

The impacts of carbon taxes and cash transfers on poverty and inequality across years: A Peruvian case study

D. Malerba¹ **F. Roscioli**² A. Gaentzsch³ H. Ward^{4,5}

¹German Institute of Development and Sustainability (IDOS)

²University of Rome Tor Vergata

³Free University of Berlin (FUB)

⁴Leiden University - CML, Department Industrial Ecology

⁵Mercator Research Institute on Global Commons and Climate Change (MCC)

23/02/2023

Stylized facts

- **Carbon pricing mechanisms** are usually indicated as efficient instruments to achieve more ambitious climate goals (High-Level Commission on Carbon Prices, 2017).
- **Compensation mechanisms may be crucial** to ensure that none is left behind and climate mitigation is socially acceptable. However, the right choice of a compensation scheme depends on the corresponding distribution of carbon footprints and the consequent tax impacts.
- In high-income countries, such as the United States, the distributional patterns of carbon taxes have been found to be **regressive** (Goulder, Hafstead, Kim, & Long, 2019). In contrast, in low- and middle-income countries, a **progressive/neutral** outcome has been identified (Dorband, Jakob, Kalkuhl, & Steckel, 2019).
- **Evidence for dynamic carbon footprint inequality estimates in low- and middle-income countries comes exclusively from China.** Mi et al. (2020) found that average household carbon footprints increased between 2007 and 2012, while carbon inequality declined.

Novelty

- We study **the role of factors that change over time, such as inflation, production patterns or targeting mechanisms** in the right design of a carbon tax on consumption and its impacts on poverty and inequality.
- We show that, in a context of rapid economic growth (6.5% per year on average between 2004 and 2011), footprints increase over time, particularly for lower deciles and **the distributional impacts of an environmental reform change by year**, driven by inflation, production and consumption patterns, as well as the distribution of income.

Malerba, D., Gaentzsch, A., & Ward, H. (2021). **Mitigating poverty: The patterns of multiple carbon tax and recycling regimes for Peru.** *Energy Policy*, 149, 111961.

- In 2015, a national carbon tax, without compensation, would increase poverty, but would have no significant impact on inequality. However, when tax revenues are recycled through transfer schemes, poverty would actually decrease.

Data Sources

Different sources of data are considered:

- *Environmentally extended input-output tables*
 - Source: Global Trade Analysis Project 9 database (GTAP 9)
 - Coverage: 2004, 2007, 2011
 - Observations: 57 categories and 140 regions
- *Household Budget Survey*
 - National Household Survey ENAHO (Encuesta Nacional de Hogares)
 - Coverage: 2004, 2007, 2011
 - Observations: 19462 for 2004, 22197 in 2007, and 24802 in 2011 and 324 items.
- *CPI indices* from the World Bank (2021) to inflate prices to 2011 levels.

Consumption-based CO₂ emission

- Using the national Input-Output Tables from GTAP9, we calculate a coefficient of emissions per dollar of final consumption in each industrial sector (Leontief, 1970; Andrew and Peters, 2013; Miller and Blair, 2009). [▶ MRIO Analysis](#)
- We manually classified the ENAHO consumption voices into the 57 sectors of GTAP9.
- By multiplying the coefficient of emission per industrial sector by the sector's final consumption, we can derive **the carbon footprint of Peruvian household arising from domestic production only** (CF_h) (Steen-Olsen et al., 2016).
- We finally aggregated the GTAP sectors into five broad sectors:
 - Food
 - Heating and electricity
 - Fuel for private transportation
 - Other transportation expenditures (public plus expenditures for vehicle repair and purchase)
 - Other items.

Assumptions

- All increases in commodity prices are handed over to the consumer.
- Economic activity and consumption from self-production, such as subsistence agriculture, are not affected by the carbon tax because it is not traded on the market.
- Production technology is homogeneous within each sector.
- Consumption better captures deprivation than income.

