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Double progressivity of infrastructure financing through carbon pricing — Insights from Nigeria

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ABSTRACT

Carbon taxes and fossil fuel subsidy reforms have been recognized as an efficient means to mobilize substantive domestic resources for sustainable development. Yet, despite their advantages compared to other taxes, concerns about potential adverse impacts on poverty and inequality have discouraged many countries from such fiscal reforms. This paper estimates which absolute and relative equity effects a comprehensive carbon pricing reform would have on households within and between income groups in Nigeria. We further analyze the distributional effects of revenues being recycled into basic infrastructure development and social safety nets. We assess the expected consumption effects of six policy packages across rural and urban income groups, combining environmental-extended input-output data with detailed household survey data. Our results suggest that, relative to their income, lower-income households would bear a smaller consumption burden from carbon pricing than high-income households, while enjoying greater gains from uniform cash transfers or access to improved water, sanitation, electricity, or telecommunication infrastructure. Additionally, if spent efficiently, such investments could disproportionately benefit the overall poorer rural population due to larger initial access gaps.

1. Introduction

Sufficiently high carbon prices provide an efficient means to incentivize low-carbon investments, preventing the lock-in of high future emissions, while mobilizing domestic resources to fund development priorities [37,84]. Green fiscal reforms could serve as catalyst to reconcile climate change mitigation, poverty and inequality alleviation and other goals spelled out in the Agenda 2030 [19,20,87]. This is particularly the case in many Sub-Saharan African countries, where, during the past decade, growth rates of greenhouse gas (GHG) emissions from fossil fuel use were among the highest, while tax-to-GDP ratios remain among the lowest globally [63,82]. Particularly in economies with large informal sectors and low administrative capacities, upstream carbon taxes can help increase the tax base and the efficiency of the tax system [7,45,47].

In Nigeria, income inequality and poverty prevalence are steadily increasing, infrastructure access rates remain low [90], and the country's tax-to-GDP ratio of 6 percent was the lowest among African countries in 2019 [63]. At the same time, Nigeria's GHG emissions are expected to

double by 2035 without additional mitigation efforts [12]. Hence, green fiscal reform could help to address economic as well as climate targets. This link is recognized by the government in its Intended Nationally Determined Contribution (INDC), which states that "fiscal reform is proving an efficient mitigation action" and "releases significant resources in the budget that can fund investments in efficient infrastructure" ([58], p. 9). Investment requirements for physical infrastructure account for the largest share of the financing gap for achieving the sustainable development goals (SDGs) [60,61,76,89].

Yet, little is known about how recycling carbon pricing revenues into basic public infrastructure would affect individual households toward inclusive development. Using Nigeria as an example, we assess the poverty and distributional effects of a fossil fuel subsidy reform and the introduction of an economy-wide USD 30/tCO₂ carbon tax, carrying out microsimulations based on household budget data in combination with an environmentally-extended multi-regional input-output (MRIO) model. We compare different policy scenarios, including an uncompensated carbon pricing reform, and a carbon price with various revenue recycling schemes, for example lump-sum cash transfers, or financing

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access to various types of infrastructure. While we find greater heterogeneity within (horizontal) than across (vertical) income groups, our results suggest pronounced double progressivity: relative to their disposable income, low-income and rural households would bear smaller consumption losses from carbon pricing and benefit more from increasing infrastructure access. Taxing emissions and investing revenues in basic infrastructure could hence be an efficient and equitable way to foster sustainable and inclusive development.

This analysis contributes to the academic literature by demonstrating how the distributional effects of recycling carbon pricing revenues into infrastructure investments can be conceptualized. Our approach of approximating gains from public infrastructure development with access-conditional transfers yields straightforward distributional insights.

Concerns of adverse effects of carbon pricing reforms on poverty and inequality can hamper their political feasibility [3,18]. However, with respect to inequality, empirical evidence suggests pronounced vertical progressivity of such measures across income groups in lower income countries, which is true both for carbon pricing and fossil fuel subsidy reforms (i.e., removing a negative carbon price) [64]. Richer households which have adopted more energy-intensive lifestyles tend to pay a larger share of their income for the tax than poorer ones (cf. [17,75]). With respect to poverty outcomes, it is important to note that the variation of distributional effects is larger within than across income groups, as consumption patterns vary with socioeconomic characteristics of households [67]. Thus, even when reforms are progressive, hence expected to reduce inequality over time, compensation schemes are ideally targeted at the most affected households across all income groups to avoid adverse poverty outcomes in the short term [14]. For Nigeria, Rentschler [73] finds that, based on 2010 data, a fossil fuel subsidy reform would be progressive both for kerosene and petrol, but would increase absolute poverty if no compensation is provided. The finding of progressivity is in line with Soile & Mu [81] who, based on a 2012 household survey, find that a subsidy reform would be strongly progressive for petrol, and roughly neutral for kerosene. Based on a computable general equilibrium model, Siddig et al. [78] also conclude that a subsidy reform would generate progressive distributional impacts.

Regarding the distributional implications of infrastructure provisions, both theoretical and empirical insights are fairly limited [79], and consequences of infrastructure access on inequality have received only scarce attention in the empirical literature [11]. In a panel analysis of two dozen low- and middle-income countries, Graham et al. [23] find that access to all basic public infrastructure is highly correlated with household wealth and that access levels are overall significantly higher among urban than rural households. Also, Calderon and Chong [10] show that infrastructure investment can reduce inequality, particularly in low-income countries. Green and Gambhir [24] emphasize that cash transfers as well as public infrastructure investment can promote equitable transitions and increase public acceptability of reforms.

