy consumption outcome



Publication Bias

The heterogeneity of the findings precluded an assessment of publication bias in the included studies.

PROCESS EVALUATIONS

The two process evaluations, Harring et al. (2024) and Shimba (2024), provide key insights into overcoming barriers to carbon pricing in East Africa and offer deep insights into the core elements required for successful carbon policy implementation, considering local contexts, institutional capacity, and stakeholder engagement.

One crucial message is the need for localised studies to understand public acceptability within East African countries' unique cultural, institutional, and economic contexts, as there is significant heterogeneity in support across the region. This includes exploring ways to earmark revenues from carbon pricing for specific uses, which can enhance public support. Additionally, investing in education and awareness campaigns is vital for improving understanding of climate change and its policies, while factoring in the importance of trust in institutions during policy design and implementation.

Another key message emphasises the importance of addressing technical and institutional barriers, as highlighted in Shimba's analysis of Tanzania. This includes mobilising funding, enhancing institutional coordination, and increasing climate change expertise through education and private sector involvement. Employing models like FINAGE to recycle carbon pricing revenues and protect vulnerable populations can also be effective strategies. Overall, these approaches aim to build adaptive capacity and foster acceptance of carbon pricing in the region (**Table 2**).

Table 2 Summary of key findings from process evaluations

Aspect	Harring et al. 2024	Shimba, 2024

Country	Ethiopia, Kenya, Rwanda, Tanzania, Uganda	Tanzania
Intervention	Fuel Tax, Fossil Fuel Subsidy Reduction	Carbon tax
Barriers	Low public acceptance: Fuel tax (~29%); subsidy removal (~31%); regulation (~35%) Lack of trust in government; competing social priorities; institutional and technical gaps Lack of studies on climate policy attitudes in low-income countries, particularly in East Africa	Lack of climate change expertise and trained manpower Lack of compliance with law; potential stakeholder resistance; lack of robust technical and institutional framework
Strategies/recommendations	Conducting localised studies to better understand policy acceptability in the unique cultural, institutional, and economic contexts of East Africa Focus on public acceptance and trust building through transparent revenue use and education	Invest in capacity building; structured legal framework; separate carbon tax revenue from common taxes; earmark funds for climate change mitigation; develop monitoring framework; focus on cost-effective approach

Implications and Conclusion

The analysis of carbon pricing interventions in East Africa includes sixteen studies with a diverse geographic distribution, focusing on countries like Uganda, Kenya, Tanzania, and Ethiopia.

Overall, the findings demonstrate that carbon pricing interventions in East African countries effectively reduce CO_2 emissions and generate significant revenue. However, their impacts on energy consumption, income distribution, and GDP are modest and context-dependent.

This report presents a meta-analysis of 12 studies with 119 effect sizes evaluating carbon pricing interventions in East Africa. This analysis aims to synthesise findings from various research efforts to provide a comprehensive understanding of the impacts of carbon pricing in the region. Six studies examined the impact of carbon pricing on CO_2 emissions and found a large decrease in emissions, suggesting that these interventions effectively reduce greenhouse gases. Three studies explored the effect of carbon pricing on revenue generation, reporting a large increase in revenue, indicating that these interventions can significantly boost government income. Two studies investigated the distributional impact of carbon pricing, revealing a moderate and positive effect, suggesting that carbon pricing interventions help in reducing income inequality by having a progressive effect, benefiting lower- income groups more than higher-income groups. The impact on GDP is slightly negative, indicating limited economic growth benefits, while the effects on income and expenditure are small and positive but statistically insignificant. Five studies focused on energy consumption, showing a small negative overall effect, indicating a modest reduction in energy use.

Lastly, the synthesis of two process evaluations of carbon pricing implementations in East Africa provides valuable insights into the essential elements for successful carbon policy implementation.

Individual studies in this review highlight the significant potential of carefully designed carbon pricing policies to drive environmental and economic changes. For example, in Uganda, Kimuli et al. (2023) and Ismail et al. (2023) demonstrated that progressive carbon tax policies, such as the Lutta scenario, aim to significantly reduce CO_2 emissions by implementing high tax rates on carbon-intensive activities. The Lutta scenario targets explicitly a 95% reduction in emissions, showcasing the potential of ambitious low-carbon strategies to achieve substantial environmental benefits while fostering economic growth. These policies often require complementary measures, like revenue recycling or investments in renewable energy, to maximise their effectiveness and address potential economic or social challenges.

Telaya et al. (2019) highlight that gradually increasing carbon taxes on petroleum fuels and kerosene in Ethiopia can achieve moderate reductions in CO_2 emissions while generating substantial revenue. These findings imply that policymakers could use such taxes as a dual-purpose strategy: reducing emissions from targeted sectors and mobilising financial resources to support environmental and social programmes. However, the study also reveals that emissions from these fuels constitute only a small portion of Ethiopia's overall emissions, suggesting that broader and more comprehensive carbon pricing policies might be required to achieve a significant national-level impact. Additionally, the revenue generated from these taxes—up to $800 million annually—could be reinvested in clean energy projects and infrastructure improvements, aligning with sustainable development goals.

The study by Timilsina & Sebsibie (2023) implies that a hypothetical $20 per tCO_2 carbon tax in Ethiopia could effectively reduce CO_2 emissions, demonstrating its potential for environmental sustainability. The smallest GDP decrease observed under the investment-based revenue recycling scheme suggests that channelling tax revenues into investments could mitigate economic impacts while still achieving significant emission reductions. The study by Zhu (2023) highlights a key trade-off for policymakers in Kenya when considering fuel tax rates. While high energy taxes (e.g., 20%) can significantly reduce carbon emissions, achieving a 17.04% decrease, they also come with severe economic costs, such as a sharp 14.46% GDP contraction. On the other hand, lower energy taxes (e.g., 0.5%) impose less financial strain, with only a 1% GDP decline, but yield much smaller environmental benefits.

IMPLICATIONS FOR POLICY

Studies in this review highlight the potential of well-designed carbon pricing policies to drive environmental and economic change. Policymakers must carefully consider how carbon pricing interventions impact different income groups and design strategies to mitigate regressive distributional effects, ensuring consumers and producers are not unfairly affected, especially poor people and small scale enterprises who rely on, and may have few substitute sources of, essential goods like fuel and electricity.

- Progressive schemes, such as equal cash transfers or transfers inversely proportional to income, help mitigate potential negative impacts on low-income groups, thereby promoting equity and widening the income distribution in favour of those who need it most.
- Measures like targeted subsidies, carbon tax rebates, revenue redistribution, reallocation of tax revenues for renewable energy infrastructure, or investments in social programmes such as agricultural support programmes could help protect lower-income households and ensure that carbon pricing policies are equitable and socially acceptable. Addressing these is crucial for building public trust and support for carbon pricing initiatives.

Transparency in carbon pricing mechanisms and public engagement strategies is likely necessary to secure long-term political and social acceptance. Integrating carbon pricing into broader sustainability policies, such as medium-term plans like poverty reduction strategies (PRSPs), could accelerate progress toward net-zero targets while fostering economic resilience.

Establishing robust monitoring and evaluation frameworks is vital to assess real-world impacts and make necessary adjustments.

Tailored policy designs that consider each country's unique socio-political and economic contexts can maximise the effectiveness of these interventions. This can usefully draw on commissioned evaluations.

Making policies flexible and adaptive, allowing for adjustments based on ongoing evaluations and new research insights, can provide real-world information. For example, some policies implemented at the sub-national level can be randomly allocated by district or other administrative levels. Where randomisation is impossible, quasi-experimental designs which use existing data sources and/or non-policy groups as comparators may be feasible. This approach can provide valuable insights into the effectiveness and efficiency of the policies to inform necessary adjustments, for example, on the modifications needed to take programmes to scale at the national level.

Another key implication is understanding market dynamics and demand elasticity when designing carbon pricing strategies. Implementing varying tax rates based on the elasticity of demand for different carbon-intensive goods, for example, higher taxes may be applied to goods with elastic demand to maximise emissions reduction.

For modelling studies, which are typically used to forecast outcomes associated with future scenarios, we suggest users view the results as a general guide as to the likely effects of a scenario, bearing in mind that estimates of cost savings, energy use, or emissions cuts are often closely linked to guesses about technology changes and economic growth.