Descriptives

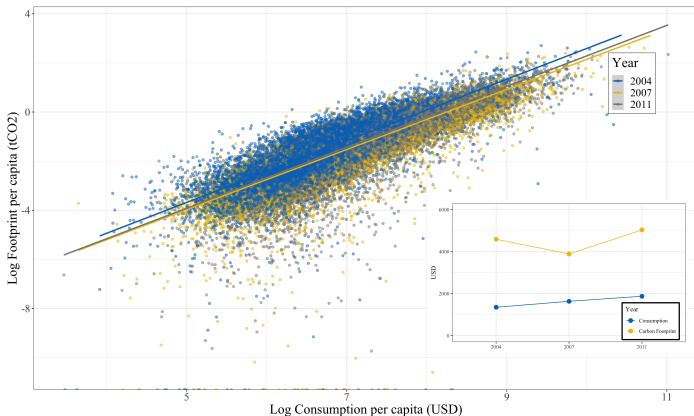


Figure: General relationship between consumption and footprint per capita, by year.

Strong positive relationship between the two for all years, as identified in the literature.

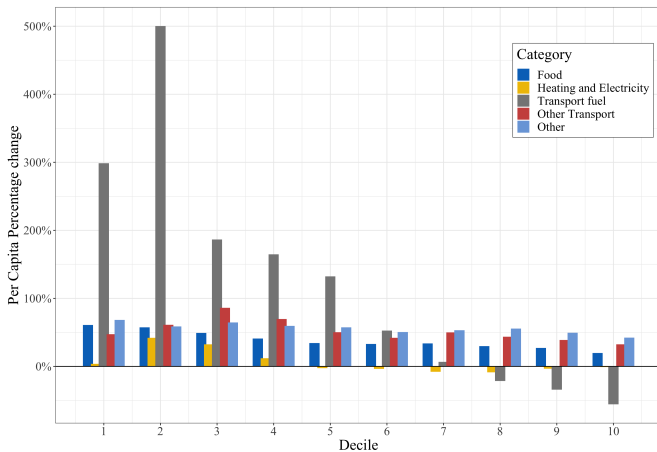


Figure: Changes in footprint by decile and sector (2004-11).

Carbon footprint inequality decreased, thus, reflecting the findings from Mi et al. (2020) in China.

Carbon tax

- To estimate the amount of carbon tax to be paid by each household (t_h), we multiply the carbon footprint (CF_h) by the tax rate (t_r).

$$t_h = CF_h * t_r$$

- We apply a carbon tax with three different rates (t_r):
 - 50.00 USD/tCO₂ as the baseline scenario.
 - 80.00 USD/tCO₂ (Carattini, Kallbekken, & Orlov, 2019; Stiglitz et al., 2017).
 - 30.00 USD/tCO₂ (Vogt-Schilb et al., 2019).
- This tax liability (t_h) is then subtracted from the total consumption of the household.

Revenue recycling

- To simulate different revenue recycling scenarios, we focus our analysis on Peru's largest social cash transfer program: *Programa Nacional de Apoyo Directo a los más Pobres – Juntos* (Borga & D'Ambrosio, 2021). [▶▶ Juntos](#)
- The revenue recycling scenarios are the following:
 - **Juntos 2011** - USD 387,00 transfer per household, at 2011 prices, to Juntos eligible (no district targeting).
 - **Juntos Nominal** - USD 387,00 transfer per household, in nominal value, to Juntos eligible (no district targeting).
 - **UBI 100** - Equal redistribution per capita of USD 100,00.
 - **UBI sum zero** - Equal redistribution per capita of total tax revenues.

Implications of a pure carbon tax

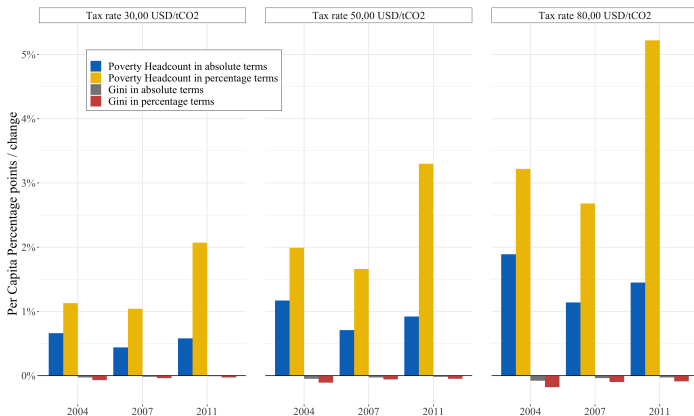


Figure: Effect of tax without redistribution on poverty and inequality.