The remainder of this paper is structured as follows: section 2 discusses the socio-economic and political context in Nigeria. Section 3 presents the data and methods used to calculate the distributional impact of carbon pricing, subsidy reform and of infrastructure investments, section 4 the results, and section 5 a short discussion and conclusion.

2. Nigeria, socio-economic and political context

Nigeria had been facing major economic and social challenges even before the onset of the COVID-19 pandemic. Macroeconomic stability and fiscal consolidation have been deteriorating, not least due to the country's fossil fuel subsidy regime [92]. Due to tax evasion, a large informal economy, and a respectively limited tax base [34], revenue mobilization remains among the lowest worldwide, with a tax-to-GDP ratio of around 6 percent [63]. Apart from the sustained fiscal deficit,

Table 1

socio-economic and development indicators for Nigeria (Source: [90,92]); * own calculation based on NBS & World Bank [57]

Indicator	2000	2018
Population (million)	123	196
GDP per capita (2011 PPP international dollar)	2,840	5,315
Poverty headcount ratio at USD 1.90 a day (2011 PPP) (% of population)	53.5 (2003)	66.2 (2016)*
Gini coefficient	40 (2003)	35.1
Human Development Index	0.47 (2005)	0.54
Energy use per capita (kg of oil equivalent)	704	764 (2014)

Nigeria's high corruption rates and low administrative capacities result in low levels of productive public investments in physical and human capital [4,33], and the country is falling far behind on the achievement of all 17 SDGs [74].¹

Nigeria's high dependence on the extractive industries is one of the main challenges for macroeconomic stabilization and sustained development. Oil revenues accounted for the majority of public revenues (60 percent) and of exports (90 percent) in 2018 [36]. Being highly vulnerable to oil price and demand shocks, Nigeria fell into deep recessions due to the 2016 and the 2020 declines in oil prices. In 2020, its economy contracted by -1.8 percent, its deepest recession in four decades, downgrading its GDP growth outlook by 3-8 percentage points [21,93]. Public expenditures on fossil fuel consumer subsidies through price controls for petrol and kerosene have been substantial as Nigeria depends on imports of oil products for at least 50 percent of its domestic consumption due to limited oil refining capacities [33]. Despite raising price controls in mid-2016 (from Nigerian Naira (NGN) 87 to NGN 145 per liter of petrol and from NGN 50 to NGN 83 for kerosene per liter [26])², subsidy expenditures accounted for more than four percent of total public expenditures, or 0.5 percent of GDP, in 2018 [34]. The 2016 subsidy reform faced little public resistance, particularly compared to the failed reform attempts in 2012 [71]. Motivated by low oil prices, in mid-2020 the country had initially abolished its fossil fuel subsidies, but reinstated them in early 2021 [85].

Nigeria faces major human development challenges. Despite being ranked as a middle-income country since 2010, access to basic public services and social security remain low. Income inequality as well as regional disparities have strongly increased, with Nigeria's Gini coefficient being amongst the highest in the world [4,73]. Throughout the past decade, more than half of the population, which is expected to grow to 262 million by 2030 [88], was living on less than USD 1.90 per day (cf. Table 1 and Fig. A 1).

Access to basic public services remains limited and unevenly distributed. To date, 20 to 30 percent of the population lack access to safely managed drinking water and sanitation, and 45 percent do not have access to grid-based electricity, while the use of petrol and diesel generators is widespread [92]. As is the case in many lower-income countries (cf. [23]), infrastructure access in Nigeria is positively related to income (cf. Fig. 1), and at comparable income levels urban households are more likely to have access than rural ones. Differences between income groups are most pronounced for grid electricity while access to improved drinking water is spread more evenly. Major public funds of up to 43 percent of the public budget have been devoted to the development of physical infrastructure [60]. Between 2016 and 2019, the government intended

¹ The only goal which is ranked "on track" with SDG achievement is '13 Climate Action'. However, being measured in terms of per capita GHG emission levels, this is an artefact of Nigeria's high population growth rates.

² The official average exchange rate in 2015/16 was approximately Nigerian Naira (NGN) 220 per USD [92], converting NGN 145 to USD 0.66. However, in this paper we account for purchasing power parity and use the PPP conversion rate which is estimated at NGN 90 per USD [35], converting NGN 145 to USD 1.6.