IMPLICATIONS FOR RESEARCH

Substantial heterogeneity among studies indicates a need for standardised research methodologies and clearer assumptions across evaluations. By using consistent analytical frameworks and incorporating diverse study designs like randomised control trials, researchers can greatly enhance the comparability and reliability of their findings.

Future research could benefit by broadening the scope to encompass a wider array of economic and social impacts, including employment effects, energy consumption and broader economic indicators.

More studies assessing the distributional impacts of carbon pricing across different income groups and regions, focusing on identifying effective compensation mechanisms to mitigate adverse effects on vulnerable populations, might help fill the gaps in these areas.

More studies are also needed to determine how changes in key assumptions, such as technology costs or demand growth, might affect policy outcomes. These might incorporate systematic sensitivity analysis in new studies or the synthesis of modelling evidence from multiple existing studies.

Long-term research tracking the effects of carbon pricing over extended periods could reveal patterns in market behaviour, emissions reductions, and socio-economic impacts.

Additional studies that assess the smaller yet cumulatively important effects of interdisciplinary approaches integrating economic, environmental, and social dimensions are necessary to provide a more holistic understanding of the interventions' effects.

More process evaluations are needed, and existing ones incorporated into systematic decision-making processes (e.g., via evidence synthesis), to facilitate sharing experiences and insights on the effectiveness of carbon pricing instruments across East Africa.

Examining how carbon pricing affects various income groups, industries, and vulnerable populations would help ensure equitable policy design.

APPENDIX A DEMAND AND SUPPLY FRAMEWORK OF CARBON PRICING INTERVENTIONS

Figure 16 illustrates the impact of implementing a Pigouvian tax to address the negative externalities associated with carbon emissions. The blue demand curve represents the quantity consumers are willing to buy at different prices, while the green market supply curve (MPC) shows the producer's cost without considering external costs. The red dashed line represents the marginal social cost (MSC), which includes the external costs like pollution. Without a tax, the market equilibrium occurs at the intersection of the demand and private supply curves, leading to overproduction and a deadweight loss—an area of inefficiency where societal welfare is not maximised. By imposing a Pigouvian tax, the supply curve shifts to account for external costs, moving the market to the socially optimal point where the social supply curve intersects with the demand curve. This adjustment reduces the quantity produced, internalises the external costs, and eliminates the deadweight loss, aligning market activities with broader societal benefits.

Figure 16: Carbon pricing using a pigouvian tax and deadweight loss

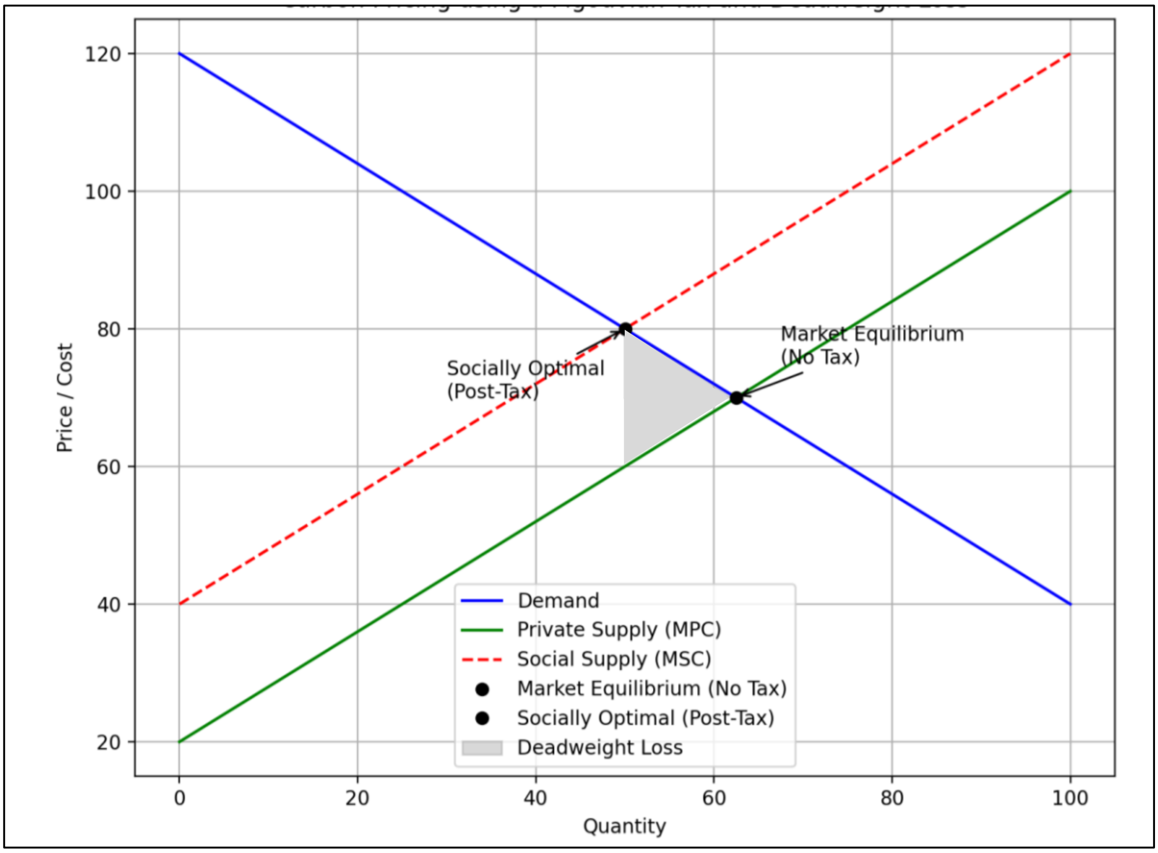


Figure 17 provides a detailed look at the effects of a Pigouvian tax on market dynamics, focusing on how it influences consumer and producer prices and generates tax revenue. Under the "polluter pays" principle, carbon taxes aim to make polluters

cover the costs of their emissions. The demand curve intersects with both the marginal private cost (MPC) and marginal social cost (MSC) curves, illustrating the market equilibrium without a tax and the socially optimal equilibrium with a tax, respectively. The tax shifts the equilibrium, raising the consumer price and lowering the producer price. The graph breaks down the tax burden, showing that both consumers and producers share it equally.

This is illustrated with a demand curve (P = 10 − Q), showing the original market equilibrium without tax at Q_1 (4 units) and price P_1. The marginal social cost (MSC) line shows the socially optimal equilibrium with tax at a lower quantity, Q_2 (3 units), and a higher consumer price, p_2. The consumer's share of the tax is the difference between p_1 and p_2, while the producer's share is between p_3 (MPC price at Q_2) and p_1.

Tax revenue is shown as (tax_consumer + tax_producer) × Q_2, indicating the shared burden based on demand and supply elasticity. If demand is more elastic, consumers bear less of the tax, while an inelastic supply shifts more burden to producers.

This visualisation underscores how the tax internalises external costs, aligns production with societal welfare, and generates revenue that could be used for environmental improvements.

