Distributional and Economy-Wide Impacts of a Carbon Tax in Ethiopia

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Abstract

This study evaluates the macroeconomic, environmental, and distributional effects of introducing a US$20 per tonne of CO_2 carbon tax on fossil-fuel use in Ethiopia. We employ a top-down macro–micro framework that links the DEMETRA computable general equilibrium model with the ETMOD tax–benefit microsimulation system to evaluate alternative revenue-recycling strategies, income-tax reductions, sales-tax cuts, and lump-sum transfers to households. The carbon tax reduces fossil-fuel emissions by 5.87% while causing a modest GDP decline of 0.18%, with carbon-intensive sectors, particularly transport and communication, experiencing the largest contractions. Revenue recycling strongly influences outcomes: sales-tax reductions minimize GDP losses and are the only strategy that lowers poverty. The carbon tax would be regressive, but recycling its revenues makes it progressive, with sales-tax reductions yielding the greatest equity gains. The findings indicate that a carefully designed carbon tax, accompanied by an effective revenue-recycling strategy, can facilitate Ethiopia's low-carbon transition, promote equitable outcomes, and safeguard vulnerable households.

Keywords: Climate change; Carbon tax; Revenue-recycling measures; CGE; Income distribution

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1. Introduction

Climate change poses a global threat, but its impacts are especially severe in low-income countries (IPCC, 2022). In Ethiopia, where subsistence and rain-fed agriculture dominate livelihoods, climate-related shocks, such as floods, rainfall variability, and heatwaves, regularly trigger food insecurity (Feleke et al., 2025; Berhanu et al., 2024). High poverty rates and constrained fiscal capacity further limit the country's ability to manage and adapt to climate risks (World Bank, 2024; Das et al., 2023). In response, Ethiopia has adopted a national climate action plan aimed at reducing emissions and enhancing adaptive capacity (Government of Ethiopia, 2025). Despite these commitments, the country has yet to implement a carbon tax as a tool to mobilize domestic revenue or promote cleaner and more efficient energy use (OECD, 2024).

Recent structural reforms in Ethiopia's transport and energy sectors provide a timely backdrop for assessing carbon pricing. In 2025, the government banned petrol and diesel vehicle imports, accelerating the shift to electric mobility to reduce fuel imports, ease foreign exchange pressures, and harness growing renewable electricity capacity (Harter, 2025). These developments highlight the potential role of price-based instruments, such as a carbon tax, to complement ongoing structural reforms. While the regulatory ban directly limits fuel demand, it does not affect operating costs of existing vehicles or generate fiscal revenue. In contrast, the hypothetical carbon tax examined in this study would provide economy-wide price signals and generate revenue that can be recycled to offset distributional impacts.

Evidence from industrialized economies indicates that carbon taxes can substantially reduce greenhouse gas emissions. For example, Finland's carbon tax lowered emissions by 31% in 2005 relative to a no-tax scenario (Mideksa, 2024), Sweden's transport-sector emissions fell by 6% per year (Andersson, 2019), and across 15 EU countries, carbon taxes contributed to 4–6% emission reductions (Metcalf & Stock, 2023). Macroeconomic outcomes, however, are heterogeneous (Köppl & Schratzenstaller, 2023). Andersen et al. (2007) report long-run growth gains in Denmark, Finland, and Sweden, but modest declines in Slovenia and the United Kingdom. The economic effects depend critically on policy design, particularly the choice of revenue-recycling mechanism (Timilsina, 2018). In low-income countries, evidence on both environmental and economic impacts remains scarce, especially regarding poverty and inequality implications.

In Ethiopia, only a limited number of studies have examined the macroeconomic effects of carbon taxation. Mengistu et al. (2019) and Timilsina and Sebsibie (2025) use computable general equilibrium (CGE) models to analyse carbon taxes and alternative revenue-recycling schemes, reporting modest GDP reductions in the former and small GDP gains when revenues are recycled through lower personal income taxes in the latter. These studies, however, rely on representative household groups and do not assess distributional outcomes or poverty impacts. Timilsina (2022) also highlights the absence of comprehensive evidence on the poverty impacts of carbon pricing.

This study addresses these gaps by evaluating the poverty and inequality effects of a hypothetical carbon tax under alternative revenue-recycling scenarios, using a top-down macro–micro modelling framework. Specifically, we examine a US$20 per tonne of CO_2 carbon tax on fossil fuels use. Sectoral and macroeconomic effects are simulated using the DEMETRA CGE model, while distributional, poverty, and inequality outcomes are assessed through the Ethiopian tax–

benefit microsimulation model (ETMOD). The models are linked through a top-down mechanism transmitting changes in employment, capital returns, agricultural value added, and commodity prices from the CGE to the microsimulation model.

This study offers three key contributions to the literature on carbon taxation and distributional analysis in low-income countries. First, it provides the first integrated macro–micro assessment of carbon taxation in Ethiopia, combining a CGE model with a detailed tax–benefit microsimulation model to capture both economy-wide adjustments and household-level heterogeneity. Second, it delivers the first analysis in Ethiopia, and one of the few in Africa, focused specifically on the poverty and inequality implications of carbon taxation, addressing a critical gap in the literature. Third, by evaluating multiple revenue-recycling options, it identifies policy designs capable of mitigating adverse distributional effects and enhancing the poverty-reducing potential of carbon taxation.

The results have important implications for Ethiopia's climate, fiscal, and social protection strategies. A carbon tax can generate substantial revenue that may be used to reduce the fiscal deficit, lower direct taxes, cut sales taxes, or finance transfers to households. In the scenario analysed, the policy package reduces real GDP by 0.18% while lowering fossil-fuel emissions by 5.87%. Sales-tax reduction, equal household transfers, and poverty-weighted transfers all perform similarly in limiting the decline in GDP among the revenue-recycling options considered. Distributionally, the carbon tax is regressive and increases poverty unless accompanied by compensatory measures such as sales-tax reductions.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature on carbon taxation. Section 3 describes the DEMETRA CGE model, the ETMOD microsimulation model, and the linkage approach. Section 4 presents the primary results, and Section 5 concludes with policy implications.

2. Literature review

Carbon taxes may impose adverse effects on production and employment when considered in isolation from their environmental benefits. However, the magnitude of these impacts depends on the structure of the economy, the energy mix, and, crucially, the design of revenue-recycling mechanisms (Timilsina, 2022). Common recycling options include increasing public expenditure or reducing distortionary taxes. Evidence from Timilsina, Cao, and Ho (2018) and Jorgenson et al. (2018) shows that coupling carbon taxation with tax-cut-based recycling generates smaller economic losses than recycling through household transfers. Tax reductions help alleviate pre-existing distortions in the production system, which accounts for their superior performance relative to lump-sum transfers (Aldy et al., 2010).