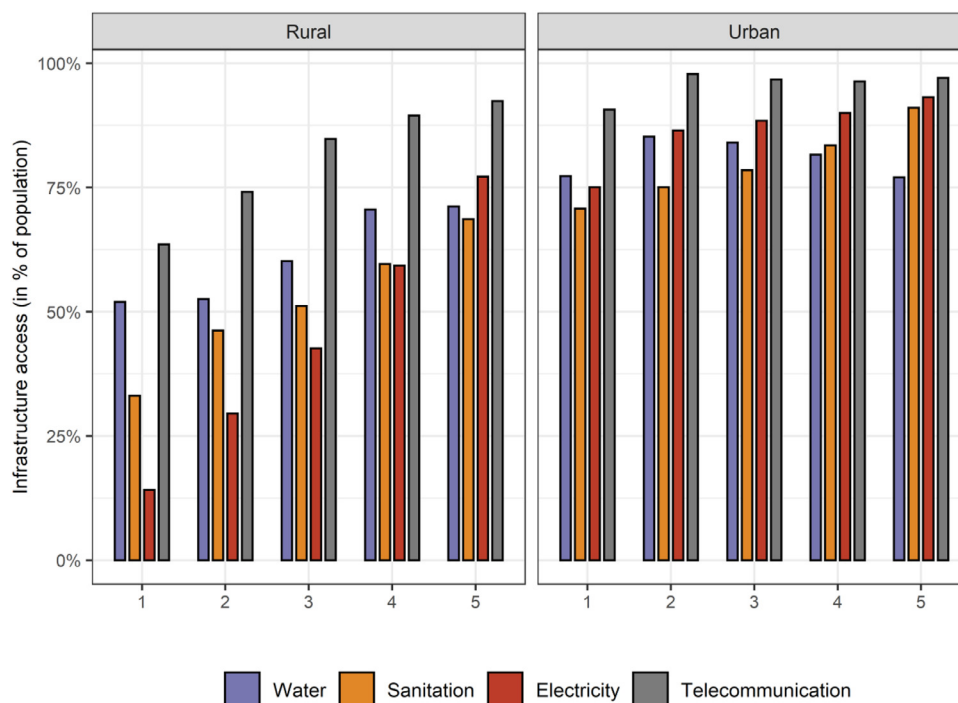


Figure 1. infrastructure access, as share of the population in each rural (R1-5) and urban (U1-5) income household quintile in Nigeria in 2015/16; note: R/U1 refers to the poorest, R/U5 to the richest rural/urban quintiles. (Source: own calculation based on [57])

to establish an infrastructure investment fund of up to USD 25 billion [62]. An economy-wide carbon tax and energy subsidy reform, which is at the heart of our analysis, could serve this purpose [12].

If no significant mitigation efforts are undertaken, Nigeria's GHG emissions are expected to double by 2035, reaching around 660 million tCO₂e annually, with most emissions growth stemming from the electricity sector [12]. The Nigerian government has expressed its willingness to engage in climate change mitigation in its Nationally Determined Contribution (NDC), submitted to the United Nations Framework Convention on Climate Change [59]. Its 2030 GHG emission reduction target is 20 percent below its business-as-usual (BAU) scenario, or 47 percent conditional on international financial and technological support. The initial NDC projected 2030 BAU emissions at 900 million tCO₂e annually, roughly 50 percent higher than World Bank projections (cf. [12,58]) so that the reduction targets represented only limited abatement. However, the revised version downward-corrects 2030 BAU projections to 450 million tCO₂e, emphasizing that this correction represents increased mitigation ambition. In 2017, households accounted for over 77 percent of the rising final energy demand in Nigeria [32]. Solid biofuels represented more than 74 percent of Nigeria's energy consumption in 2017 [32], as 70 percent of households depend on firewood as primary cooking fuel (own calculation based on [57]). Over 88 percent of firewood is acquired without purchase (own calculation based on [57]). As firewood use is not amenable to market-based regulation, such as taxes, its associated emissions are excluded from this analysis.

3. Data and methodology

The consumption incidence of the carbon price is estimated based on a microsimulation approach, combining household-level microdata with input-output tables. The microdata also serve to calculate the incidence of the fossil fuel subsidy reform across income groups, deploying monthly subnational price data, as well as of the considered compensation schemes, namely expanding social safety nets, approximated with lump-sum cash transfers, or expanding access to basic public infrastructure. This section introduces the data, method, and underlying assumptions.

Table 2

average annual per capita expenditure, or disposable income (PPP USD), household size and percentage share of total population by rural (R) and urban (U) household quintiles (1-5) in 2015/16 (Source: own calculation based on [57])

		Per capita expenditure (PPP USD)		Household size mean	Share of total pop %
		mean	median		
Rural	1	191	201	7.8	15.1
	2	340	340	7	13.5
	3	482	476	6.3	13.3
	4	712	692	5.2	13.5
	5	1605	1292	3.6	12.9
Urban	1	400	412	6.4	6.8
	2	643	638	6	6.2
	3	898	897	5.2	6.4
	4	1279	1256	4.3	6.1
	5	2455	2107	3.5	6.3

3.1. Data

Data on household consumption and infrastructure access are retrieved from the 2015/2016 General Household Survey (GHS), conducted jointly by the Nigerian National Bureau of Statistics (NBS) and the World Bank [57]. To account for the country's large spatial heterogeneities and to prevent the blurring of structural differences, we analyze the rural and urban population separately, splitting the 5,000 sample households before representative quintiles are formed. Consistent with the literature, we proxy lifetime income with aggregate annual per capita consumption expenditures, or disposable income (cf. [28,48,69,83]).

The distribution of average per capita income and household size, represented in Table 2 and Fig. A 1, demonstrates the stark socioeconomic differences between rural and urban populations. Rural households account for approximately two thirds of the total population. The income distribution across groups and the spread within the richest groups, R5 and U5, indicates the existence of a comparatively affluent upper class in Nigeria. On a per capita basis, lower-income quintiles represent a greater share of the population due to their greater aver-

age household size.³ In 2015/2016, over two thirds of the population lived below the purchasing power parity (PPP) USD 1.9 per capita per day poverty line (cf. Fig. A 1 in the Appendix; own calculation based on [57]).⁴

The carbon intensity of goods and services, i.e., the emissions per monetary unit, in Nigeria are estimated based on an input-output table constructed from the Global Trade Analysis Project database (GTAP 9; [53]) for the year 2011⁵, following the procedure described by Peters et al. [66]. The resulting input-output system has 57 sectors in 140 countries and world regions. The environmental extension of the GTAP database allows to relate monetary flows for final demand to indirect carbon emissions for each sector, taking account of all fossil energy commodities, their emission factors and energy conversion coefficients as well as other inputs used in production [43]. Because the environmental extension of GTAP includes only CO₂ emissions related to the combustion of fossil energy (but excludes, e.g., methane or CO₂ emissions from land use change), the carbon price referred to in this paper can be interpreted as an upstream CO₂ tax on fossil fuels.