A carbon tax of US50/tCO₂ would increase poverty in all years analyzed. In all years, the Gini coefficient decreases with largest effects in 2004.

Implications of the environmental fiscal reform with 50 USD/tCO₂ tax rate

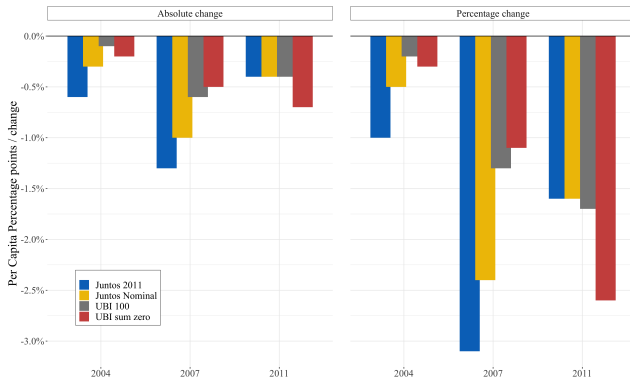


Figure: Effect of environmental fiscal reform on poverty.

For UBI sum zero, the effect on poverty reduction improves over time. In 2011, the poverty rates are the lowest, so higher prices increase poverty less in absolute terms, but more in proportional terms. In 2004, the reduction in poverty was twice as large when considering inflation.

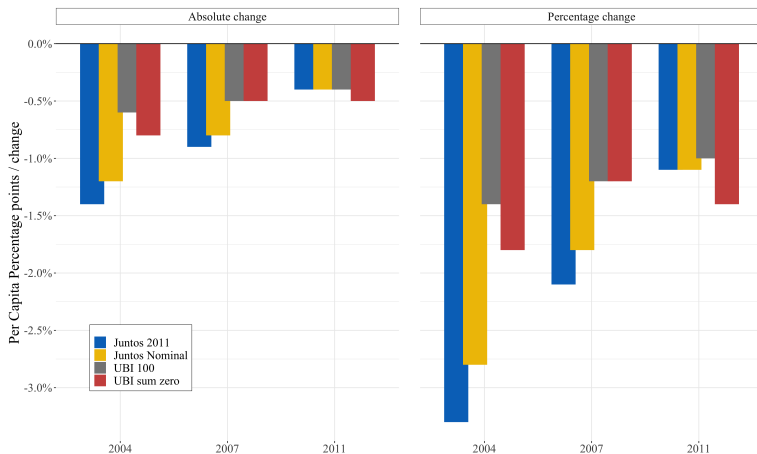


Figure: Effect of the environmental fiscal reform on inequality based on the Gini coefficient.

Considering inequality, the effects of an environmental fiscal reform are even more similar between proportional and absolute changes.

Summary

These results are driven by different mechanisms:

- **Consumption and production patterns, and the consequent overall revenues raised by the carbon tax.** When we consider scenarios where the transfers schemes depend on the revenues from the carbon tax (UBI sum zero), the effect on poverty reduction improves over time.
- **The distribution of income/consumption.** In 2011, the poverty rates are the lowest and the mean of the distribution is higher; therefore, higher prices increase poverty less in absolute terms, but more in proportional terms.
- **Inflation erodes part of the real value of transfers.** In 2004, the reduction in poverty was twice as large when inflation was considered, both proportionally or in absolute terms.