The distributional impacts of carbon taxation depend largely on the share of fuel in household consumption, particularly among low-income groups (Klenert et al., 2018). Evidence from industrialised countries consistently shows that low-income households spend a larger proportion of their income on carbon-intensive goods and face greater constraints in transitioning to cleaner alternatives. As a result, carbon taxation often exhibits regressive short-run effects (Fremstad & Paul, 2019; Douenne, 2020; Callan et al., 2009). Rural households are especially vulnerable because of their higher reliance on carbon-intensive fuels for transport and livelihoods, leading to more pronounced regressive impacts relative to urban households (Ravigné & Nadaud, 2022; Büchs et al., 2011). Nevertheless, regressivity can be mitigated, or even reversed, through well-designed revenue-recycling mechanisms, particularly targeted or lump-sum transfers that disproportionately benefit lower-income households (Douenne, 2020; Fremstad & Paul, 2019).

Designing revenue-recycling arrangements for a carbon tax entails an inherent equity–efficiency trade-off. Caron et al. (2018) show that recycling revenues through reductions in distortionary taxes improves economic efficiency, whereas uniform lump-sum transfers are more effective in alleviating the regressive burden of carbon taxation. Similarly, Jorgenson et al. (2018) and Williams et al. (2014) find that cuts in capital taxes yield the largest efficiency gains by stimulating investment but also produce the most regressive outcomes. Labour tax reduction, by contrast, increases consumption, resulting in a more progressive distributional effect, although they remain less progressive than lump-sum transfers.

Research on carbon taxation in low-income countries remains limited, partly due to their relatively small share of global emissions and the political sensitivities surrounding energy price reforms (Timilsina et al., 2024). Macroeconomic costs are generally lower in economies with low fossil-fuel intensity (Dorband et al., 2019), yet distributional outcomes vary. Several studies report progressive effects in developing countries where fossil-fuel consumption is concentrated among higher-income households. For example, carbon taxation disproportionately burdens richer households in Indonesia (Yusuf & Resosudarmo, 2015) and India (Rathore & Bansal, 2013), with similar findings for Ghana, Nigeria, and Uganda (Ayhan et al., 2025).

Conversely, other evidence points to regressive outcomes. Jiang and Shao (2014) find that a carbon tax in Shanghai disproportionately affects low-income households. Comparable regressive outcomes are reported for China (Guo et al., 2022), South Africa (Okonkwo, 2021), Brazil (da Silva Freitas et al., 2016) and Singapore (Nurdianto & Resosudarmo, 2016). In the absence of compensatory policies, carbon taxation can increase poverty across diverse national contexts (Nurdianto & Resosudarmo, 2016).

Evidence for Ethiopia remains limited. Mengistu et al. (2019) use a dynamic CGE model to simulate a carbon tax increasing from US$5 per tonne of CO_2 in 2018 to US$30 by 2030, finding a modest reduction in GDP growth and a larger burden on higher-income households, consistent with their greater fossil-fuel consumption. They further show that recycling revenues via corporate or sales tax reductions minimizes GDP losses. Using a static CGE model, Timilsina and Sebsibie (2025) analyses a uniform US$20 per tonne of CO_2 carbon tax and highlight that outcomes depend critically on recycling: GDP increases when revenues reduce personal income taxes, while regressivity is mitigated only under lump-sum transfers. However, both studies use representative household groups, limiting their ability to capture within-group heterogeneity and quantify poverty and inequality impacts. Consequently, the evidence remains insufficient to inform debates on social acceptability and pro-poor policy design, motivating an integrated macro–micro approach.

3. Methodology

3.1 Economy-wide modelling

Modelling the introduction of carbon tax on any economy is challenging as the introduced tax feeds into the economy through several channels. Computable General Equilibrium (CGE) models can analyse the economy-wide effects of a carbon taxes because they include, through changes in relative prices, the inter-sectoral and supply chains linkages, the fiscal effects and the household consumption and welfare implications resulting from the introduction of carbon pricing policies. The addition of the microsimulation model allows for a detailed analysis of distributional, and poverty impacts of the scenarios which the CGE alone, based on representative household groups, will not capture.

This study employs a single-country static open-economy CGE. The Dynamic Equilibrium Model for Economic development Resources and Agriculture (DEMETRA) model for Ethiopia allows for a detailed characterization of impacts at distinct levels: sectoral (output and production costs), household (income, consumer prices, consumer demand, welfare), and macroeconomic (GDP, employment, trade).

DEMETRA is a development of the STAGE-DEV model (Aragie et al. 2016). It inherits behavioural relationships to account for economic relationships in developing countries, such as the dual role of semi-subsistent agricultural households. The model has been applied in studies focusing on Ethiopia, i.e., on the socioeconomic impacts of COVID-19 and government recovery measures (Nechifor et al. 2024) and on the implications of the Russia invasion of Ukraine (Yalew et al. 2024) and more in general on food security and agricultural policies in developing countries (Nechifor et al. 2021; Ntah et al. 2024; Sahoo et al. 2025).

The DEMETRA model includes an assumption of perfect competition (i.e., prices and quantities are not subject to market power on the supply or demand side). This assumption also involves zero economic profit conditions through which economic costs of production are reflected in producer prices. DEMETRA includes a separation of marketed and subsistence commodities with a consistent accounting of home production for home consumption (HPHC) allowing for the study of semi-subsistence production and consumption processes. The model, as all other standard CGE models, is a 'real model' in which money is used as a means of exchange while monetary policies are not accounted for. Additional documentation and technical details are available online[1].

Ethiopia is modelled as a small open-economy and thus its domestic price changes do not affect world market prices whereas world market price changes (of the country's exports and imports) are exogenous. In line with the Armington assumption (Armington 1969), the imported and domestically produced varieties of commodities are imperfect substitutes. The elasticities used in production, commodity, and households' consumption nests are ad hoc values within the range provided by literature relevant for low-income countries (e.g., Lofgren, 1994; Diao et al., 2012; Hertel & van der Mensbrugghe, 2019).

The model adopts a linear expenditure system (LES) and constant elasticity of substitution (CES) utility functions as household demand, with income elasticities estimated from the 2015–2016 Ethiopian LSMS-ISA Socioeconomic Survey (Vigani et al. 2019). The top level of the nest employs

[1] https://datam.jrc.ec.europa.eu/datam/model/DEMETRA/

a Stone-Geary utility function to capture subsistence and discretionary demand, while a CES function at the second level permits substitution among energy commodities.

The production function aggregates intermediate inputs and production factors through nested CES driven by relative price changes, and Leontief production functions. The production technology nest of activities is flexible and allows substitution possibilities among several factors and intermediate inputs at distinct levels. The specification of the production function for the current study is the following one. The top level is specified as a CES aggregation of a composite intermediate input, and a composite valued-added input. The composite (aggregate) intermediate input is a Leontief aggregation of non-energy and energy intermediate inputs. The energy intermediate composite is a CES aggregation of mineral commodities, fossil fuels (petroleum and coal commodities) and electricity, allowing for a substitution of energy inputs based on the change in their relative prices. The composite value-added is a CES aggregation of a composite labour (unskilled, semi-skilled, and skilled), a composite capital (livestock, agricultural capital, non-agricultural capital), and land inputs.