3.2. Microsimulation and fossil fuel subsidy estimation

We analyze the distributional consumption effects of a comprehensive carbon pricing reform, consisting of a) the introduction of an economy-wide (PPP 2015) USD 30/tCO₂ carbon price and b) the removal of the existing fossil fuel consumption subsidy. Income loss is measured on the consumption side as the additional expenditures that would be needed to maintain a household's pre-reform consumption. Because household expenditure data are empirical observations in the presence of subsidized retail prices of petrol and kerosene in Nigeria, we additionally estimate the distribution of the consumption subsidy across income groups in order to adjust the baseline carbon price from negative to zero.

3.3. Microsimulation

For the assessment of consumption effects, we focus on the short-term welfare changes in terms of compensating variation. We carry out a microsimulation, assuming fixed consumption patterns, i.e., households do not adjust their behavior in response to the price changes. This approach yields a reliable short-term and upper-bound estimate appropriate in the face of constrained data availability [8]. Estimating the own- and cross-price elasticities of demand, differentiated across products, income levels and socio-economic settings, would require strong assumptions, including on retail prices across the consumption basket, and potentially determine distributional results (refer to section 5 for a brief discussion). Consistent with the literature, all price increases resulting from an economy-wide carbon price are expected to be fully passed through from suppliers and producers to final consumers (cf. [40]).

We use a carbon footprint approach, based on the Leontief inverse, similar to Hubacek et al. [30]. We first calculate the total emissions of final demand commodities consumed by households, which is the sum of all emissions associated with the production. The direct emissions from household fossil fuel combustion are added for those sectors that produce final demand fuel commodities. Thereafter, we divide them by

³ The GHS survey is carried out at a household level - with households being the smallest unit of observation. This does not allow quintiles to be formed based on head count.

⁴ Note that a large share of the population is clustered around the poverty line, suggesting that a small economic shock, or data treatment for that matter, can change the estimated poverty rate.

⁵ Total embedded emissions and their distribution across sectors in Nigeria are comparable between GTAP 9 (for 2011) and the recently released GTAP 10 (for 2014), please see Table 2 in the SI. Updating the GTAP dataset would not change our results qualitatively.

their corresponding monetary values from the household survey to arrive at embodied carbon intensities (following the method described by Hubacek et al. [30] and Dorband et al. [17]).

The required steps are as follows. Adapted from basic MRIO analyses (cf. [44,51]), overall emission intensities of sector k in country (or world region) j , ei_k^j result as single entries of the vector:

$$ei = c(I - A)^{-1} \quad (1)$$

where c is a vector assigning a carbon coefficient to each sector of each country. The $(I - A)^{-1}$ matrix, or Leontief inverse (cf. [44]), accounts for all upstream inputs that are required to produce one unit of final demand for each sector. A is the normalized matrix of technical coefficients based on inter-sectoral commodity flows, I is the identity matrix.

Let Y_{rj}^{k-HH} represent the total amount of flows from sector k in region r , entering the final demand of households (HH) in region j , according to the MRIO data. Let dir_{jk}^{HH} denote the direct emissions of households in regions j in sector k . Let x_{jk}^h denote the expenditure of household h of the corresponding household survey of region j for sector k . The average embodied carbon intensity of a good produced by sector k consumed in region j then results as:

$$e_{kj} = \frac{\left(\sum_r ei_k^r \cdot Y_{rj}^{k-HH} \right) + dir_{jk}^{HH}}{\sum_h x_{jk}^h} \quad (2)$$

We use sectoral expenditures based on the household survey for calculating e_{kj} in order not to over- or under-attribute emissions to households (cf. [17,30]).

As we consider one country only, Nigeria, we use e_k and x_k^h for Nigerian households.

We define the consumption effects ce_h as the total additional expenditures of household h after the policy intervention. This refers to a multiplicative function of (i) average embodied carbon intensities e_k in (tCO₂/USD) of consumption items from each sector k , (ii) total expenditures x_k^h by household h on sector k , and (iii) the tax rate τ (USD/tCO₂). The consumption effect ce_h results as:

$$ce_h = \sum_k x_k^h * e_k * \tau \quad (3)$$

As represented in Fig. 2, based on conversion tables provided by GTAP, the 160 consumption items covered in the Nigerian microdata are mapped to the corresponding 33 GTAP sectors, which comprise (non-durable) end-consumer products, and assigned their sector's average embodied carbon intensity (for detailed concordance tables of items and sectors refer to Table in the SI). The purchasing power parity (PPP) conversion factor for 2015/16 [35] is used to convert NGN expenditures to USD.

3.4. Fossil fuel subsidy spending

We estimate (i) per capita fuel consumption volumes and (ii) respective subsidy payments across income groups in Nigeria based on detailed empirically observed, and temporarily and spatially disaggregated fuel price data. Per capita fuel consumption volumes l_{ft} (i) are calculated by dividing the per capita expenditures x_{pc} on fuel f by the average retail liter price p_{fst} recorded for the month t , in which the household was surveyed [54,55], and state s , in which the household lives, and scaled up to annual consumption:

$$l_{ft} = X_{pcfst} / p_{fst} \quad (4)$$

There are no reliable estimates of government subsidy spending in Nigeria. Therefore, we calculate (ii) the subsidy that is officially spent per liter of fuel, in accordance with the approach of the Nigerian government, as the difference between the fixed price and the 'expected open market price' (EOMP), which is the so called 'landing cost' plus distribution margins, according to the Nigerian Petroleum Products Pricing Regulatory Agency (PPRA). For the months of the household survey, the official fixed prices of kerosene and petrol were NGN 83 and NGN