Conclusions

- **The carbon footprints of Peruvian households increased** between 2004 and 2011. The increase was proportionally higher for lower income deciles, underlying the carbon intensity of poverty reduction. In terms of sectors, **the increase was mainly driven by the consumption of transport fuel**, especially for the second decile.
- **A simple carbon tax would increase poverty.** And proportionally more in 2011, almost twice as much as in 2004 and 2007, reaching 5% in 2011 with a tax of 80 USD. But the lower three deciles would witness the lowest incidence in all years.
- **An environmental fiscal reform would increase consumption of the bottom five deciles.** Most importantly, the final effect is significantly dependent on the design, the scenario and, most importantly, the year under examination.

Policy implications

- **Higher tax rates lead to higher revenues to be directed towards compensation**, possibly through a minimum share of revenues.
- **Transfers should not decrease in real terms even if the tax level does.** To adapt recycling schemes, one quick fix is to anchor the transfer amount to inflation; as we have shown, small changes in the design can imply 200,000 more people in poverty.
- **Changes in energy production could have significant effects on the absolute and distributional effects of a carbon tax.** In addition, surplus funds from an early carbon tax could be used to switch to low-carbon-intensive energy technologies or support energy efficiency, reducing the burden at later stages.

Limitations

- We perform an incidence analysis without evaluating general equilibrium effects, such as behavioral responses, changes in consumption patterns, labor supply, health effects, or firm adjustments.
- We acknowledge the need for a global carbon tax. However, given the high barriers to reaching such an agreement, we focus on a national tax, even if this could entail a loss in international competitiveness.
- There is a debate as to whether the consumption data from ENAHO should be scaled according to the IO data. We scaled them as robustness check; however, we presented here the unscaled version because our entire paper is based on poverty estimation and this was retrieved from the ENAHO survey data by the Peruvian government.
- We did not categorize the consumption voices of ENAHO into GTAP 9 categories using a correspondence table based on their coding standards due to the lack of indication from the Peruvian Statistical Office.

Thank you.

EE-MRIO Analysis

IO modeling, including EE-MRIO, is grounded in the work of Wassily Leontief (Leontief, 1970), who formalized calculating the output of an economy as the sum of intermediate (industry-to-industry transactions) and final demand.

$$x = Ax + y$$

where x is the total output, A is the matrix of technical coefficients of the economy, and y is the final consumption demand. Using matrix equations, this is written as:

$$x = (I - A)^{-1}y$$

where I is an identity matrix and $L = (I - A)^{-1}$ is the Leontief inverse matrix, which captures all direct and indirect inputs used to create one unit of the final demand output.

This is extended to environmental applications by treating them as input to production. In fact, the GHG reporting allows for the estimation of t CO₂e directly emitted by each industry. These direct emissions, f , are divided by the output per industry (x) to obtain e , the vector of t/CO₂e per unit of output of each sector (Andrew and Peters, 2013; Miller and Blair, 2009).

$$e = fx^{-1}$$

[back](#)

Juntos

- Juntos started in **2005** in prioritized geographic regions and provinces, and was gradually expanded (although it is still not available nationwide). Juntos is also targeted at the household level for chronic poor and vulnerable households with children.
- Peru adopts a unified targeting approach for social assistance, **SISFOH**, which gives each household a score that is then used to classify the households as extreme poor, poor, and non-poor based on a multidimensional proxy-means test (Berner & Van Hemelryck, 2021); To qualify, households must consist of children aged 14 years (or younger) or a pregnant woman.
- Since the government does not disclose the exact targeting algorithm, we replicate it based on Linares García (2009) and Silva Huerta and Stampini (2018).

	2004	2007	2011
poverty headcount	58,7%	42.4%	27.8%
<i>Households eligible by:</i>			
Individual targeting	44.8%	39%	33.1%
Individual and geographical targeting	5.2%	10.2%	8.6%
Juntos recipient	0%	6.01%	8.48%

[back](#)

Revenues

- Calculating how much of the total revenues would have to be recycled to compensate the lowest four deciles. We find the following.
 - 7.8% in 2004
 - 11.1% in 2007
 - 11.4% in 2011
- Only a small share of revenues would be needed in the case of perfect targeting, leaving a large share to be used also for other purposes.
- The budget of Juntos is quite small, around 0.15% of GDP in 2009 (Jaramillo, 2014). A carbon tax of USD 50 would raise revenues equal to around 1.5% of the GDP.
- With the USD50/tCO₂ tax, which is our central tax level, almost all scenarios would use around 100% of the revenues. With the USD30/t CO₂ tax, the share would increase to 200%.