For this study, the model has been extended to include emissions for Ethiopia and a carbon tax. The emissions module (Mwatu et al., 2026) makes the model suitable for analysing the interface between energy efficiency and low carbon development policies. Each type of fossil fuel (coal, oil, natural gas) has a specific emission factor, which represents the amount of CO2 emitted per unit of energy consumed. These emission factors determine total emissions. The quantity of energy commodities used by all activities as intermediate inputs and consumed by households is measured to determine the overall emissions. CO2 emissions resulting from the combustion of fossil fuels are linear functions of the quantity of energy commodities used. From the Ethiopian SAM, the three commodities classified as fossil fuel products and associated with a CO2 emission coefficient are: mineral commodities, petroleum, and coal commodities. Baseline emissions are based on the GTAP 11 database reference year 2017 (Chepeliev 2022; Aguiar et al. 2022). The emissions are mapped to commodities consumed by households and intermediate inputs employed by activities based on a mapping with the Ethiopia SAM to calculate the GHG coefficients.

In the model, the carbon taxes allow for differences in the CO2 emissions associated with different energy commodities and the agents that use the energy commodities (producers and consumers (McDonald and Thierfelder n.d.). The carbon tax is modelled as an excise tax to the use of fossil fuels by industries in the corresponding branch of the production function and as an excise tax to the LES demand function of each household, associated with the households' consumption of fossil fuels. The tax collected from intermediate and final consumption enter the government budget as an additional income source.

The model simulations are based on the following closure rules to describe as realistically as possible the conditions of the Ethiopian economy:

a. Savings-driven investment by which investment adjusts based on fixed saving propensities of households and enterprises.
b. To account for Ethiopia's significant unemployment rate, labour supply is endogenous (and wage rate fix) with full labour mobility across economic sectors of each regional labour type defined by skill level.
c. Fixed government consumption with variable government borrowing funded through variable internal means and fixed external loans and grants. This rule avoids possible 'free lunch' on the internal market to increase short-term internal debt that must be repaid back in a longer term.

d. Fixed foreign savings and variable exchange rate. This rule avoids possible 'free lunch' on the external market to increase short-term external debt that must be repaid back in a longer term.
e. CGE models rely on a numeraire since these models capture changes in relative prices of commodities and factors of production, rather than specific price levels. The PPI is the selected numeraire to allow the CPI to change relative to the PPI in the simulations and provide insights on the impacts of the shocks on the consumer purchasing power.

Model database

The model is calibrated using the 2015/16 Social Accounting Matrix (SAM) for Ethiopia (Mengitsu et al. 2019). The SAM comprises annual economic transactions structured around 61 economic activities (11 of which account for households as home producers), 71 marketed commodities (and 23 home commodities) and 28 household groups. Household groups are disaggregated into 11 administrative regions and by the rural, peri-urban, and urban division.

The agriculture activities comprise 11 regional representative farmers, and 5 national crop-growing activities, 6 livestock raising activities and 6 food industry activities. The remaining 33 activities are related to natural resources, industries, trade, utilities, construction, private and public services. The SAM also comprises 94 commodities, of which 58 are agri-food primary and industrial commodities. There are 33 primary labour accounts (3 skill levels for each 11 regions), land (rainfed and irrigated per each region), capital and livestock. There are four tax accounts representing domestic sales taxes, import tariffs and duties, direct (income) taxes, and carbon tax (zero level in the base year). The SAM comprises additional account for enterprises, government, and the rest of the world, trade, and transport margin (or transaction costs), and disaggregated investment accounts.

Table 1 presents the percentage shares of fuel, electricity, and capital in total output across broad commodity groups. Capital constitutes the dominant cost component in most sectors, with particularly high shares in financial intermediation, wholesale and retail trade, hotels and restaurants, and real estate and business services. Fuel accounts for a relatively small share of output in most sectors, with the notable exception of transport and communication, where it represents 26.84 percent of total output. Electricity contributes only a modest share across all commodity groups, with the highest proportions observed in health and social work, mining, manufacturing and utilities, and other services. At the aggregate level, capital accounts for 24.03 percent of total output, compared with 3.20 percent for fuel and 0.37 percent for electricity, indicating that capital is the largest of the three input-cost components reported in the table.

Table 1: Percentage share of fuel, electricity, and capital from total output by sector

Sectors	Fuel	Electricity	Capital
Agriculture and fishing	0.03	0.00	0.84
Mining, manufacturing and utilities	4.28	1.24	26.53
Construction	3.13	0.35	21.38
Wholesale and retail trade	0.05	0.24	60.70
Hotels and restaurants	0.00	0.73	52.06
Transport and communication	26.84	0.59	19.89
Financial intermediation	0.46	0.10	69.79
Real estate and business	0.00	0.00	32.87
Public administration and defence	4.08	0.34	26.68

Education	1.29	0.62	15.54
Health and social work	1.55	1.30	5.85
Other	3.00	1.08	19.82
Total	**3.20**	**0.37**	**24.03**

Source: Authors' calculations.

3.2 Microsimulation model (ETMOD)

ETMOD, Ethiopia's tax–benefit microsimulation model assesses household-level impacts of carbon-tax reforms. Microsimulation models apply statutory tax and transfer rules to representative household survey data, enabling detailed evaluation of policy effects on income distribution, welfare, and government revenues.

ETMOD, developed within the SOUTHMOD framework (Decoster et al., 2019), uses microdata from the fifth wave of the Ethiopian Socioeconomic Survey (ESPS-5), conducted in 2021–2022 by the Central Statistical Agency in collaboration with the World Bank. The dataset includes 4,959 households and 22,687 individuals, representative of approximately 22.2 million households and 105.2 million individuals. It provides rich information on demographics, employment, consumption, income sources, and household characteristics (Shahir et al., 2025).

This study uses ETMOD Version 4.0, which incorporates Ethiopia's principal direct and indirect taxes, social insurance contributions, and social assistance program, including the personal income tax, value-added tax (VAT), and the Productive Safety Net Program (PSNP). ETMOD enables a detailed assessment of how fiscal policy reforms affect household disposable income, poverty, inequality, and government revenue.

We estimate the static, first-round effects of a set of counterfactual carbon-pricing reforms. The analysis does not model behavioural responses to the carbon tax; therefore, the results reflect the arithmetic application of policy rules, without accounting for potential adjustments in labour supply, consumption patterns, or other behavioural responses.