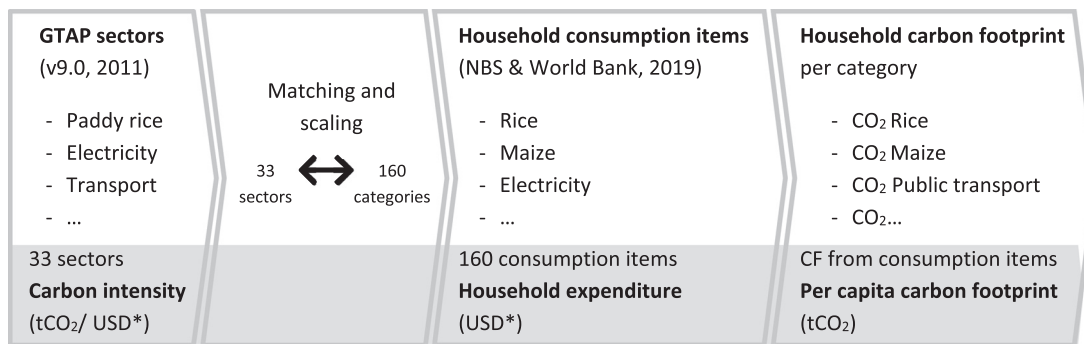


Figure 2. mapping household consumption items to input-output sectors; *2015 PPP USD from household survey (cf. [17])

87 per liter, respectively [11]. As the EOMP is not available for the survey months, but the monthly landing costs are available [56], we produce our own month- and fuel-specific EOMP and Nigeria-wide subsidy estimates per liter, sl_{ft} .

$$sl_{ft} = (\text{EOMP}_{ft} + \text{estimate of dispatch margin}) - \text{fixed price}_{ft} \quad (5)$$

We assume that, in the face of a subsidy removal, fuel prices for households would rise additionally by sl .

With this approach, we arrive at more realistic estimates of fuel consumption than have traditionally been deployed in the literature, and we account for the large (price) heterogeneities between states [73] as well as for fluctuations of spot market prices over time: to estimate subsidy spending based on household fuel expenditures (as liter units are often not reported in the household surveys), previous studies have assumed that actual retail prices of kerosene and petrol match the officially fixed, subsidized price [81] or are twice as high [73], and that liter units are subsidized by an equal amount throughout Nigeria. However, the average retail prices reported by the NBS for the months of the GHS 2015/2016 household survey are around 30 percent higher for petrol, and around 340 percent higher for kerosene, than the officially fixed prices, with large variations across states and months [54,55]. Because subsidies are not delivered directly but via a complex system of price controls, illegal re-selling, fuel smuggling and other fraud tends to lead to higher actual end-consumer prices [26].

3.5. Compensation schemes: lump-sum and infrastructure provision costs

We estimate the distributional outcome of a carbon pricing reform when the government revenues (and foregone spending on subsidies) are recycled either as uniform per capita lump-sum transfers or as investments in public infrastructure provision. We do not account for potentially inefficient revenue collection and redistribution, e.g., due to inefficient public financial and tax administration, as estimates of such margins are deemed rather arbitrary [6]. Thus, we estimate upper bounds, both for tax payments and revenue spending (refer to section 5 for a brief discussion).

The average per capita infrastructure investment potential – or compensation ‘gain’ – of each income group depends on the pre-reform infrastructure access gaps as well as on the provision costs per unit. Based on qualitative survey questions, having access to infrastructure services is defined such that ‘improved’ water and sanitation facilities (specified by the World Bank [92]), on- or off-grid electricity, or a landline or mobile phone exist in a household. We assume that investments are spread equally across households which report not having access initially. That is, we calculate infrastructure investment gains as transfers to all households lacking initial access. For this reason, carbon pricing revenues can be regarded as being distributed in relation to access gaps for the type of infrastructure considered. In our approach, we consider per capita provision cost estimates from Jakob et al. [37] to ensure that no income

group receives an average per capita payoff that exceeds the costs of providing universal access.

4. Results

The consumption incidence is represented separately for the three price reforms, i) a carbon tax, ii) the fossil fuel subsidies reform and iii) both price reforms together, including descriptive statistics on consumption patterns and decomposed consumption carbon footprints. We consider vertical and horizontal distribution across and within rural and urban income quintiles. We then extend the analysis to include various revenue recycling schemes, namely lump-sum compensation and the provision of basic infrastructures.

4.1. Consumption patterns, carbon footprints and carbon pricing incidence

The effects of a carbon tax on consumption depend on the carbon intensity of consumption items as well as on their relative importance within a household’s consumption basket, i.e., on their carbon footprint. For a more detailed representation, direct and indirect energy consumption are further broken down into five product categories: fossil fuels and electricity (direct), public transport, other goods and services, and food (indirect). Household consumption patterns show that, with rising income, consumption shares of food decrease while those of carbon-intensive electricity, fuels, and public transport increase (cf. Fig. 3 left). Furthermore, at similar income levels, rural households spend less than urban households on those more carbon-intensive categories. This reflects that rural households have less access to public infrastructure and meet larger shares of their energy demand with traditional biomass. More than 70 percent (less than 30 percent) of the rural (urban) population rely on collected firewood (own calculation based on [57]). Average per capita carbon footprints range from 0.06 tCO₂ (R1) to 1.3 tCO₂ (U5), averaging at 0.38 tCO₂ throughout the Nigerian population (Fig. 3 right).⁶ This is still relatively low in global comparison (c.f. [13]). Indirect footprints from food, goods and (non-transport) service consumption make up 40 percent of the footprint among urban, and 60 percent of the footprint among rural households.

