Energy Policy 149 (2021) 111961

Contents lists available at ScienceDirect

Energy Policy

journal homepage: http://www.elsevier.com/locate/enpol

Mitigating poverty: The patterns of multiple carbon tax and recycling regimes for Peru

Daniele Malerba[a,b,*], Anja Gaentzsch[c], Hauke Ward[d,e,f]

[a] German Development Institute, Deutsches Institut für Entwicklungspolitik (DIE), Bonn, Germany
[b] Global Development Institute, The University of Manchester, UK
[c] SOCIUM, University of Bremen, Germany
[d] Institute of Environmental Sciences (CML), Department of Industrial Ecology, Leiden University, the Netherlands
[e] The Mercator Research Institute on Global Commons and Climate Change (MCC), Germany
[f] Potsdam Institute for Climate Impact Research, Germany

ARTICLE INFO

JEL classification:
H23
I38
F64
C67
O54
Q52
Q54

Keywords:
Carbon tax
Input-output analysis
Income distribution
Poverty
Cash transfer

ABSTRACT

Carbon taxes are an economically effective and efficient policy measure to address climate change mitigation. However, they can have severe adverse distributional effects. Recycling parts of the fiscal revenues to vulnerable, lower income households through cash transfers (social assistance) is an option to also overcome associated political difficulties. This paper simulates the distributional impacts of such a combined policy reform in Peru. In a first step, we assess the distributional impacts of varying carbon tax rates. In a second step, we evaluate different scenarios of recycling revenues through existing or expanded transfer schemes towards vulnerable households. The results indicate that a national carbon tax, without compensation, would increase poverty but have no significant impact on inequality. When tax revenues are recycled through transfer schemes, however, poverty would actually decrease. Depending on the amount to be redistributed and the design of the cash transfer scheme, our simulations show a proportional reduction in the poverty headcount of up to around 17%. In addition, the paper underlines how crucial it is to go beyond aggregate measures of poverty to better identify losers from such reform; and assure that the "leave no one behind" principle of the Sustainable Development Goals (SDGs) is addressed.

1. Introduction

Literature has highlighted that a mix of policies may be needed as trade-offs, next to synergies, usually arise when trying to jointly achieve different Sustainable Development Goals (SDGs) (Pradhan et al., 2017). For example, eradicating poverty by fostering economic growth (Dollar et al., 2016) can harm the environment and contribute to emitting more greenhouse gases (Malerba, 2020). Similarly, mitigating climate change can especially hurt the poor in the short-term. This is particularly relevant for carbon pricing mechanisms, such as carbon taxes and emissions trading systems (ETS) (Cramton et al., 2017). As lower income deciles may spend proportionally more on carbon intensive goods and have less capabilities to adjust their consumption to price increases arising from such policies, their burden might therefore be significantly higher compared to other income groups. According to the World Bank (2020), many governments are planning to use carbon pricing mechanisms in the near future to achieve climate targets. These mechanisms are usually advocated due to their high efficiency, even if it is clear that other (non-price) policy instruments are necessary to fully address climate change mitigation (Stiglitz, 2019). Given the recent difficulty in implementing carbon pricing in many countries (Carattini et al., 2019; Vogt-Schilb et al., 2019), compensating low-income households is crucial (instrumentally) for the acceptability of such policies (Maestre-Andrés et al., 2019). It is also intrinsically necessary, for the achievement of social goals which are prioritized in low- and middle-income countries (LMICs). This paper explores how climate change mitigation and poverty reduction can jointly be met, in the case of Peru, by combining a carbon tax with cash transfer schemes.

This paper addresses two research gaps. First, more work is needed to fully understand distributional impacts of carbon pricing policies in LMICs, as simulation studies point to ambiguous conclusions (Renner, 2018; Saelim, 2019). While initial findings indicate regressivity, no such

---

* Corresponding author. German Development Institute, Deutsches Institut für Entwicklungspolitik (DIE), Tulpenfeld 6, 53113, Bonn, Germany.
E-mail address: daniele.malerba@yahoo.it (D. Malerba).