3.3 Scenarios

To examine the implications of a hypothetical carbon-tax regime, all counterfactual scenarios are evaluated against a baseline representing Ethiopia's 2024/25 tax–benefit system without carbon taxation. The baseline holds prevailing prices, employment patterns, and household income profiles constant. Building from this reference point, we simulate five hypothetical reform scenarios:

1. **No recycling**: introducing a US$20 per tonne of CO_2 carbon tax without any accompanying revenue-recycling measures, providing a benchmark for its direct fiscal and welfare effects
2. **Personal income tax (PIT) reduction**: Carbon-tax revenue is recycled through a reduction in household direct-tax liabilities.
3. **Sales tax reduction**: Carbon-tax revenue is recycled by reducing sales taxes on commodities whose fuel-related intermediate input share is below 20 percent of total intermediate consumption expenditure.
4. **Equal household transfer**: Carbon-tax revenue is recycled through equal lump-sum transfers to households. This scenario evaluates the distributional consequences of a universal transfer mechanism.

5. **Poverty-weighted transfer**: Carbon-tax revenue is recycled through household transfers weighted by poverty headcount shares. This scenario examines whether targeting transfers toward poorer household groups improves distributional and poverty outcomes.

These scenarios capture a broad set of policy options, ranging from no redistribution to revenue use aimed at supporting most vulnerable households, thereby enabling comparative assessment of how alternative recycling strategies influence macroeconomic performance, sectoral output, and prices.

For each scenario, ETMOD calculates household disposable income. Monetary variables, including agricultural income, wage earnings, self-employment income, consumption expenditures by category, and the poverty line, are updated from the 2022 benchmark to 2024 prices using the appropriate CPI. To ensure comparability across households of different sizes and compositions, disposable income is equivalized using the national adult-equivalence scale, and poverty is assessed against the nationally defined absolute poverty line.

Welfare effects are assessed for baseline and reform scenarios using two Foster–Greer–Thorbecke (FGT) indicators:

- $FGT(0)$: headcount poverty rate, measuring the share of individuals living below the poverty line.
- $FGT(1)$: poverty gap index, capturing the average proportional shortfall from the poverty line among the poor.

3.4 Macro-micro linkage

To assess the distributional implications of climate-related fiscal reforms, we establish a top-down linkage between CGE model and ETMOD. The CGE model generates economy-wide adjustments in labour demand, capital returns, sectoral value added, and consumer prices following the introduction of the carbon tax. These macroeconomic outcomes are then mapped into household-level microdata to re-evaluate disposable income, consumption, real purchasing power, welfare, and poverty indicators. This sequential integration ensures consistent transmission of macro shocks to heterogeneous households while preserving the detailed tax--benefit environment captured by ETMOD.

Labour market transmission. In the CGE model, the labour market is specified with fixed real wages and unemployment adjusting endogenously. Under this closure, sectoral shocks translate into changes in employment levels rather than wage movements, an assumption consistent with Ethiopia's labour market, where unemployment is widespread and short-run wage adjustment is limited. We obtain the sector-specific proportional change in labour demand as:

Let LD_j^o denote baseline labour demand in sector j and LD_j^s labour demand under policy scenario s. The proportional change in labour demand is:

$$\lambda_j^s = \frac{LD_j^s - LD_j^o}{LD_j^o} \tag{1}$$

For sectors experiencing employment contraction $\left(\lambda_j^s < 0\right)$, we map the CGE shock to microdata by randomly selecting workers employed in sector j and removing them from employment with probability $-\lambda_j^s$. Formally, the post-shock individual employment indicator evolves as:

$$E_h^s = \begin{cases} 0 \text{ with probability } -\lambda_j^s \\ 1 \; otherwsie \end{cases} \tag{2}$$

Post-shock labour income for individual h is determined by:

$$w_h^s = E_h^s \cdot w_h^0, \tag{3}$$

where w_h^0 is baseline wage income. This implies the labor income change:

$$\Delta y_h^L = w_h^s - w_h^0 \tag{4}$$

This mechanism captures labour market adjustments consistent with the CGE model while preserving heterogeneity across industries.

Capital and agricultural income transmission. Capital income, rK^h, is updated according to the change in the economy-wide return to capital. Because capital is assumed perfectly mobile in the CGE, households receive proportional adjustments to business and self-employment income based on the simulated change in the rental rate, $\frac{r^s - r^0}{r^0}$. Agricultural income, y^{agri}, is separately scaled using the proportional variation in agricultural value added, $\frac{VA_{agri}^s - VA_{agri}^0}{VA_{agri}^0}$.

Consumer prices and cost of living. Consumer price changes are passed through to the microsimulation model at the COICOP-harmonised commodity level, covering 32 expenditure items. Let p_i^0 denote baseline purchaser prices and p_i^s post-reform purchaser prices for commodity p_i^s, and let q_i^h denote household h's baseline consumption quantity. Assuming fixed consumption quantities in the short run, the implied cost-of-living effect for household h is:

$$\sum_{i=1}^{32} p_i^0 q_i^h \left(\frac{p_i^s - p_i^0}{p_i^0}\right) \tag{5}$$

Household-level welfare and real disposable income. Combining these impacts, the total household-level income change is formulated analogously to Vandyck et al. (2021) as:

$$\Delta y^h = rK^h \cdot \frac{r^s - r^0}{r^0} + \Delta y_h^L + y^{agri} \cdot \frac{VA_{agri}^s - VA_{agri}^0}{VA_{agri}^0} + \Delta BT - \sum_{i=1}^{32} p_i^0 q_i^h \left(\frac{p_i^s - p_i^0}{p_i^0}\right), \tag{6}$$

where ΔBT represents changes in benefit entitlements and tax liabilities following the reform. Labor income effects are captured entirely through (4). Equation 6 denotes a money-metric welfare change under fixed consumption quantities.

We define real disposable income under the policy scenario as baseline disposable income augmented by the money-metric welfare change:

$$y_h^{real,s} = y^{h,0} + \Delta y^h, \tag{7}$$

where $y_h^{real,s}$ represents household purchasing power. The adjustment Δy^h accounts for employment changes, capital return variations, agricultural income scaling, tax–benefit reforms, and price fluctuations applied to the baseline income $y^{h,0}$.

4. Results

4.1 Macroeconomic and Sectoral Effects

Table 2 shows that a hypothetical carbon tax in Ethiopia generates a small decline in real GDP, with limited variation across revenue-recycling options. The no-recycling scenario produces the largest GDP loss, while the sales-tax reduction and household-transfer scenarios slightly moderate the contraction. The decline in GDP and exports is mainly associated with adjustment pressures in fuel-intensive activities, particularly transport, although modest gains in less fuel-intensive and more capital-intensive sectors partly offset these losses. Under no recycling, investment increases marginally, reflecting the additional public revenue retained from the carbon tax. In contrast, the recycling scenarios produce small investment declines as carbon-tax revenue is returned through tax reductions or household transfers, altering demand patterns and economy-wide resource allocation.