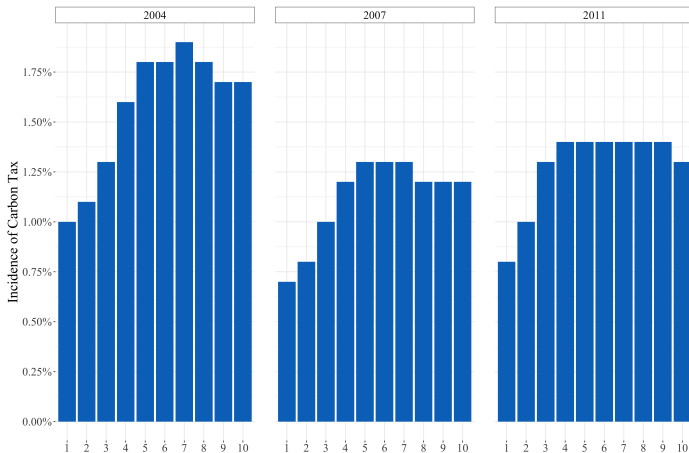


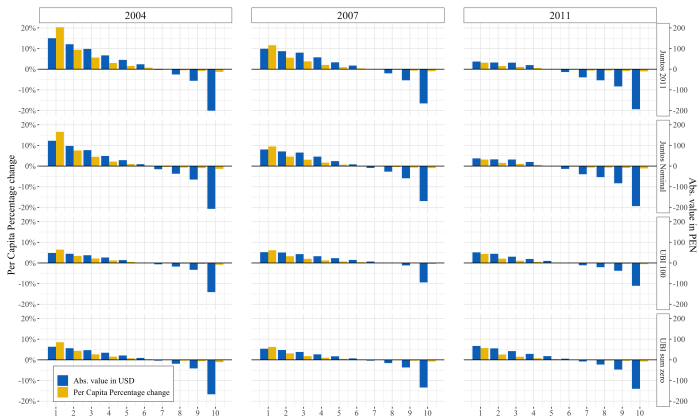
Figure: Incidence of a tax of 50 USD per t/CO₂ by consumption decile.

In summary, there is a significant difference in the absolute impacts between years, with 2004 showing a higher incidence.

Descriptive statistics

	2004	2007	2011
<i>Population (mln)</i>	27.89	28.6	29.48
<i>GDP per capita (USD)</i>	2393.67	3572.36	5826.83
<i>Poverty Headcount</i>	58,7%	42.4%	27.8%
<i>Inequality (Gini)</i>	0.436	0.429	0.381

[back](#)



In absolute terms the richest deciles lose more compared to what the lowest decile gain, especially in the first three scenarios, where not all the revenues are used. A 1% change in poverty means a change of 120,000 people in 2007, 81,000 in 2011 and 162,000 in 2004. While a change in 1 p.p. in poverty represents around 283,000 people in 2007, 276,000 in 2011, and 293,000 in 2004.

back

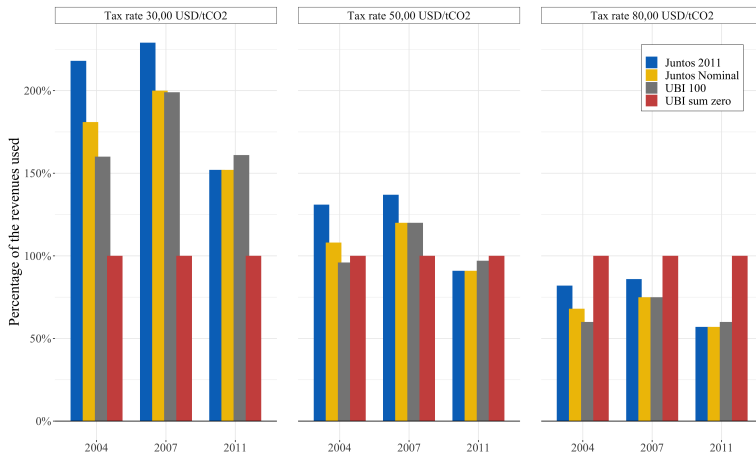


Figure: Share of revenues used, by tax level and recycling scheme.