Figure 17: Tax revenue generation from carbon pricing

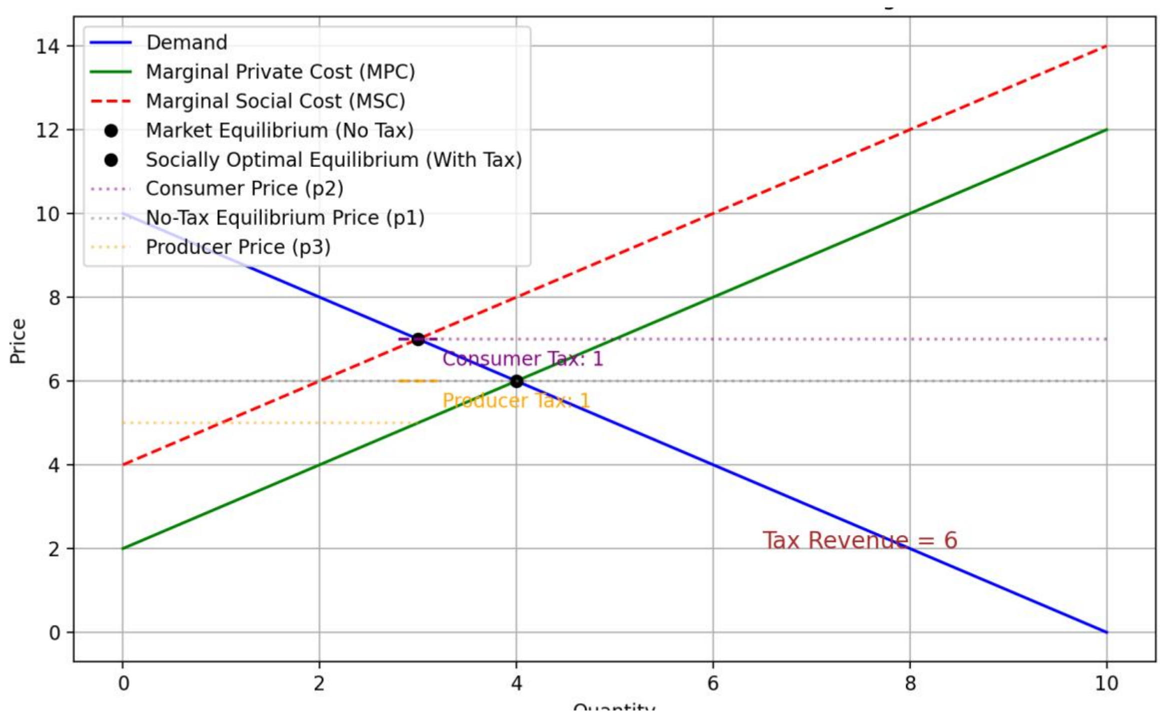
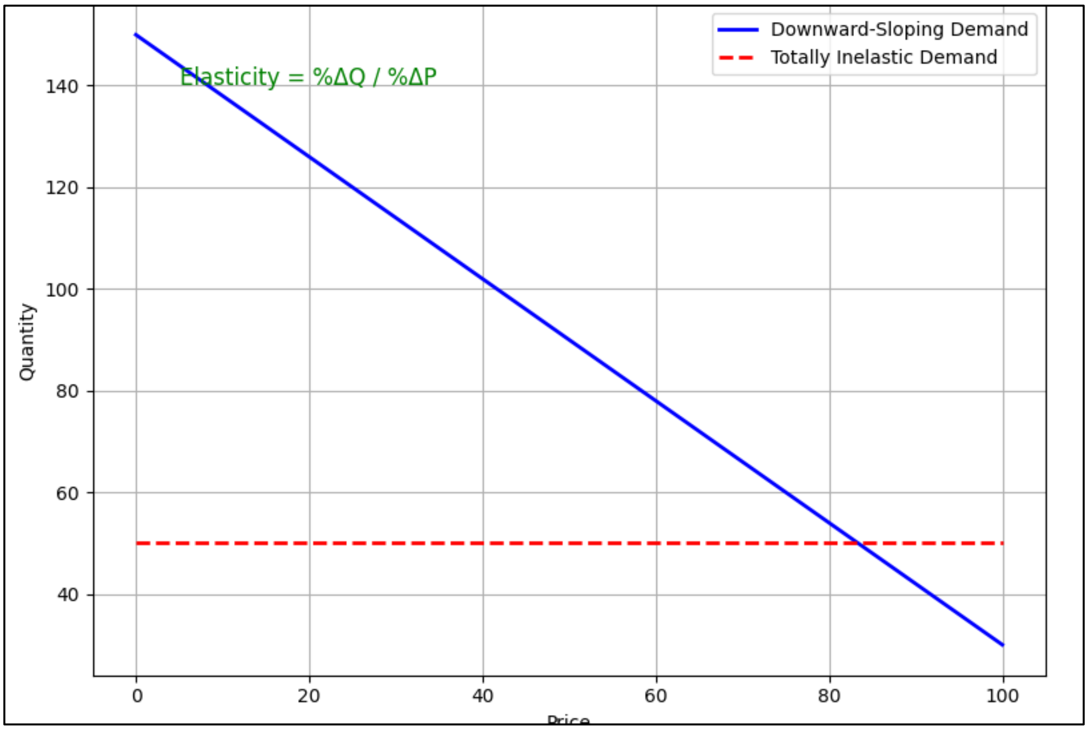


Figure 18 illustrates how demand elasticity affects the impact of a Pigouvian tax on carbon emissions. Suppose demand for carbon-intensive goods is elastic (as shown by the blue line). In that case, a price increase due to a tax will significantly reduce quantity demanded, effectively lowering emissions. Conversely, if demand is inelastic (represented by the red dashed line), a price increase will not affect consumption levels, making the tax less effective in reducing emissions. Demand is typically inelastic for essential goods like fuel or electricity, meaning consumers continue purchasing despite price rises, bearing more of the tax. If goods are more elastic, consumers cut back, reducing emissions.

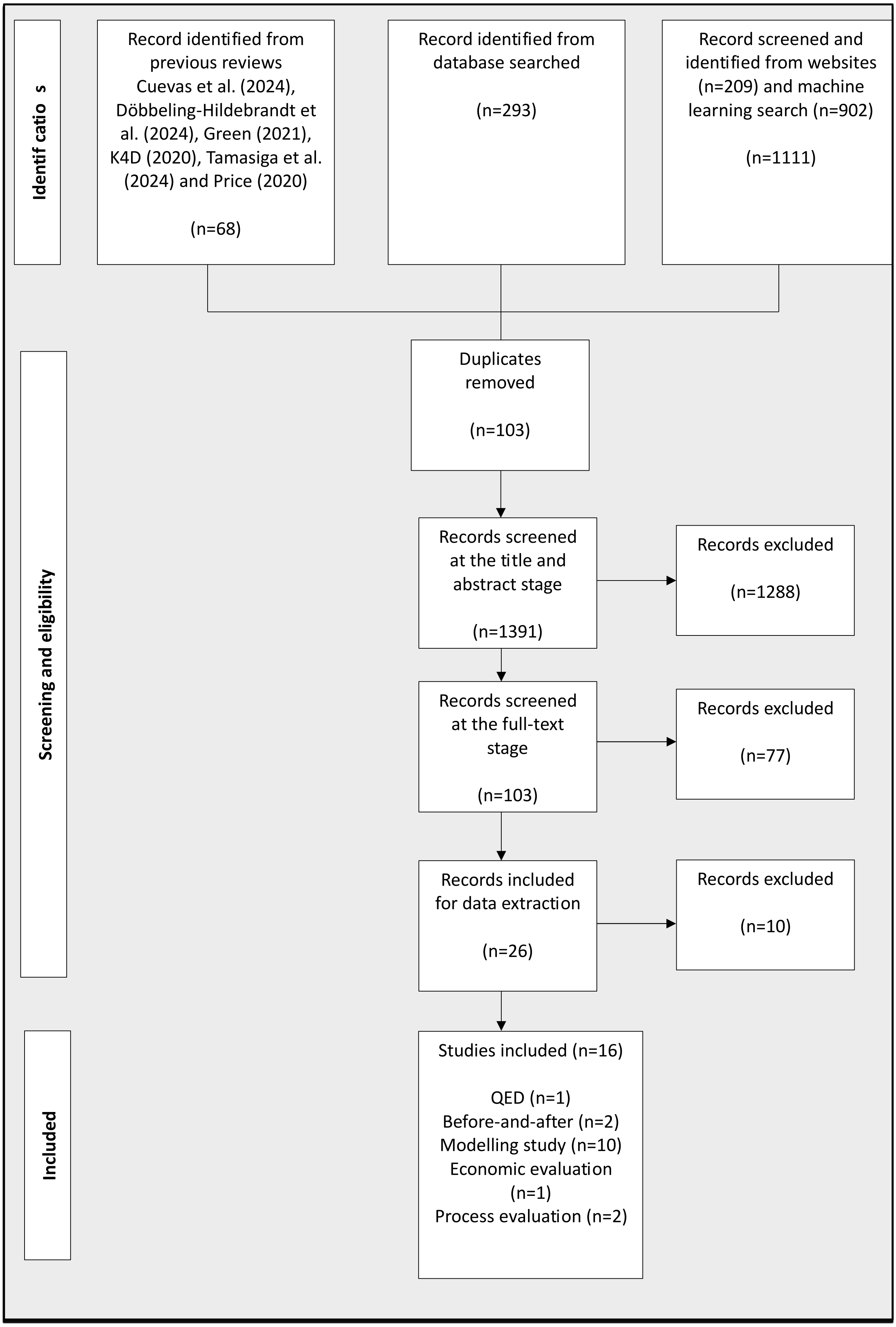
Understanding elasticity helps policymakers predict and enhance the effectiveness of carbon pricing interventions by identifying which sectors or goods are more responsive to price changes.