The results show that revenue recycling substantially cushions the impact of carbon pricing on household consumption. Consumption falls most sharply under the no-recycling scenario, while PIT reduction, sales-tax reduction, and household-transfer mechanisms considerably reduce this loss. In the household-transfer recycling scenarios, the carbon-tax shock first increases gross government revenue, and the additional revenue is then recycled to households through higher government transfer expenditure. As a result, both gross government revenue and transfer expenditure increase, while government saving is held fixed under the model closure. Among the recycling options, the sales-tax reduction scenario provides the strongest support to household consumption, lowers the CPI, and generates the smallest GDP, investment, and export losses. This scenario targets commodities with relatively low fuel intensity while excluding fossil-fuel and highly fuel-intensive products, including transport, mineral products, and cement. CO_2 emissions decline substantially across all scenarios, by about 5.83–6.03%, with the largest reduction under equal household transfers and the smallest under sales-tax reduction. Overall, the findings suggest that well-designed revenue recycling can reduce the macroeconomic costs of carbon pricing without compromising its environmental effectiveness. This result is broadly consistent with Mengistu et al. (2019).

Table 2: Macroeconomic and CO_2 emissions effects of carbon-tax scenarios relative to the baseline

Variables	No recycling	PIT reduction	Sales tax reduction	Equal household transfer	Poverty-weighted transfer
Real GDP	-0.18	-0.17	-0.16	-0.16	-0.16
Investment	0.32	-0.31	-0.23	-0.26	-0.23
Government revenue	2.28	-0.14	-0.13	2.11	2.11
Household consumption expenditure	-0.44	-0.10	-0.12	-0.11	-0.12
Export	-3.12	-3.36	-3.11	-3.36	-3.34
Import	-0.84	-0.91	-0.85	-0.91	-0.90
CPI	0.11	0.12	-0.14	0.11	0.12
CO_2 emission	-5.87	-5.98	-5.83	-6.03	-6.01

Source: Authors' calculations.

The effects of the carbon tax on domestic production vary substantially across sectors and revenue-recycling mechanisms. Table 3 shows that the aggregate contraction in domestic output is modest, ranging from –0.26% under the sales-tax reduction scenario to –0.31% under PIT reduction and equal household transfers. Despite this limited aggregate effect, sectoral responses are highly heterogeneous. Transport and communication sector experiences the largest contraction in all scenarios, declining by between –1.49% and –1.60%, followed by wholesale and retail trade, agriculture and fishing, and other services. In contrast, mining, manufacturing and utilities, hotels and restaurants, and financial intermediation expand under all policy options. Hotels and restaurants record the strongest increase, reaching 1.07% under equal household transfers, while mining, manufacturing and utilities expand by as much as 0.55% under the sales-tax reduction scenario.

These differences are closely linked to production structure and relative input-price adjustments. Table 1 shows that transport and communication is the most fuel-intensive sector, with fuel accounting for 26.84% of total output. Consistently, Table A3 indicates that the carbon tax raises fuel prices by approximately 22% across scenarios, while electricity prices decline only marginally. Since electricity represents a small share of total production costs, the fall in electricity prices provides limited compensation for the rise in fuel costs. As a result, fuel-intensive sectors experience stronger contractions, whereas sectors with lower fuel intensity and relatively larger capital shares, such as hotels and restaurants and financial intermediation, perform comparatively better.

Changes in capital costs and investment demand further shape sectoral outcomes. Table A2 shows that the rental price of capital declines across all scenarios, ranging from –1.05% under sales-tax reduction to –1.48% under poverty-weighted transfers. Lower capital costs partly support expansion in capital-intensive sectors, particularly financial intermediation and hotels and restaurants. Construction follows a distinct pattern: output increases by 0.33% under no recycling but contracts under all recycling scenarios. This is consistent with the macroeconomic results, where aggregate investment rises only when carbon-tax revenue is retained by the government. Once revenues are recycled through tax reductions or household transfers, investment declines modestly, contributing to lower construction output.

Table 3: Percentage change in domestic output by sector, relative to the baseline, under alternative policy reform scenarios

Sectors	No recycling	PIT reduction	Sales tax reduction	Equal household transfer	Poverty-weighted transfer
Agriculture and fishing	-0.66	-0.52	-0.52	-0.47	-0.48
Mining, manufacturing, and utilities	0.32	0.37	0.55	0.36	0.39
Construction	0.33	-0.22	-0.15	-0.22	-0.18
Wholesale and retail trade	-0.83	-0.84	-0.76	-0.83	-0.83
Hotels and restaurants	0.54	0.98	1.02	1.07	0.95
Transport and communication	-1.53	-1.60	-1.49	-1.60	-1.59
Financial intermediation	0.18	0.25	0.24	0.22	0.23

Real estate	-0.17	0.03	0.01	-0.19	-0.17
Public administration and defence	0.08	0.03	0.04	0.03	0.04
Education	-0.02	0.00	-0.01	-0.01	-0.01
Health and social work	-0.19	-0.04	-0.11	-0.03	-0.02
Other service	-0.70	-0.29	-0.15	-0.34	-0.32
Total	**-0.30**	**-0.31**	**-0.26**	**-0.31**	**-0.30**

Source: Authors' calculations.

Wholesale and retail trade and real estate illustrate that sectoral outcomes are not determined solely by direct fuel intensity. Wholesale and retail trade contracts across all scenarios despite its very low direct fuel share, reflecting its strong dependence on transport and communication services as intermediate inputs. Since transport and communication accounts for about 63% of wholesale and retail trade's intermediate consumption, higher transport-related costs are transmitted indirectly to the sector, increasing operating costs and reducing activity. Real estate also performs weakly, contracting under the no-recycling, equal-transfer, and poverty-weighted transfer scenarios, with only marginal expansion under PIT and sales-tax reduction. This pattern reflects its demand-driven nature and exposure to broader income and expenditure adjustments, particularly among urban households.

Revenue recycling options moderate part of the contractionary effect of carbon pricing and changes the distribution of sectoral adjustments. The sales-tax reduction scenario generates the smallest aggregate output decline and comparatively stronger expansion in mining, manufacturing and utilities, hotels and restaurants, and other services. Household-transfer scenarios also support consumption-oriented activities through higher household purchasing power. Agricultural output declines in all scenarios, although the fall in agricultural value added is smaller under household-transfer mechanisms, as shown in Table A2. In general, the findings indicate that sectoral responses to carbon pricing depend not only on fuel intensity, but also on relative factor prices, investment demand, household consumption patterns, input-output linkages, and the allocation of recycled carbon-tax revenues.

4.2 Effects on purchaser price

A carbon tax alters relative prices by increasing the cost of fuel-intensive goods and services while moderating, or even reducing, the prices of commodities with lower carbon dependence. Table 4 reports percentage changes in purchaser prices for selected commodity groups that account for a substantial share of household consumption in the SAM. These price adjustments constitute the principal transmission mechanism linking the CGE model to the microsimulation analysis presented in the following section. The results indicate a heterogeneous pattern across sectors and policy scenarios. Transport and communication sector records the largest price increase in all scenarios, ranging from 1.00% to 1.13%, reflecting the sector's strong dependence on fuel inputs and the substantial rise in fuel prices induced by the carbon tax. Mining, manufacturing and utilities and health and social work also experience moderate price increases, whereas most other sectors register price declines.