The carbon intensity of consumption increases with income. Hence, a carbon tax would be progressive in Nigeria, affecting the consumption spending of poorer households relatively less (Fig. 4 left). Median payments for a USD 30 carbon tax, as percentage of household expenditure, rise from 0.8 percent (R1) to 1.5 percent (U5) across all income groups. Additional expenditures due to a fossil fuel subsidy reform are also progressive, strictly rising with income, with the exception of kerosene in urban areas. In urban areas, the kerosene subsidy reform would be neutral or partially regressive, affecting the second income quintile the

⁶ Note that we account for consumption-based emissions only. This excludes, for example, emissions from military activities, government consumption or commodities that are not used as inputs to consumer goods or services.

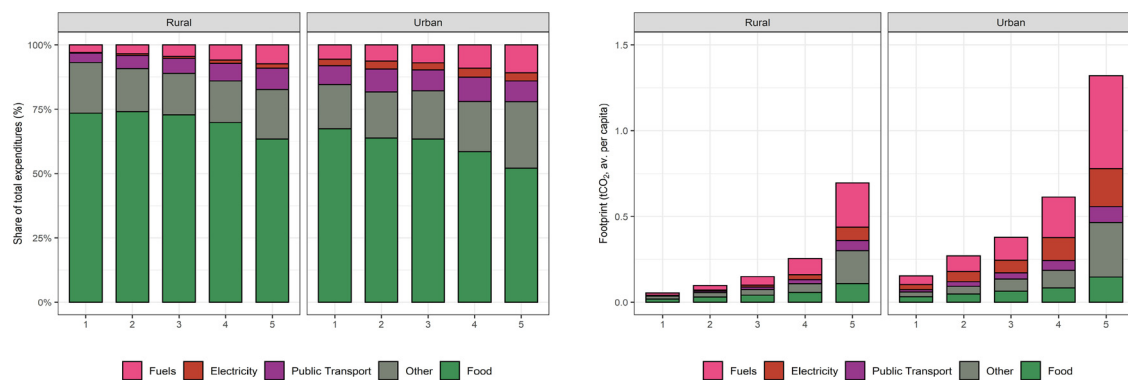


Figure 3. average expenditure shares by product category for rural and urban income quintiles in Nigeria in 2015/16 (left), and average per capita carbon footprints (right); note: boxes represent the 25th to 75th percentile, whiskers the 5th and 95th percentile.

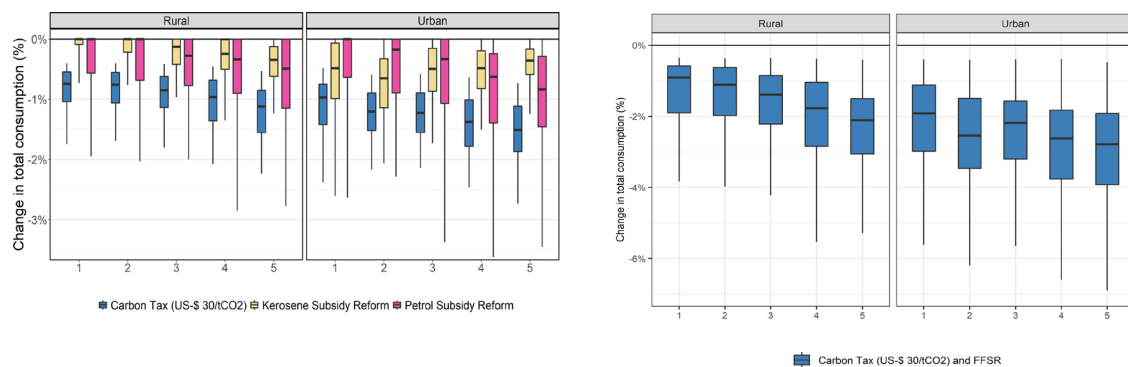


Figure 4. distribution of consumption incidence of fossil fuel subsidy reforms (kerosene and petrol) and a carbon tax of PPP USD 30/tCO₂ (left), and of a comprehensive carbon tax and subsidy reform (right); note: boxes represent the 25th to 75th percentile, whiskers the 5th and 95th percentile.

most. For petrol, and in rural areas also for kerosene, we find that many households would not be affected at all by a subsidy reform, as they do not consume these fuels. Thus, we confirm previous findings that the current subsidy regime increases inequality (cf. [73]). Carbon taxation and subsidy reform together would be almost strictly progressive (Fig. 4 right). Quintile medians of additional expenditures range between 0.9 percent (R1) and 2.7 percent (U5). Clearly, in relative terms, the reforms analyzed would impact the lowest rural and urban quintiles least and affect rural households overall less than (the overall richer) urban households.

The horizontal distribution within income groups reveals quite considerable heterogeneity between households of the same income group. Overall, the horizontal spread of the consumption changes, that is the variation within income groups, is greater than the variation between income groups (vertical distribution). With regard to vertical equity, the highest and lowest quintile medians differ by 1.9 percentage points (U5 median – R1 median), while for the horizontal spread within the groups, the median difference between the 5th and 95th percentiles of quintiles is 4.6 percentage points. In the short run, a quarter of the poorest rural and urban quintile could experience expenditure increases of up to 2 percent (R1) and 3 percent (U1) of their disposable income under the combined carbon tax.