Figure 18 Elasticity of demand



A key policy implication is understanding market dynamics and demand elasticity when designing carbon pricing strategies. Implement varying tax rates based on the elasticity of demand for different carbon-intensive goods. Higher taxes may be applied to goods with elastic demand to maximise emissions reduction. Utilise the tax revenue to invest in renewable energy, subsidise cleaner technologies, and support affected industries and communities, ensuring a just transition. Monitor and adjust tax rates and policies based on changing market conditions and behaviours to enhance effectiveness and efficiency.

APPENDIX B PRISMA STUDY SEARCH DIAGRAM


Identif catio s
Record identified from previous reviews Cuevas et al. (2024), Döbbeling-Hildebrandt et al. (2024), Green (2021), K4D (2020), Tamasiga et al. (2024) and Price (2020)
(n=68)
Record identified from database searched
(n=293)
Record screened and identified from websites (n=209) and machine learning search (n=902)
(n=1111)
Screening and eligibility
Duplicates removed
(n=103)
Records screened at the title and abstract stage
(n=1391)
Records excluded
(n=1288)
Records screened at the full-text stage
(n=103)
Records excluded
(n=77)
Records included for data extraction
(n=26)
Records excluded
(n=10)
Included
Studies included (n=16)
QED (n=1)
Before-and-after (n=2)
Modelling study (n=10)
Economic evaluation (n=1)
Process evaluation (n=2)

APPENDIX C: TABLE OF INCLUDED STUDIES

Study author last name and Country	Study design	Intervention sub-category	Outcome Subdomain	Confidence assessment
Aggarwal (2024); Uganda	Modelling study using partial-equilibrium microeconomic model	Carbon tax (Carbon price of US$40/ton on Ugandan households.)	1. Household welfare 2. Energy consumption pattern 3. Shifts in food consumption baskets and nutritional intake (calories, protein, and micronutrients)	Medium confidence
Al-Guthmy (2020); Kenya	Modelling study using static arithmetic microsimulation model	Carbon tax (Personal carbon trading (PCT) quota allocation methods for road transport in Kenya.	1. CO_2 emissions 2. Fuel consumption 2. income/ expenditure	Low confidence
Asare (2024; Tanzania)	Modelling study using static arithmetic microsimulation model	Carbon tax and fuel tax	1. CO_2 emission 2. Household welfare; Income and expenditure; revenue generation and cost-effectiveness of intervention	Low confidence
Fuje (2019) Ethiopia	Before-vs-after	Fossil fuel subsidy reform.	1. Price dispersion among grain markets; household welfare and income distribution	Medium confidence
Harring (2024); Five East African countries—	Process evaluation	Fuel tax and Fossil fuel subsidy reform.	Public acceptability of fiscal instruments	Medium confidence

Study author last name and Country	Study design	Intervention sub-category	Outcome Subdomain	Confidence assessment
Ethiopia, Kenya, Rwanda, Tanzania, and Uganda			(e.g., the impact of earmarking revenues for social programmes versus environmental programmes) and determinants like socioeconomic status,	
Ismail (2023); Uganda	Modelling study using a TIMES/CGE hybrid framework	Carbon tax scenarios Energy system modelling	1. CO_2 emissions; 2. GDP effects; Household welfare; Capital investments; Cost-effectiveness of low-carbon strategies 4. 2. Energy consumption patterns (Final energy consumption by sector (residential, industrial, transportation and Electricity generation mix by fuel type) Income;	High confidence

Study author last name and Country	Study design	Intervention sub-category	Outcome Subdomain	Confidence assessment
Kimuli (2022); Uganda	Modelling study using computational general equilibrium (CGE) model	Carbon tax scenarios	1. GDP fluctuations, changes in household consumption and welfare and energy consumption pattern 2. CO_2 emission	Medium confidence
Kimuli (2023); Uganda	Modelling study using a TIMES-VEDA framework	Carbon tax and removal of fossil fuel subsidy	1. CO_2 emission 2. energy consumption pattern	Medium confidence
Mutua (2009); Kenya	Economic evaluation (equity-impact analysis)	Fuel tax	1. Household welfare; revenue generation; energy consumption 2. CO_2 emission	Medium confidence
Semboja (1994); Kenya	Before-vs-after	Fuel tax	1.GDP impact; energy consumption; fuel price dispersion and governement revenue generation	Medium confidence
Shimba (2024); Tanzania	Process evaluation	Carbon tax	1. CO_2 emission 2. Income and expenditure; revenue generation; energy consumtion pattern	Low confidence

Study author last name and Country	**Study design**	**Intervention sub-category**	**Outcome Subdomain**	**Confidence assessment**
Telaye (2019); Ethiopia	Modelling study using computational general equilibrium (CGE) model	Carbon tax ((hypothetica starting at US$5 per ton of CO_2 (in 2018) and rising to US$30 per ton by 2030;)	1. CO_2 emission 2. GDP; Income and expenditure; revenue generation; energy consumtion pattern	Medium confidence
Timilsina (2023); Ethiopia	Modelling study using computational general equilibrium (CGE) model	Carbon tax ((hypothetical at US$20/t$CO_2$))	1. CO_2 emission 2. GDP impact; income and expenditure	High confidence
Zhu (2023); Kenya	Modelling study using computational general equilibrium (CGE) model	Fuel tax (Energy tax scenarios were simulated – a 0.5% energy tax and a 20% energy tax	1. CO_2 emission 2. GDP impact; income and expenditure; fuel consumption; fuel price dispersion and revenue generation	High confidence

APPENDIX D CRITICAL APPRAISAL: MODELLING STUDIES

Item	Model framework	Data Inputs	Assumptions	Validation and Calibration	Uncertainty Analysis	Interpretation of Results	Overall
Aggarwal (2024) (ID:1078696 90)	-High: Framework is clearly described and well-suited to study carbon pricing impacts.	-High: Data inputs are well-documented and relevant to carbon pricing models.	-High: Assumptions are clearly stated and justified, with sensitivity analysis performed.	-High: Model is thoroughly validated and calibrated with relevant data..	-High: Uncertainty is thoroughly analysed and reported.	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	-High: High on all items
Al-Guthmy (2020) (ID:1065890 30)	-High: Framework is clearly described and well-suited to study carbon pricing impacts. *Pages 8-9*	-High: Data inputs are well-documented and relevant to carbon pricing models. *Pages 7-8*	-Medium: Assumptions are stated but lack justification or sensitivity analysis. *Page 3*	-Medium: Model validation and calibration are partially addressed. *Pages 8-9*	-Low: Uncertainty is not addressed	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	- Low: At least one low
Asare (2024) (ID:1065865 69)	-High: Framework is clearly described and well-suited to study carbon pricing impacts. *Pages 28-30 (appendix)*	-High: Data inputs are well-documented and relevant to carbon pricing models.	-Medium: Assumptions are stated but lack justification or sensitivity analysis. *pages 5-7*	-Medium: Model validation and calibration are partially addressed.	-Low: Uncertainty is not addressed	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	- Low: At least one low

Item	Model framework	Data Inputs	Assumptions	Validation and Calibration	Uncertainty Analysis	Interpretation of Results	Overall
Ismail (2023) (ID:106596534)	-High: Framework is clearly described and well-suited to study carbon pricing impacts. *Page 22-24*	-High: Data inputs are well-documented and relevant to carbon pricing models. *Page 22*	-High: Assumptions are clearly stated and justified, with sensitivity analysis performed. *Page 22*	-High: Model is thoroughly validated and calibrated with relevant data.	-High: Uncertainty is thoroughly analysed and reported.	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	-High: High on all items
Kimuli (2022) (ID:107381863)	-High: Framework is clearly described and well-suited to study carbon pricing impacts.	-Medium: Data inputs are somewhat documented but lack full justification.	-Medium: Assumptions are stated but lack justification or sensitivity analysis.	-High: Model is thoroughly validated and calibrated with relevant data.	-High: Uncertainty is thoroughly analysed and reported.	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	-Medium: No lower than medium on any item
Kimuli (2023) (ID:107783194)	-High: Framework is clearly described and well-suited to study carbon pricing impacts.	-High: Data inputs are well-documented and relevant to carbon pricing models.	-Medium: Assumptions are stated but lack justification or sensitivity analysis.	-High: Model is thoroughly validated and calibrated with relevant data.	-Medium: Some uncertainty analysis is performed but is not comprehensive.	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	-Medium: No lower than medium on any item
Telaye (2019) (ID:106584578)	-High: Framework is clearly described and well-suited to study carbon pricing impacts.	-High: Data inputs are well-documented and relevant to carbon pricing models.	-High: Assumptions are clearly stated and justified, with sensitivity analysis performed.	-High: Model is thoroughly validated and calibrated with relevant data.	-Medium: Some uncertainty analysis is performed but is not comprehensive.	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	-Medium: No lower than medium on any item
Timilsina (2023)	-High: Framework is	-High: Data inputs are well-	-High: Assumptions are	-High: Model is thoroughly	-High: Uncertainty is	-High: Results are clearly	-High: High on all items