The magnitude of these price changes varies across revenue-recycling mechanisms. In general, recycling carbon-tax revenue reduces consumer price pressures relative to the no-recycling scenario. Among the alternative mechanisms, the sales-tax reduction scenario generates the strongest mitigation effect, producing the largest price declines across most commodity groups. Purchaser prices decline by 0.97% in wholesale and retail trade, 1.18% in hotels and restaurants, 1.11% in financial intermediation, and 0.72% in real estate under this scenario. The stronger price response reflects the direct reduction in indirect taxation combined with the relatively lower fuel intensity of these sectors. By contrast, PIT reduction and household-transfer scenarios produce more moderate price adjustments, although they still dampen inflationary pressures compared with the no-recycling case.

Table 4: Percentage change in purchaser prices by sector, relative to the baseline, under alternative policy reform scenarios

Sectors	No recycling	PIT reduction	Sales tax reduction	Equal household transfer	Poverty-weighted transfer
Agriculture and fishing	-0.07	0.09	-0.09	0.15	0.16
Mining, manufacturing, and utilities	0.62	0.49	0.16	0.45	0.45
Construction	0.16	0.07	0.04	0.04	0.04
Wholesale and retail trade	-0.59	-0.70	-0.97	-0.74	-0.76
Hotels and restaurants	-0.69	-0.78	-1.18	-0.83	-0.85
Transport and communication	1.13	1.03	1.01	1.00	1.00
Financial intermediation	-0.75	-0.87	-1.11	-0.91	-0.92
Real estate	-0.28	-0.37	-0.72	-0.41	-0.41
Public administration and defence	-0.15	-0.22	-0.19	-0.24	-0.25
Education	-0.18	-0.24	-0.28	-0.26	-0.26
Health and social work	0.21	0.14	0.11	0.12	0.12
Other service	-0.08	-0.14	-0.53	-0.16	-0.17

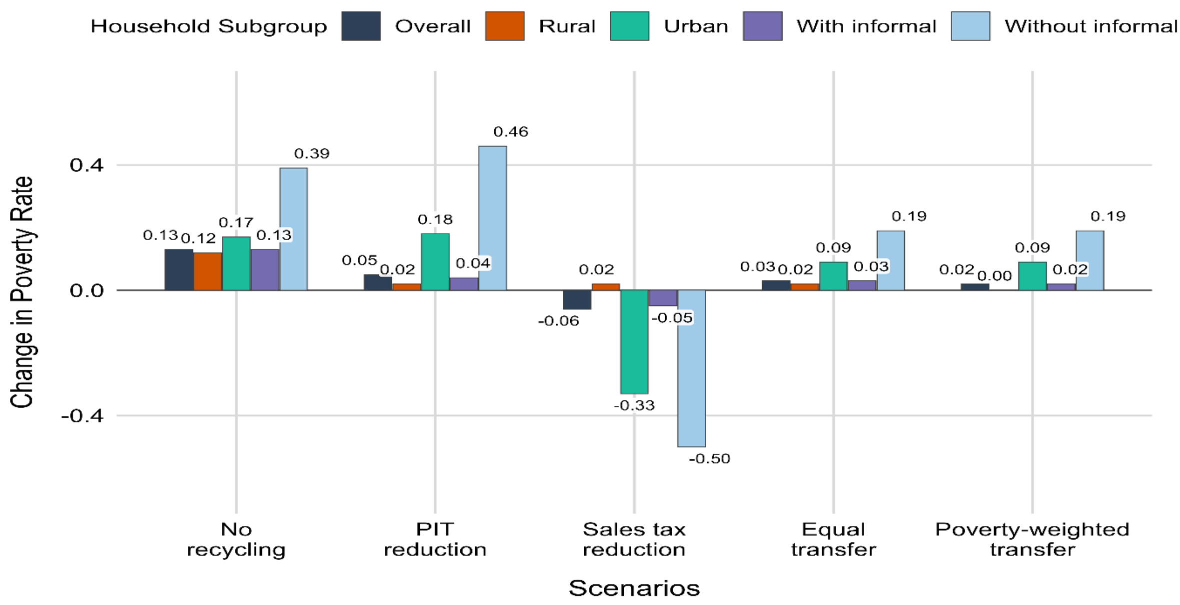
Source: Authors' calculations.

4.3 Distributional Effects

This subsection examines the distributional effects of the carbon tax on income, poverty, and inequality. Macroeconomic shocks introduced into the CGE model are transmitted to ETMOD through scenario-specific changes in employment, factor returns, and consumer prices. Employment income is adjusted according to sectoral changes in labour demand, mapped to the industrial classifications in the ETMOD microdata (Table A1). Business and self-employment income are scaled using changes in the return to capital, while agricultural earnings are adjusted in line with changes in agricultural value added. In addition, household consumption expenditures across 32 commodity groups are re-evaluated using CGE-derived consumer price changes (Table 4), allowing us to capture cost-of-living effects. The resulting changes in disposable income are then used to compute poverty and inequality indicators.

Figure 1 presents the effects of the carbon tax on headcount poverty. All scenarios except sales tax reduction increase poverty relative to the baseline: the overall rate rises by 0.13 percentage points (pp) under no recycling and by 0.02 pp under poverty-weighted transfer. The burden is disproportionately concentrated among urban households and those without informal-sector earners, indicating limited capacity to buffer higher consumer prices or reallocate income sources. By contrast, sales tax reduction, where revenues are recycled through reductions in sales taxes, reduces poverty by 0.06 pp. Most household groups benefit, though rural households still experience a slight increase, suggesting structural vulnerability to price shocks.

Figure 1: Change in poverty headcount rate (percentage points) relative to baseline under alternative carbon-tax policy scenarios, based on equivalized real disposable income



Source: Authors' calculations.

Changes in the poverty gap, reflecting the depth of poverty across household subgroups, shows patterns parallel to those observed in the headcount rate (Figure A1 in the appendix). No recycling, PIT reduction, equal household transfer, and poverty-weighted transfer scenarios exacerbate poverty intensity, with no recycling exerting the largest effect, raising the overall gap by 0.24 pp. Urban households and those without members engaged in formal employment are disproportionately affected. By contrast, sales tax reduction case reduces the poverty gap for most households, with the largest improvement observed among urban households, who has greater access to fuel-intensive sectors such as transport and water (–0.47 pp).

Table 5 highlights the heterogeneous effects of carbon-tax scenarios across the income distribution. No recycling option is the least favourable: the contraction is largest in relative terms for the bottom quintile. Sales tax reduction generates net income gains for nearly all quintiles. The bottom quintile records the largest improvement, while the richest quintile experiences only a marginal loss. This outcome reflects the general equilibrium transmission mechanism: lower indirect taxes dampen consumer price increases, partially offsetting the carbon-induced cost shock and yielding a progressive net effect.