The stark variation of consumption effects within income groups exemplifies that, despite the overall progressivity, compensation schemes need to be well-designed to support the most affected parts of the population irrespective of household income. Carbon tax incidence on consumption is strongly driven by fuel consumption patterns which, in turn, may be a product of socioeconomic circumstances. Infrastructural access to electricity, to public or shared transport, or market access to kerosene or liquefied petroleum gas are strong determinants of the level and composition of fuel consumption (cf. [42]). In the following, we discuss the

distributional effects of using tax revenues for increased public infrastructure spending.

4.2. Compensation through basic infrastructure provision and uniform lump-sum transfers

For the distributional analysis, we contrast changes in consumption from a carbon pricing reform between five revenue recycling scenarios: one with uniform lump-sum per capita transfers and four scenarios estimating monetary benefits conditional on initial access to basic infrastructure. We measure infrastructure benefits narrowly in monetary terms, based on per capita spending toward provision costs, disregarding the potentially large welfare gains from improved health, time savings, economic benefits, or environmental improvements (e.g., [29,80]). The sizes of per capita transfers per recycling scenario, listed in Fig. 5, depend on the share of the population receiving transfers. Thus, infrastructure with high initial access levels, such as telecommunication (cf. Fig. 1), is associated with higher per capita cash transfers as revenues are distributed to a smaller share of the population.

All policy bundles show progressive effects across income groups, with rural households more likely to experience positive income changes from infrastructure investments due to their comparatively lower income and lower initial infrastructure access rates (cf. Fig. 5). Within quintiles, particularly revenue recycling into infrastructure development shows heterogeneous income effects as relatively larger transfer amounts are paid to only the share of the population without prior access. In absolute terms, the universal lump-sum transfer would leave the bottom four rural and the bottom first urban quintiles, at median, between 7 percent (R1) and 1 percent (R4) better off. In relative terms, especially in rural areas, electricity provision proofs to be much more progressive than uniform lump-sum transfers. At medians, households

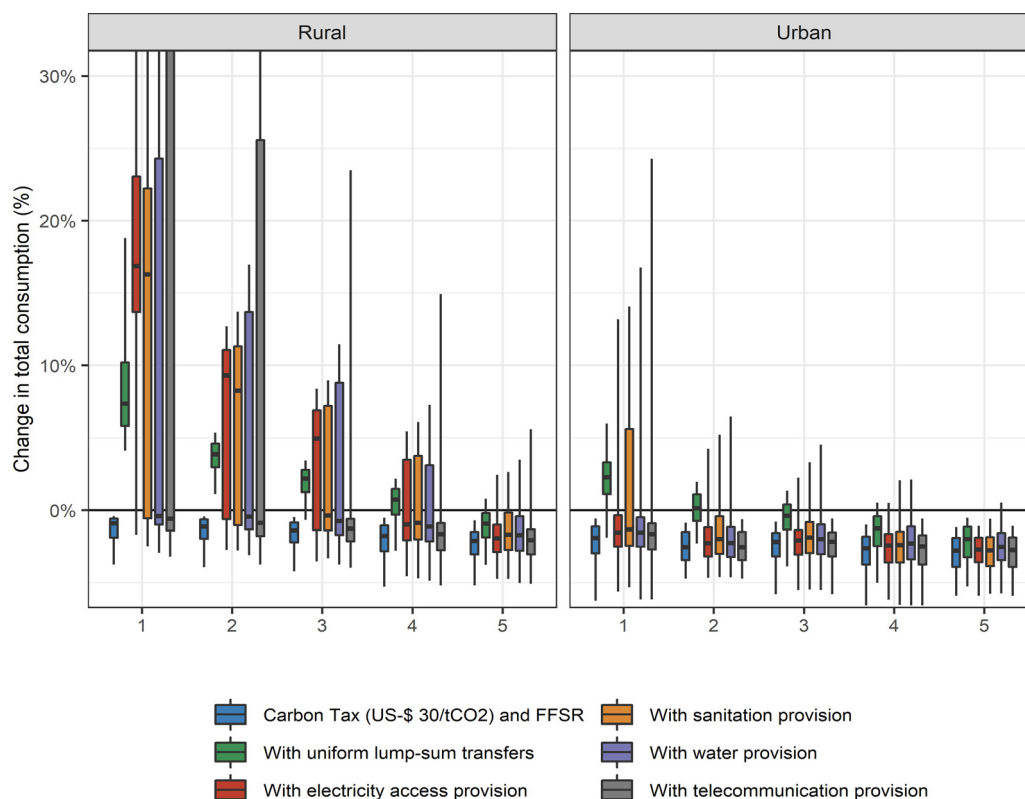


Figure 5. distribution of consumption changes from six policy packages for a comprehensive carbon tax and subsidy reform: (i) without compensation, (ii) with uniform lump-sum transfers (USD 17), (iii) with investment transfers for electricity access (USD 39), (iv) improved water access (USD 52), (v) sanitation access (USD 42) and (vi) telecommunication access (USD 109); note: infrastructure gains are approximated as lump-sum transfers based on lack of initial access.

in the lowest to third rural quintiles would gain between 17 percent (R1) and 5 percent (R3). In urban areas, lump-sum transfers and sanitation provision are more progressive. However, the spread of policy outcomes is much smaller, both vertically and horizontally. In absolute terms, the median household in the lowest urban quintile would be 0.7 percentage points better off with transfers toward sanitation access than without transfers, while the highest urban quintile would experience no median benefit. As penetration rates of water and telecommunication access are already high (>50 percent) across all income quintiles, at medians, the associated benefits would not be sufficiently large to compensate for the consumption incidence. Alternatively, if revenues were not spread across the whole income distribution, but focused on the poor, one third of the revenues would, for example, suffice to fully reimburse the population living below the poverty line for their real income losses due to rising consumer prices.