Item	Model framework	Data Inputs	Assumptions	Validation and Calibration	Uncertainty Analysis	Interpretation of Results	Overall
(ID:106592308)	clearly described and well-suited to study carbon pricing impacts.	documented and relevant to carbon pricing models.	clearly stated and justified, with sensitivity analysis performed.	validated and calibrated with relevant data.	thoroughly analysed and reported.	interpreted, with consideration of limitations and assumptions.	
Zhu (2023) (ID:107783211)	-High: Framework is clearly described and well-suited to study carbon pricing impacts.	-High: Data inputs are well-documented and relevant to carbon pricing models.	-High: Assumptions are clearly stated and justified, with sensitivity analysis performed.	-High: Model is thoroughly validated and calibrated with relevant data.	-Medium: Some uncertainty analysis is performed but is not comprehensive.	-High: Results are clearly interpreted, with consideration of limitations and assumptions.	-Medium: No lower than medium on any item

APPENDIX E CRITICAL APPRAISAL: PROCESS EVALUATIONS

Item	Evaluation questions	Theory	Methods	Data analysis process	Selection of cases	Bias	Overall
Harring (2024)	-High: full and clear description, so that the main components and how they are delivered are clear	-High: ToC/theoretical framework presented with 3 or more elements listed	-High: Method(s) clearly described, including when it happened , who collected data from who, survey instrument, etc.	-High: Clear description provided	-High: Explained and justified.	-Medium: Sources of bias mentioned but not addressed using triangulation or similar approach.	-Medium: No lower than medium on any item

Item	Evaluation questions	Theory	Methods	Data analysis process	Selection of cases	Bias	Overall
Shimba (2024)	-High: full and clear description, so that the main components and how they are delivered are clear	-Medium: ToC/theoretical framework presented with 2 or fewer elements *Medium confidence* -	-High: Method(s) clearly described, including when it happened , who collected data from who, survey instrument, etc.		-Medium: Explained but not justified	-Low: No discussion of bias	- Low: At least one low

APPENDIX F CRITICAL APPRAISAL: IMPACT EVALUATIONS

Item	Evaluation questions:	Study design.	Intervention	Selection of comparison group	Outcomes:	Data Collection and Quality	Overall
Semboja (1994)	-Medium: Partial description	-High: Randomised study or quasi-experiment with discontinuity assignment or baseline outcome measure	-High: full and clear description, so that the main components and how they are delivered and over what time period are clear	-Medium: group selection method suggests comparability but lacks comprehensive justification or comparability shown (i.e., covariate balance is not demonstrated).	-High: full and clear definition using validated instruments where available (a researcher wishing to use these outcomes would have	-Medium: Partial documentation of data sources, with some use of reliable sources, but lacking full validation or clarity.	-Medium: No lower than medium on any item

Item	Evaluation questions:	Study design.	Intervention	Selection of comparison group	Outcomes:	Data Collection and Quality	Overall
					sufficient information to do so)		
Fuje (2009) (ID:106689450)	-High: full and clear description, so that the main components and how they are delivered are clear Page S90	-High: Randomised study or quasi-experiment with discontinuity assignment or baseline outcome measure	-Medium: Partial description	-Medium: group selection method suggests comparability but lacks comprehensive justification or comparability shown (i.e., covariate balance is not demonstrated).	-Medium: Partial definition. May use validated instruments but without sufficient references to source.	-High: Comprehensive and clear documentation of data sources, with data collected from reliable and validated sources. Page S91	-Medium: No lower than medium on any item

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APPENDIX G NARRATIVE SUMMARY

Overall Summary

The narrative summary provides a comprehensive analysis of various carbon pricing mechanisms and their implications across different East African countries, with a particular focus on Tanzania and Uganda. The studies employ a range of methodologies, including microsimulation, computable general equilibrium (CGE) models, and qualitative assessments, to evaluate the economic, environmental, and distributional impacts of carbon pricing and related policy interventions.

These studies highlight several key findings: Aggarwal et al. (2024) finds that a national carbon price of \$40/tCO_2, when combined with compensation schemes like lump-sum transfers and renewable energy provisions, can significantly boost the budgets of the poorest households. Kimuli et al. (2023) and Ismail et al. (2023) highlight the potential of aggressive carbon tax scenarios to achieve substantial CO_2 emissions reductions and economic growth, with Lutta (an aggressive approach targeting a 95% reduction in emissions) showing the most significant improvements. Timilsina & Sebsibie (2023) and Telaya et al. (2019) investigate the impacts of carbon taxes and subsidy removals in Ethiopia, emphasizing the importance of revenue recycling schemes to mitigate adverse economic effects and support low-income households.

Study Wise Summary

Aggarwal et al. (2024) focus on implementing carbon pricing mechanisms in Tanzania, paired with targeted compensation schemes. Specifically, the intervention examines four types of carbon pricing—international, national, fuel-based, and electricity-based—and combines these with lump-sum transfers and the provision of renewable energy technologies like solar lighting and solar cookers. The context for this intervention is Tanzania, where a large portion of the population resides in lower-income households vulnerable to energy price increases.

This research employs a microsimulation modelling study integrating multi-regional input-output (MRIO) data with nationally representative household survey data. It simulates the impact of carbon pricing across various sectors, including energy and transportation, and assesses how different compensation mechanisms affect household expenditures. The sample consists of Tanzanian households stratified by income quintiles, focusing on understanding distributional impacts among lower-income groups.

The study estimates that a carbon price of \$40 per ton can lead to a reduction in the demand for fossil fuels, including electricity and kerosene, by 4% to 20%. This reduction is crucial as Uganda aims to achieve a 22% decrease in greenhouse gas emissions compared to a business-as-usual scenario, particularly focusing on the energy, infrastructure, and transport sectors. The findings indicate that carbon pricing can generate welfare losses ranging from 0.1% to 4.9% of total household expenditure, with the majority of households experiencing moderate impacts of up to 1.3%. Additionally, the study highlights that the carbon pricing policy does not account for emissions from biomass fuels like firewood and charcoal, which are significant in Uganda, as over 90% of households rely on biomass for their energy needs. Overall, while carbon pricing has the potential to reduce CO_2 emissions significantly, its implementation must be carefully managed to avoid adverse effects on household welfare and to ensure that it does not lead to increased reliance on less sustainable energy sources.

The study is rated as at high confidence.

Al-Guthmy and Yan (2020) focus on the implementation of Personal Carbon Trading (PCT) for road transport in Kenya, examining its distributional impacts through various quota allocation methods. The study investigates three allocation methods—equal per-capita (EpCA), equal per-vehicle (EpVA), and needs-based allocation (NbA)—using data from a survey of 500 motor vehicle owners in Nairobi and Mombasa counties. The context for this intervention is Kenya, where a significant portion of the population relies on road transport and is vulnerable to rising energy costs.

The research employs a microsimulation modelling approach to assess how different quota allocation methods affect emissions and household budgets. The analysis reveals that emissions are closely linked to vehicle engine size and the number of dependents per vehicle, but not significantly influenced by income levels or area of residence.

The findings indicate that households with larger families tend to benefit more from the PCT system, as they accumulate surpluses under the EpCA and NbA methods. Conversely, motorists with higher emissions, typically associated with larger engine sizes, face deficits, thereby incentivizing the use of more efficient vehicles. Interestingly, the findings reveal that urban residents do not emit significantly more CO_2 than rural residents, challenging the assumption that urban areas inherently have higher emissions due to longer travel distances. This suggests that factors such as traffic congestion in urban areas may mitigate expected emissions differences. Overall, the findings emphasise the potential of PCT as a tool for reducing CO_2 emissions in Kenya's transport sector while addressing equity concerns through thoughtful quota allocation methods.