Table 5: Percentage change in equivalized real disposable income by quintile, relative to the baseline, under alternative policy reform scenarios

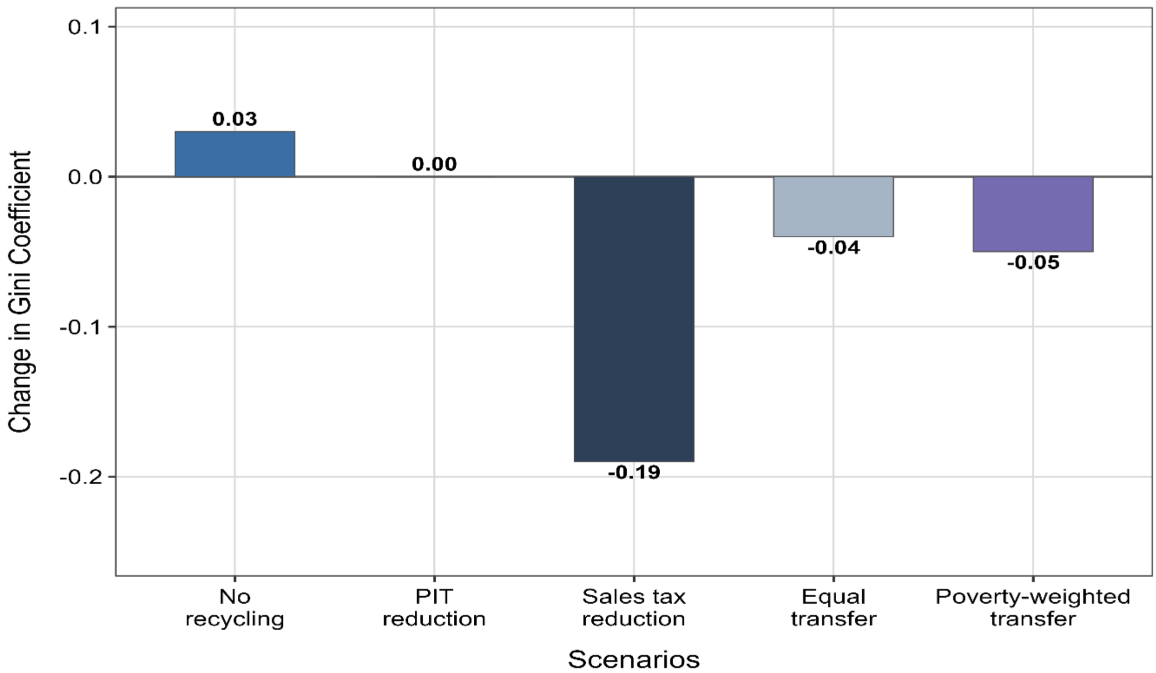
Quintiles	No recycling	PIT reduction	Sales tax reduction	Equal household transfer	Poverty-weighted transfer

1st	-0.69	-0.49	4.50	0.43	0.60
2nd	-0.24	-0.16	0.73	0.01	0.04
3rd	-0.49	-0.37	0.13	-0.27	-0.25
4th	-0.41	-0.32	0.05	-0.24	-0.22
5th	-0.37	-0.36	-0.18	-0.34	-0.34

Source: Authors' calculations.

Figure 2 shows that the counterfactual carbon-tax reform is regressive in the absence of effective compensation, imposing a relatively larger burden on lower-income households. However, the effects on income inequality vary across revenue-recycling mechanisms. The Gini coefficient does not increase under all recycling schemes, and the sales-tax reduction scenario produces the largest decline in inequality (–0.19). These findings suggest that recycling carbon-tax revenues through targeted sales-tax reductions can help offset adverse distributional effects, reduce poverty, and narrow income disparities, while also limiting macroeconomic losses. The distributional outcome therefore depends critically on the design of the recycling mechanism rather than on the carbon price itself.

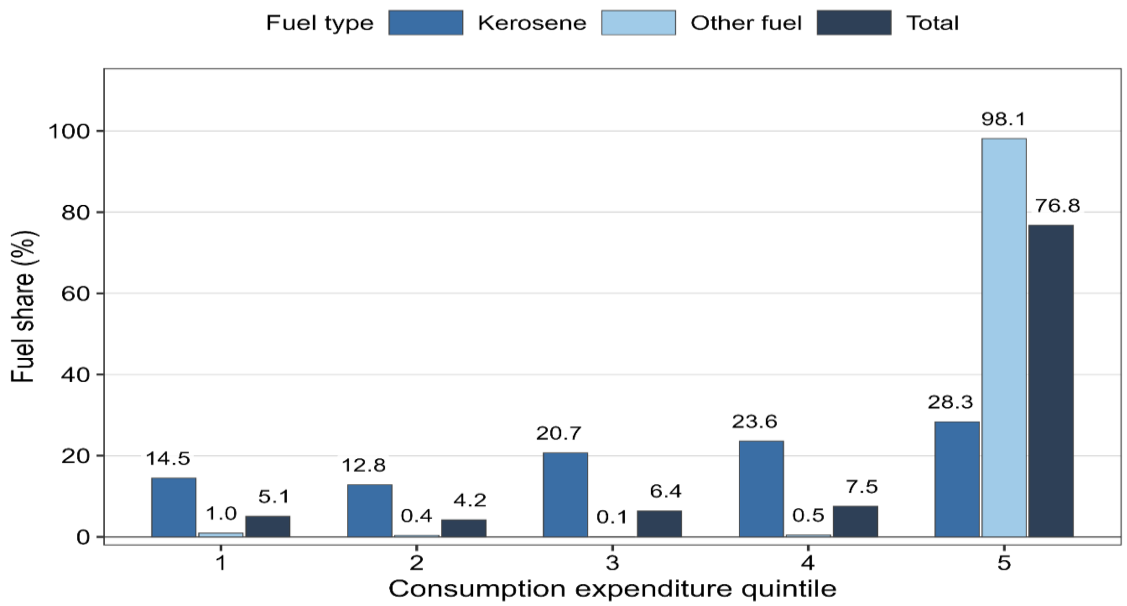
Figure 2: Change in income inequality (Gini coefficient), relative to the baseline, under alternative policy reform scenarios



Source: Authors' calculations.

The distribution of fuel consumption explains why a carbon tax in Ethiopia is regressive. Kerosene use is considerable among lower- and middle-income households, making these groups more exposed to price increases in this fuel category (Figure 3). By contrast, higher-income households account for a larger share of consumption of other fuels, which partly offsets the overall inequality effect of the tax. The modest poverty increases observed under all scenarios except sales tax reduction are driven mainly by kerosene price hikes, which disproportionately affect middle-income households with substantial kerosene use.

Figure 3: Fuel Consumption distribution by category



Source: Authors' calculations.

5. Conclusion

This study applies a top-down linkage approach that integrates the DEMETRA CGE model with the ETMOD tax–benefit microsimulation model to assess the potential impacts of a hypothetical carbon tax in Ethiopia, set at US$20 per tonne of CO_2 tax. We evaluate its environmental, macroeconomic, and distributional effects under alternative revenue-recycling scenarios, including a direct income tax cut, reduction in sales taxes, and lump-sum transfers to households. Shocks from the macroeconomic model are transmitted to the microsimulation model using changes in employment, agricultural value added, and commodity prices as linkage variables.