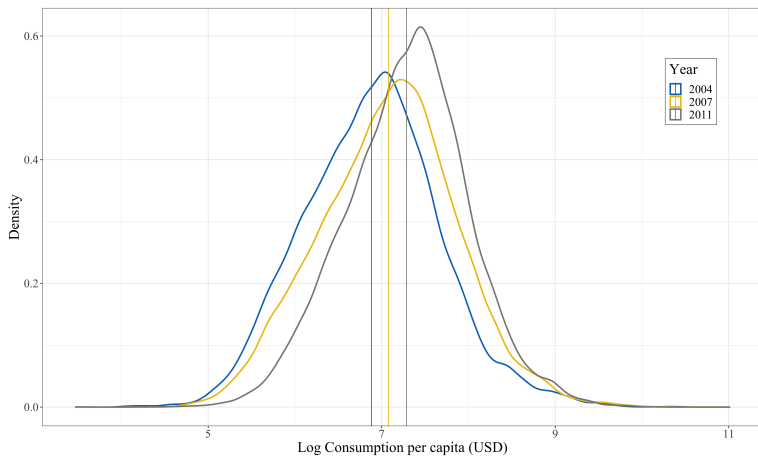


Figure: Distribution of consumption by year.

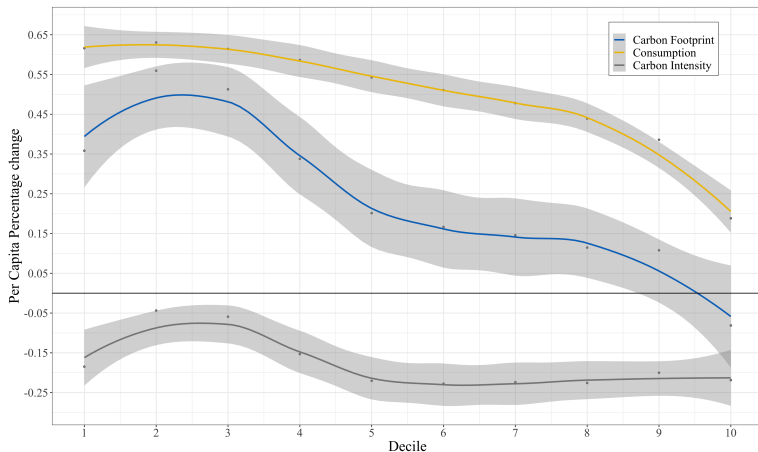


Figure: Anonymous growth incidence curve for the period 2004-2011.

Inequality in carbon footprints has decreased between 2004 and 2011.

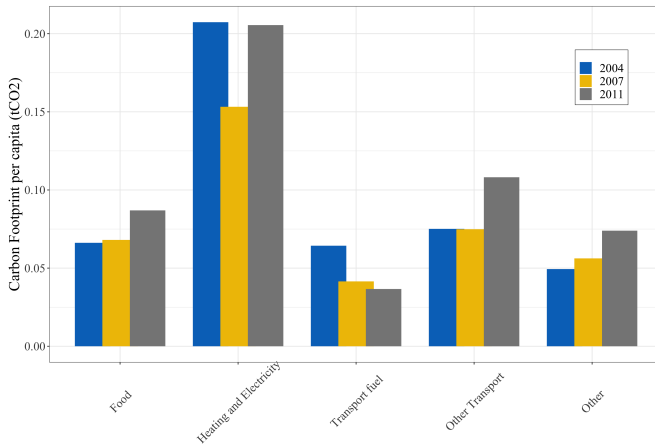


Figure: Footprint per capita by sector and year.

The overall effect is mainly caused by trends in urban areas, where carbon footprints are higher on average and where most of the population resides.