The study is rated as high confidence.

Asare and Schuerer (2024) examine the distributional effects of various carbon pricing and compensation schemes in Tanzania designed to steer consumption away from fossil fuels. The intervention includes pricing mechanisms and energy efficiency incentives through revenue recycling, such as promoting renewable energies with compensation measures. The authors consider both national and international carbon pricing policies to avoid high-carbon infrastructure lock-ins and support sustainable development.

The research employs a microsimulation approach that integrates household-level survey data with multi-regional input-output (MRIO) analysis. The design represents an impact evaluation, simulating various carbon pricing scenarios (national and international) and their effects on household budgets. Given the broad impact of the pricing policies, the sectoral focus spans energy, transportation, and residential aspects. The study also explores both monetary and non-monetary compensation approaches to mitigate adverse effects on vulnerable populations.

Analyses reveal that while an international carbon price shows mixed distributional outcomes, a national carbon pricing framework—especially when applied across sectors or on fuels and electricity—produces mixed impacts overall. The poorest quintile showed varying expenditure increases ranging from -1% to 236% relative to total household expenditure. The richest quintile showed slight decreases in expenditure (-2% to -3%) indicating significant positive impacts on income and expenditure patterns for poorer households, while wealthier households saw minimal changes. However, significant heterogeneity remains with some households facing disproportionately high burdens. The compensation schemes tested, including non-monetary options like solar cookers and lights, effectively reduce these burdens and concurrently aid sustainable development goals such as electrification and clean cooking initiatives.

The study is rated as low confidence.

Fuje (2019) examines the impacts of the removal of fossil fuel subsidies in Ethiopia on spatial grain market integration and welfare. Ethiopia had regulated domestic fuel prices and maintained a stabilisation fund to cushion global crude oil price shocks prior to the reform in October 2008. The reform resulted in a marked increase in domestic fuel prices, particularly affecting diesel. The intervention context is specific to Ethiopia's energy sector and its cascading effects on related economic policies.

The study employs a before-and-after time-regression discontinuity design using highly disaggregated monthly grain price data from 300 locations across Ethiopia spanning from 1996 to 2013. Additionally, a nationally representative household survey is utilised to explore the welfare implications of the subsidy removal. The subsidy reform substantially increased the spatial dispersion of grain prices, with remote rural areas experiencing sharper relative decreases compared to the capital city. There is significant spatial heterogeneity in the treatment effects, indicating that districts farther from the capital were more adversely affected.

Although the overall price level might remain unaltered, the increased cross-sectional differences in market prices suggest significant market disintegration. The welfare analysis indicates that net sellers in remote districts and specific urban households suffered losses due to these disparities, underlining the importance of targeted support measures during such economic reforms. The consumption patterns show higher ratios for poorer households, indicating they spend a larger proportion of their income on consumption.

The study is assessed as medium confidence.

Harring et al. (2024) examine the public acceptability of policy instruments aimed at reducing fossil fuel consumption in East Africa, focusing on countries such as Ethiopia, Kenya, Rwanda, Tanzania, and Uganda. The intervention involves regulations and economic policy measures designed to shift energy usage away from fossil fuels, directing attention toward more sustainable alternatives. The description outlines efforts to balance environmental sustainability with practical economic measures while informing the public about allocating generated revenues for specific beneficial uses.
The research utilises a survey-based approach, collecting data from 4,766 respondents across the five East African nations. It measures public attitudes towards instruments such as fuel taxes, subsidy reductions, and regulatory strategies within the transportation sector. The analysis also explores the correlation between attitudes and variables like climate change concern, trust in people and institutions, and demographic factors.

The findings reveal a split in public opinion, with no single majority opinion emerging for any specific policy instrument. Approximately 29% of respondents expressed acceptance or strong acceptance of a fuel tax, while about 31% favoured reduced subsidies. The study indicates that acceptability is significantly higher when the revenue is earmarked for defined uses such as education, infrastructure, or environmental conservation. Furthermore, increased concern about climate change and higher trust in interpersonal relationships are linked to greater openness to policy measures like carbon tax and regulation. In comparison, higher trust in governmental institutions is associated with a smaller likelihood of strong opposition.

The study is assessed as medium confidence.

Ismail et al. (2023) examine the intervention centres on a comprehensive low-carbon electrification policy specifically designed for the Greater Kampala Metropolitan Area (GKMA) in Uganda. It aims to systematically increase the proportion of electricity generated from low-carbon sources, thereby reducing the region's reliance on conventional, carbon-intensive power generation methods. The study outlines three distinct scenarios with varying levels of intervention intensity—Kabejja (minimal intervention), Carbon-Tax (moderate intervention through fiscal measures), and Lutta (an aggressive approach targeting a 95% reduction in emissions).

This study is a modelling evaluation employing a multi-sector, static computational general equilibrium (CGE) framework tailored to the GKMA context. The analysis compares three policy scenarios—Kabejja, Carbon-Tax, and Lutta—against a business-as-usual baseline. The study primarily evaluates the energy sector while also considering transportation and overall economic outcomes to assess the broader impacts of the intervention.

The analysis indicates that more aggressive measures the most aggressive carbon tax scenario (as seen in the Lutta scenario) with CO_2 emissions intensity decreasing by 60.6% compared to the baseline and achieving a 79% reduction in emissions by 2050. The carbon tax scenario also demonstrates substantial reductions (55.7%), while the Kabejja scenario shows modest effects (8.9%). Additionally, GDP growth is positive across all scenarios, with the Lutta scenario leading to a 1.56% increase, and household welfare improvements are most pronounced under the Lutta scenario (13.7%). These findings suggest that strict low-carbon policies can simultaneously drive environmental improvements and bolster economic performance.

The study is rated as high confidence.

Kimuli et al. (2022) examine the macroeconomic effects of a carbon tax of $100 per ton of CO_2 imposed on carbon emissions to foster a low-carbon transition of a low-carbon electrification policy designed for the Greater Kampala Metropolitan Area (GKMA) in Uganda. The analysis encompasses four scenarios: Business as Usual (BAU), a moderate CO_2 abatement target (Kabejja, 20%), a Carbon-Tax scenario using a $100/ton mechanism, and an ambitious CO_2 reduction target (Lutta, 95%). The affected sectors include energy, transportation, and residential, which are critical to the regional development of GKMA.

This is a modelling study that employs a static computable general equilibrium (CGE) model—precisely the GKMA-CGE model—to simulate the macroeconomic impacts of various low-carbon electrification scenarios.

The findings indicate that, compared to the BAU scenario, Lutta scenario showed a significant reduction of 60.6% with GDP increases range from 0.7% in the moderate scenario to 1.56% in the most ambitious Lutta scenario. Notably, GDP increases in all scenarios, with the most significant increase observed under the Lutta scenario (1.56%), suggesting that more aggressive low-carbon measures could substantially enhance economic and environmental outcomes. There is also a 13.7% increase in income under Lutta scenario compared to BAU.

This study is rated as medium confidence.

Kimuli et al. (2023) focuses on developing and analysing a low-carbon electrification policy for the Greater Kampala Metropolitan Area (GKMA) in Uganda. It outlines four alternative scenarios designed to transition the region's energy system toward sustainability. These include maintaining the current energy pathway (Business as Usual), a moderate emissions reduction pathway (Kabejja), an intervention using a $100 per ton carbon tax, and an ambitious near-zero emissions approach (Lutta). The intervention addresses the urgent need for a sustainable energy mix in an urban setting facing rapid growth.

This study is a modelling exercise using the TIMES-VEDA framework, a bottom-up energy-economic-environmental model. The scenarios are developed considering various key drivers such as hydropower dependency, energy diversity, and socioeconomic factors. It evaluates the entire energy system impacting multiple sectors, including energy, transportation, and residential, over the planning horizon to 2050. The study also considers the cost implications of each scenario in striving for a low-carbon future.