The results indicate that a carbon tax could reduce fossil-fuel emissions by 5.87%, with the magnitude of emission reductions varying across recycling options: recycling through a sales-tax reduction yields the smallest reduction, whereas equal household transfer produces the largest. The reform could induce a moderate economic contraction, although recycling revenues through sales-tax reductions and lump-sum household transfers appears most effective in limiting GDP losses. Sectoral effects are heterogeneous: output declines in carbon-intensive sectors, particularly transport and communication, while less fuel-dependent but capital-intensive sectors, such as hotels and restaurants and financial intermediation, experience modest gains.

From a policy perspective, the carbon tax leads to a modest increase in poverty and has regressive distributional effects, disproportionately affecting urban households and those with at least one formally employed member. However, these adverse impacts can be effectively offset through appropriate revenue recycling. In particular, recycling carbon-tax revenues through sales-tax reductions reduces the burden on low-income households and can reverse the regressive incidence of the reform. Among the recycling options considered, sales-tax reductions deliver the largest reduction in income inequality, highlighting their relevance for designing socially balanced carbon pricing policies.

This analysis is subject to the standard limitations of static CGE modelling. The framework captures short-run adjustment effects but does not account for longer-term structural transformation. Over time, carbon pricing may facilitate deeper adaptation through sustained capital reallocation, technological upgrading, and the expansion of emerging low-carbon sectors, processes that are not fully represented in a static setting. Consequently, the reported GDP and sectoral effects should be interpreted as short-run impacts. Future research could extend the analysis using a dynamic CGE framework to assess long-term growth, structural change, and green transition pathways.

Overall, the findings suggest that Ethiopia can implement a carbon tax that advances climate objectives, mobilizes domestic revenue, and enhances distributional equity, provided that the accompanying revenue-recycling strategy is carefully designed. Lowering sales taxes or integrating carbon pricing with social-protection programs appears most effective in protecting vulnerable households while maintaining the environmental benefits of the tax. A carbon tax without revenue recycling would remain regressive, increase poverty, and impose avoidable welfare costs.

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Appendix

Table A1: Percentage change in labour demand by sector, relative to the baseline, under alternative policy reform scenarios

Sectors	No recycling	PIT reduction	Sales tax reduction	Equal household transfer	Poverty-weighted transfer
Agriculture and fishing	-0.37	-0.18	-0.22	-0.11	-0.11
Mining, manufacturing, and utilities	0.39	0.41	0.56	0.39	0.40
Construction	0.34	-0.22	-0.15	-0.20	-0.18
Wholesale and retail trade	-0.96	-0.98	-0.87	-0.99	-1.00
Hotels and restaurants	0.40	0.83	0.87	0.86	0.79
Transport and communication	-1.48	-1.59	-1.46	-1.60	-1.60
Financial intermediation	0.00	0.06	0.09	0.00	0.01
Real estate	-0.24	-0.05	-0.05	-0.28	-0.27
Public administration and defence	0.06	-0.00	0.01	-0.01	-0.01
Education	-0.05	-0.05	-0.06	-0.06	-0.06
Health and social work	-0.15	-0.02	-0.09	-0.06	-0.05
Other service	-0.74	-0.33	-0.20	-0.33	-0.32
Total	**-0.32**	**-0.24**	**-0.24**	**-0.19**	**-0.18**

Source: Authors' calculations.

Table A2: Percentage change in price of capital and agricultural value added, relative to the baseline, under alternative policy reform scenarios

Variables	No recycling	PIT reduction	Sales tax reduction	Equal household transfer	Poverty-weighted transfer
Price of capital	-1.26	-1.41	-1.05	-1.47	-1.48
Agricultural value added	-0.64	-0.29	-0.34	-0.15	-0.13

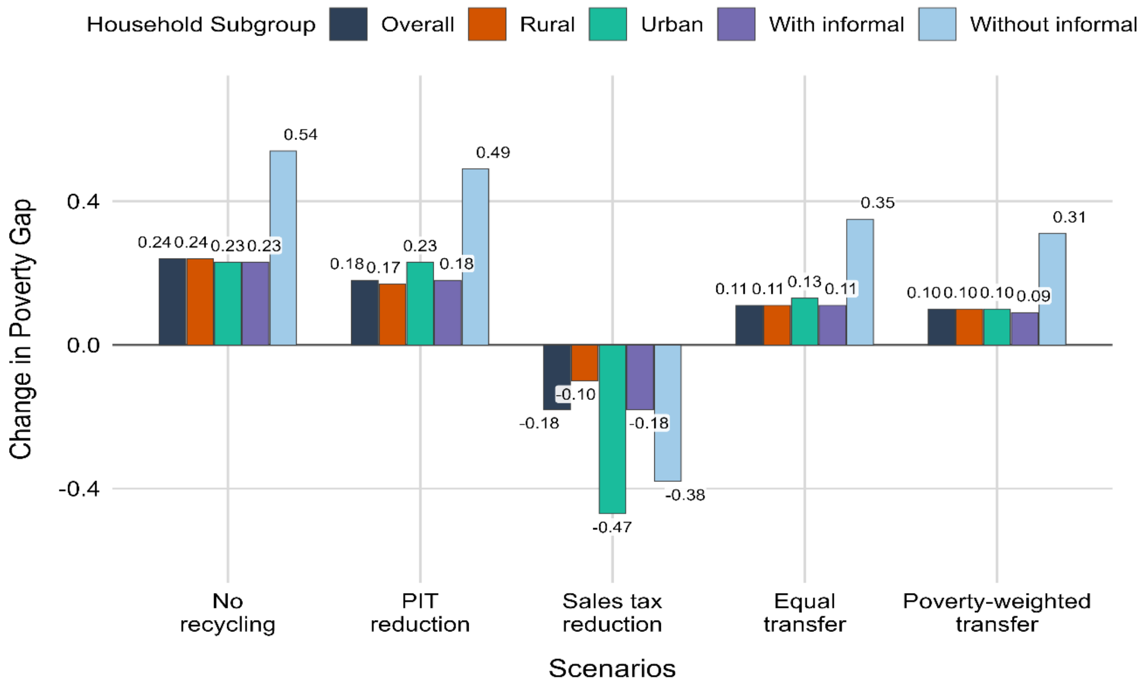
Source: Authors' calculations.

Table A3: Percentage change of price of energy products, relative to the baseline, under alternative policy reform scenarios

Variables	No recycling	PIT reduction	Sales tax reduction	Equal household transfer	Poverty-weighted transfer
Fuel	22.22	22.06	21.97	22.03	22.03
Electricity	-0.11	-0.22	-0.39	-0.26	-0.26

Source: Authors' calculations.

Figure A1: Change in poverty gaps (percentage points) relative to baseline under alternative carbon-tax policy scenarios, based on equivalized real disposable income



Source: Authors' calculations.