5. Conclusion

This study examines how a revenue-neutral carbon pricing reform with public investment in basic infrastructure can further inclusive sustainable development in Nigeria. We find that such a green fiscal reform would entail double progressivity: on the one hand, relative to their disposable income, low-income households would experience smaller consumption effects from the higher consumer prices than richer ones. In absolute terms, the median consumption incidence would be small across all income groups. On the other hand, revenue recycling toward basic infrastructure access to water, sanitation, electricity, and telecommunication favors low-income and – overall poorer – rural households. In absolute terms, uniform infrastructure transfers could more than compensate these segments of the population.

Our approach constitutes a pragmatic research strategy that renders the analysis tractable and allows us to focus on the key mechanisms of

how carbon pricing revenues could translate into infrastructure access across the income distribution. Yet, our results need to be interpreted in light of a number of methodological limitations.

First, the consumption effect refers to a first-order, short-term estimates of fiscal impact. From a political economy perspective, these estimates are arguably decisive for the immediate public reaction to reform. However, they yield upper bounds as we disregard household income effects, induced energy efficiency, substitution, as well as changes in factor prices and in returns to labour and capital (cf. [5,16]).⁷ While this is an obvious shortcoming, our approach has the merit of yielding a straightforward measure of welfare changes in terms of compensated variation, and to be less sensitive to model assumptions than more theory-based general-equilibrium approaches. For distributional analyses, the latter require detailed specifications of demand elasticities, differentiated by income groups and by consumer goods and fuels. In the context of Nigeria, such estimations are hampered by the lack or poor quality of necessary information [6,8,25]. Including equilibrium and income effects would likely yield an overall smaller, possibly positive, and more progressive incidence [50,64].

Second, not including demand responses, we are unable to assess whether carbon pricing could induce shifts to traditional biomass, which could hamper the transition to clean energy and yield adverse health outcomes. However, the empirical literature does not find a systematic relationship between biomass use and fossil fuel prices or income. Rather, locational, social and structural factors tend to be decisive, as well as the estimation methods used [38,46,52,68,77]. For urban Senegal, Rose et al. [72] show that a subsidy removal for liquified petroleum

⁷ Tax payments might be further overestimated if the carbon intensities and consumption patterns observed in 2015/2016 are distorted by the existing fossil fuel subsidy regime.

gas was associated with an increased demand for biomass cooking fuels. In Tanzania and Uganda, the cross-price elasticity between biomass and kerosene is found to be small or insignificant while rising electricity prices can increase both biomass and kerosene consumption [2,65]. In Nigeria, firewood is used for cooking across the income distribution, by about 80 percent of households in the poorest rural and 30 percent in the richest urban quintile. In cases where fuel switching to untaxed biomass might occur, the associated adverse health impacts from indoor air pollution and, potentially, from changes in food baskets and nutrition intake may not be distributed equally, but concentrate on low incomes and women [2,70].

Third, the estimated benefits of infrastructure access transfers abstract in a number of ways. Public funds may be misallocated or not productively invested within a given time period due to limited absorptive and administrative capacity [15,39,72]. The extent of pro-poor redistribution would depend on the equitable spread of investments throughout Nigeria and may be curtailed by Nigeria's low efficiency of public expenditures or if investments are targeted to politically well-connected constituencies [4,33,86]. Furthermore, access gains cannot compensate the immediate consumption shock as they do not directly translate into monetary gains and the, albeit larger, indirect welfare benefits would accrue with considerable time lags. Thus, while cash transfers cannot substitute for more structural reforms towards achieving the SDGs, some immediate redistribution may be necessary to alleviate the initial consumption effect and reduce public resistance – as widely discussed in the carbon pricing literature (cf. [9,22,27,41,49]). Targeted transfers could be paid in advance of the fiscal reform to increase their visibility, administered in a similar way as Nigeria's successful farmers' e-wallet system for fertilizer subsidy (cf. [91]).

From our analysis two conclusions emerge. First, the often up-held argument of carbon pricing reforms entailing adverse effects on poverty and income inequality does not, per se, hold in Nigeria. Our analysis shows that reform outcomes, in terms of consumption effects, show large variation within and between income groups. Second, with the collected revenues, the government could largely compensate households below the poverty line and make meaningful progress in closing Nigeria's major infrastructure access gaps, hence contributing to achieving the Agenda 2030. More research is needed to understand what drives the large variation of consumption effects among households of similar income levels (horizontal distribution), as well as to quantify the distribution of (likely positive) employment and income changes due to both carbon pricing and infrastructure investments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.wds.2022.100011.

Appendix

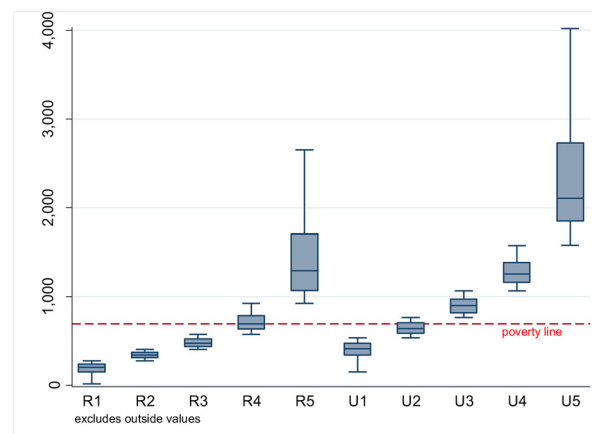


Fig. A1: annual per capita consumption as proxy for life time income (PPP USD) and poverty line (USD 1.9/day), by rural (R1-5) and urban (U1-5) household quintiles in 2015/16 (Source: own calculation based on [57]).

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