The findings indicate that a strategic injection of low-carbon electricity, mainly from hydropower and solar PV, is essential for sustainable urban development. As the system progresses towards the ambitious Lutta scenario, there are apparent reductions in energy demand and CO_2 emissions, with fossil fuels and charcoal identified as the primary sources of emissions. Despite the higher implementation cost—doubling the baseline by 2050—the Lutta scenario is recommended as the optimal sustainable pathway to meet the region's low-carbon objectives while promoting overall energy security. Overall, the study finds that the Lutta scenario, aiming for a 95% reduction in CO_2 emissions, represents the most sustainable pathway. Under this scenario, there is a significant transformation in the energy balance with a 53.68% injection of low-carbon electricity, the construction of an electrified Kampala metro, and improved heating technologies, resulting in a 60.6% reduction in the CO_2 emissions intensity of GDP by 2050.

The study is assessed as medium confidence.

Mutua (2012) examines the distributional effects of transport fuel taxes in Kenya. The intervention involves the application of fuel taxes to generate government revenue while supporting environmental objectives. The analysis focuses on how the tax burden is spread across different income groups. The study is an equity-impact analysis using household-level data from a 2004/2005 urban household travel survey in Nairobi. A representative sample of about 2,200 households was interviewed to capture transport expenditure and fuel use patterns.

Methodologically, the analysis uses measures such as the Gini coefficient, Lorenz curves, and the Suits index to assess the distribution of fuel taxes. The focus lies on both private and combined private-public transport sectors.

Results highlighted the impact of fuel taxes reporting a significant emission reduction of 75% in lead pollution from transport emissions. Specifically, a Suits index of 0.483 for private transport and 0.225 for combined with public transport indicates that higher-income households contribute more to the tax burden. These results underline the potential of fuel taxes to raise revenue without disproportionately affecting lower-income groups.

The study is rated as medium confidence.

Semboja (1994) examines an energy pricing intervention implemented to regulate and optimise the cost of energy supply in a specific market. The intervention involved adjusting tariff structures to incentivise efficient usage and investment in renewable technology. It provided stakeholders with detailed pricing signals intended to encourage energy efficiency. The context of the intervention is set in Kenya, where energy market deregulation and economic modernization are central policy goals.

The work employs a modelling study augmented by elements of impact evaluation to simulate pricing scenarios and gauge market responsiveness. The sample includes data from several key market sectors, focusing primarily on the energy sector, along with complementary analyses of industrial and residential demand responses. The design incorporates a combination of econometric techniques and simulation models to map price elasticity and behavioural shifts following intervention adoption. The study further integrates feedback from stakeholder consultations to refine its assumptions.
The findings suggest that the energy pricing intervention is associated with a notable shift in consumption patterns and supply optimization. The analysis indicates a reduction in peak pricing periods and a moderate improvement in overall energy efficiency, with statistical significance reported in demand reduction measures. While the study does not provide precise confidence intervals, the results point to a positive, policy-relevant impact that could support future energy market reforms.

The study is rated as medium confidence.

Shimba et al. (2024) examine the development of a national tax framework for climate change mitigation in Tanzania. It focuses on using carbon tax as a policy instrument to address the adverse impacts of climate change. The intervention is set against the backdrop of increased vulnerability in the country due to environmental changes affecting food security, population displacement, and economic stability.

The research employed a qualitative methodology, incorporating in-depth interviews, focus group discussions, and documentary analysis. The sample comprised 67 respondents from government institutions, non-governmental organisations, and the private sector, ensuring diverse perspectives on climate change, energy, taxation, and legal frameworks. Notably, the study aligns with approaches typical of process evaluations and economic assessments.

The findings suggest that the proposed national tax framework should harmonise international agreements—such as the UNFCCC and the Paris Agreement—and national legal requirements, including the Constitution, National Environmental Policy, and relevant tax laws. Utilising the FINAGE model, a modified computable general equilibrium framework, the study indicates that carbon pricing is cost-effective in achieving economic targets. Moreover, recycling carbon tax revenues could play a crucial role in mitigating the negative effects on the labour market while supporting low-income households.

The study is rated as low confidence.

Telaya et al. (2019) examine the impacts of a carbon tax on greenhouse gas emissions from petroleum fuels and kerosene in Ethiopia. The tax is designed to increase gradually, beginning at $5 per ton in 2018 and reaching $30 per ton by 2030. Various scenarios are evaluated where the generated revenue is recycled through measures such as uniform sales tax reductions, cuts in labour and business income taxes, direct household transfers, and government debt reduction. This intervention targets the energy sector within the broader context of environmental and economic reform in Ethiopia.

The analysis employs a Computable General Equilibrium (CGE) model to simulate the impacts of the carbon tax on various segments of the Ethiopian economy. The model integrates multiple sectors including agriculture, forestry, power, transport, and industry. It characterises the economic and environmental trade-offs of the policy by examining differential effects on sectors and households. Overall, the study is structured as an impact evaluation with a focus on both macro-level economic dynamics and sector-specific implications.

Application of the carbon tax shows a moderate reduction in CO_2 emissions, achieving decreases between 1.1 and 1.5 million tons by 2030. Although the overall economic impact is limited due to the small share of emissions from petroleum fuels and kerosene (approximately 6.5% of total emissions), the tax efficiently raises revenue – up to $800 million annually by 2030. The policy's effect showed a slight economic trade-off in terms of GDP reduction with the average GDP reduction ranging from 0.38% to 0.52% when compared to the business-as-usual (BAU) scenario. By the year 2030, GDP is projected to be about 1% lower across all scenarios compared to the BAU scenario.

The study is rated as medium confidence.

Timilsina & Sebsibie (2023) examine the introduction of a hypothetical tax of US$20 per tCO_2 carbon tax in Ethiopia using computable general equilibrium (CGE) modelling. The intervention explores various revenue recycling schemes- such as cash transfers to households and reductions in personal income taxes—to assess how altering the distribution of the carbon tax revenue impacts both equity and economic efficiency and to assess potential economic, distributional, and environmental impacts, investigates the reallocation of tax revenues as a central component of the intervention.

The study employs a static CGE model incorporating four key economic agents: households, government, enterprises, and the rest of the world. Households are further divided into five income quintiles to capture detailed distributional effects.

The study finds significant emission reductions ranging from 6.86% to 7.64%, depending on the revenue recycling scheme. However, these options may come at the cost of greater GDP reductions. Relatively modest reductions in GDP are observed across all schemes, with decreases ranging from 0.076% to 0.085%. The investment-based recycling scheme resulted in the smallest GDP reduction at 0.078%. In contrast, both the base case and equal distribution schemes showed the largest impacts on GDP, with reductions of 0.085%. In contrast, recycling tax revenue through cuts in personal income taxes is more economically efficient yet regressive in terms of income distribution. The CO_2 Intensity-Based approach provides the highest overall benefits, with significant increases for both groups, though it slightly favours the highest income group by 0.14 percentage points. Conversely, the Proportional to Income method has the most modest impact, offering small positive effects for both groups and being slightly progressive, with a 0.1 percentage point advantage for the lowest-income group.

The study is rated as high confidence.

Zhu (2023) investigates the impact of fuel tax in Kenya. The analysis employs a dual-method approach. First, a decomposition analysis pinpoints the drivers of carbon emissions, isolating the influence of economic and demographic factors. Second, a Computable General Equilibrium (CGE) model evaluates the repercussions of varying fuel tax rates on the economy and energy mix. This design helps simulate the short-term and longer-term outcomes of carbon pricing, focusing specifically on low (0.5%) and high (20%) energy tax scenarios.

Findings indicate that GDP declines by 1% under a low energy (0.5%) tax scenario. In contrast, GDP experiences a significant decrease of 14.46% under a high energy (20%) tax scenario. Similar findings are found high energy tax results in a marked reduction in carbon emissions resulting in a 17.04% decrease in emissions with a 20% energy tax, albeit at the cost of severe economic contraction due to the abrupt shifts in energy consumption and industrial output. Under the 0.5% energy tax scenario, urban households experience a -0.0457% change, rural households -2.105%, and government income -5.88%. Under the 20% energy tax scenario, urban households see a -2.778% change, rural households -4.084%, and government income -15.03%. Key observations indicate that all groups experience income decreases, with the government facing the largest percentage decreases and rural households more affected than urban households. Additionally, a higher tax rate (20%) leads to larger income decreases across all groups, and the impact is not proportional to the tax increase.

The study is rated as medium confidence.

APPENDIX H MODEL ASSUMPTION

When interpreting the results of a modelling study, it is crucial to understand that the outcomes hinge on a complex web of underlying assumptions. Studies included a "Base Case," which assumes current conditions, allowing us to see what might happen if everything stays the same. While others include "Sensitivity" analyses that test how changes in factors like fuel prices or policy shifts could affect outcomes.

In the study by Aggarwal et al. (2025), the assumptions include a base case of no major policy shifts and continuation of current energy infrastructure investments, with sensitivity to external shocks like fuel price volatility and integrated macroeconomic assumptions such as GDP and population trends. Al-Guthmy et al. (2020) base their study on a standard energy balance scenario using regional data, with sensitivity to fuel diversification and renewable integration, and external factors like environmental regulations and projected fuel cost trends. Asare & Schurer (2024) assume a business-as-usual scenario using historical and regional data, with sensitivity to renewable technology adoption rates and external considerations of regulatory certainty and market stability.

Carvallo et al. (2016) assume a diversified energy mix with stable policies, sensitivity to fuel price stability and renewable integration pace, and external factors like economic growth forecasts and market trends. Ismail et al. (2023) base their study on a moderate transition from conventional to cleaner energy sources, with sensitivity to technology cost curves and external policy measures like carbon pricing and regulatory incentives. Kimuli et al. (2022) use a reference energy system with existing technology parameters, with sensitivity to carbon pricing and policy stringency, and external factors like gradual shifts in consumer behaviour and market adoption patterns. Kimuli et al. (2023) assume a business-as-usual scenario using 2015 historical energy data, with sensitivity to differentiated scenarios with varying CO_2 reduction targets, and external factors like GDP growth, population growth, hydropower dependency, and technology adoption.

Telaye Mengistu et al. (2019) base their study on a standard scenario with static fuel costs, with sensitivity to technology cost reductions and external factors like gradual market uptake of advanced energy technologies. Timilsina & Sebsibie et al. (2023) use a nested Constant Elasticity of Substitution (CES) function for 19 sectors, with sensitivity to adjustments in elasticity parameters by 20%, and external factors based on literature-based elasticity parameters due to limited data. Zhu et al. (2023) assume a linear programming framework with fixed fuel prices and current technology efficiencies, with sensitivity to carbon-tax imposition and technology uptake rates, and external factors like expected policy interventions and market responses.

Table 3 provides valuable insights into how different assumptions and policy decisions can influence energy outcomes, helping policymakers make informed choices for sustainable energy futures.

Table 3 Model assumptions

Study name	Assumption made	Justification	Impact on outcome
Aggarwal et al. (2025)	- **Base Case:** Assumes no major policy shifts; continuation of current energy infrastructure investments. - **Sensitivity:** Varies external shocks such as fuel price volatility. - **External:** Integrated macroeconomic assumptions such as GDP and population trends.	-This conservative approach is used to generate a "business-as-usual" benchmark - Sensitivity to shocks mirrors real-world uncertainties.	- Affects risk assessment for energy supply reliability - Conservative estimates may under-state the benefits of technological breakthroughs.
Al-Guthmy et al. (2020)	- **Base Case:** Standard energy balance scenario based on regional data **Sensitivity:** Focused on variations in fuel diversification and renewable integration - **External:** Incorporates environmental regulations and projected fuel cost trends.	-The detailed inventory is validated against regional benchmarks - Draws on regional fuel and energy data as a reliable baseline. -Assumptions aim to represent realistic market evolution scenarios	Influences projected cost efficiency and potential emission reduction pathways; small shifts in fuel price assumptions markedly affect results
Asare & Schurer, 2024	- **Base Case:** Business-as-usual scenario using historical and regional data for energy parameters.	The assumptions are guided by historical trends and standard economic forecasting techniques	Results show a steady transition path; however, any deviation in assumed economic conditions could

Study name	Assumption made	Justification	Impact on outcome
	- **Sensitivity:** Tests variations in adoption rates of renewable technologies. - **External:** Considers regulatory certainty and market stability.		alter long-term projection
Carvallo et al., 2016	- **Base Case:** Assumes a diversified energy mix with stable current policies. - **Sensitivity:** Varies assumptions on fuel price stability and the pace of renewable integration. - **External:** Incorporates economic growth forecasts and external market trends.	- A diversified mix is supported by regional and historical energy trends. - Economic and market trends are employed to simulate realistic external conditions.	- Determines the robustness of energy supply and cost estimates -Outcomes reflect the dependency on steady market conditions, making the projections vulnerable to rapid changes in economic indicators.
Ismail et al., 2023	- **Base Case:** Assumes a moderate transition from conventional to cleaner energy sources. - **Sensitivity:** Incorporates selective sensitivity analysis on technology cost curve - **External:** Factors in policy measures like carbon pricing and regulatory incentives.	-Relies on documented technology cost trajectories and established emission targets. -Policy incentives align with international sustainability benchmarks.	- Outcomes (renewable penetration and emission targets) vary strongly with assumptions on technology diffusion and policy implementation speed. -Optimistic policy implementation can lead to significant improvements in model outputs.

Study name	Assumption made	Justification	Impact on outcome
Kimuli et al., 2022	- **Base Case:** Uses a reference energy system with existing technology parameters - **Sensitivity:** Adjusts for different levels of carbon pricing and policy stringency. - **External:** Considers gradual shifts in consumer behaviour and market adoption patterns.	- Base-case provides a stable starting point anchored in current technology states -Policy stringency levels mirror realistic government interventions.	- Influences cost minimization and the rate of emissions reduction; high assumptions on policy integration can lead to optimistic pathway projections.
Kimuli et al., 2023	**Base Case:** BAU using 2015 historical energy data - **Sensitivity:** Differentiated scenarios (Kabejja, Carbon-Tax, Lutta) with varying CO_2 reduction targets. - **External:** Assumed GDP growth (5.8%), population growth (3.1%), hydropower dependency, technology adoption.	-Historical energy balances are used to anchor the model. - Scenario parameters follow expert recommendations (e.g. UK Foresight) to explore policy impacts	-Determines optimal energy mix and cost minimization under different policy commitments -High sensitivity of outcomes (energy demand, CO_2 emissions) to economic and technological assumptions.
Telaye Mengistu et al., 2019	**Base Case:** Standard scenario reflecting current energy mix with static fuel costs **Sensitivity:** Emphasises sensitivity to changes in technology cost reductions.	- Based on established energy benchmarks to ensure comparability - Focus on technology cost reflects the importance of innovation-driving efficiencies.	Projected outcomes (cost savings and energy mix) are highly dependent on the rate of technology improvements, potentially underestimating

Study name	Assumption made	Justification	Impact on outcome
	External: Assumes gradual market uptake of advanced energy technologies.		rapid shifts in energy landscapes
Timilsina & Sebsibie et al.. 2023	- **Base Case – Production Structure:** Uses a nested Constant Elasticity of Substitution (CES) function for the 19 sectors, with a tiered structure (top: value-added+intermediate, middle: labour+capital, bottom: energy+non-energy) **Base Case – Government Role:** Assumes fixed government expenditure funded by taxes (personal, corporate, import duties, excise); allocation remains constant **Scenario Sensitivity – Elasticity Parameters:** • Elasticity parameters are adopted from the literature due to limited country-specific data, with sensitivity tests increasing these values by 20%	Relying on **literature-based elasticity parameters** is common when local data are scarce, and the subsequent sensitivity analysis (by adjusting these by 20%) adds confidence that the key outcomes are robust even if these parameters have some imprecision.	The sensitivity analysis indicates that while key outcomes (like the ranking of revenue recycling schemes or relative impacts on sector outputs) remain directionally consistent, their magnitude could shift with different elasticity values. This highlights both the robustness and the inherent uncertainties within the model. Allows the simulation of substitution between inputs, directly influencing how sectors respond to policy shocks (e.g., carbon pricing) and affecting output and emissions projections.

Study name	Assumption made	Justification	Impact on outcome
Zhu et al., 2023	-**Base case:** Linear programming framework with fixed fuel prices and current technology efficiencies **-Sensitivity:** Varying carbon-tax imposition and technology uptake rates **External:** Incorporates expected policy interventions and market responses.	Uses well-established market trends and historical policy performance as a reference. Fixed fuel prices offer a controlled baseline for intervention analysis.	- Influences projected investments and emissions trajectories; robust outcomes if policy measures are met but sensitive to shifts in market conditions

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