https://doi.org/10.1016/j.enpol.2020.111961
Received 13 April 2020; Received in revised form 27 September 2020; Accepted 8 October 2020

general pattern can be identified, also given the relevance of country-specific factors (Dorband et al., 2019). Nonetheless, even in cases where carbon pricing has progressive effects that reduce inequality, poorer households need to be compensated for short-term welfare losses due to higher prices (Jakob and Edenhofer, 2015; Klenert et al., 2018). Recycling revenues from the carbon pricing mechanisms through transfer schemes, such as cash transfers, is a relevant option for LMICs (Vogt-Schilb et al., 2019). Given significant differences in societal structures, poverty incidence and transfer programs across LMICs, it is vital to understand the individual country context and identify which combinations of compensatory cash transfers and carbon tax levels work best. This is the second research gap, which has to consider the following factors. Due to limited institutional capacities, at least in the short term, such compensation schemes would have to rely on the existing social policy infrastructure. In addition, most studies do not go beyond changes in aggregate poverty and inequality measures, although it is important to fully understand winners and losers from the policy reform (Renner, 2018).

Given this background, we address the following research questions in the context of Peru: (i) What would be the fiscal, poverty and distributive impacts of a carbon tax? (ii) How well is the current social protection architecture suited to offset unintended adverse consequences, if (part of) the revenues from the carbon tax are recycled towards existing programs? (iii) What alternative cash transfer schemes could do better in terms of compensation (poverty reduction) and use of tax revenues?

Peru represents a highly relevant case study for exploring the interaction between a carbon tax and transfer policies. Peru is one of the fastest growing countries in Latin America, with average growth rates of around 6% annually between 2003 and 2015. This development has improved the situation of lower income groups and contributed to a significant reduction in poverty. At the same time, this growth has come alongside environmental costs. CO_2 emissions have increased by around 65% between 2002 and 2013, even if the emission intensity of GDP did not change (ECLAC and OECD, 2016). In addition, the introduction of a carbon tax in Peru could further incentivize less carbon intensive development and help achieving national emission targets (Jakob, 2018).

We address the aforementioned research questions in a sequential two-step approach. We start by estimating the carbon footprint of households. To do this, we conduct a macro-based analysis, using an environmentally extended multi-regional input-output dataset (MRIO) generated from the GTAP 9 database (Aguiar et al., 2016) with the procedure described by Andrew and Peters (2013). We merge this with information on household consumption captured in the National Household Survey ENAHO (*Encuesta Nacional de Hogares*), which is an annual nationwide survey that covers all regions of the country. We link the highly detailed list (more than 324) of consumption items observed in the Peruvian household to the 57 sectors listed in the MRIO dataset, considering consumption items and supply chains at high detail. This way we can first estimate the households' carbon footprint, capturing both direct (fuel combustion) and indirect (carbon that has eventually been emitted for the production of consumed goods and services) impacts of consumption patterns. We then simulate the impacts of an economy-wide carbon tax of different levels on poverty and income inequality. While some tax-incidence studies also take emission from abroad into account, hence resulting in a global carbon tax approach (Carattini et al., 2019; Dorband et al., 2019; Ward et al., 2019), our approach considers national emissions, only (see Saelim (2019); Wang et al. (2019)). Finally, we simulate potential measures for offsetting real income losses experienced by low-income individuals through existing and alternative cash transfer programs. Our simulation provides an assessment of short-term impacts, before firms adjust supply chains and inputs and consumers change consumption patterns (see Vogt-Schilb et al. (2019); Schaffitzel et al. (2020)). Hence it does not take into account general equilibrium effects in response to price changes.

We find that a carbon tax would increase poverty, while keeping inequality substantially unchanged. Compared to the limited existing literature (Brenner et al., 2007; Yusuf and Resosudarmo, 2015; Renner, 2018; Dorband et al., 2019), it confirms that, in the case of Peru, the effect of a carbon tax is not regressive. Most importantly, the analysis shows that poverty can be decreased, compared to the pre-tax situation, by recycling even just part of the revenues through cash transfer programs. The analysis shows that existing programs work well, but reveal a high exclusion error. Alternative programs may, therefore, work better in assuring that the majority of the poor are not worse off. The paper also shows that focusing on aggregate changes in poverty hides poverty transitions and fiscal impoverishment of the poor. Therefore, it is crucial to go beyond aggregate measures of poverty to better understand the losers from the reform and assure that the "leave no one behind" principle of the SDGs is addressed.

The paper is structured as follows. Section 2 discusses in more detail the use of carbon taxes and compensatory mechanisms in the context of Peru. Section 3 presents the data and the descriptive statistics. Section 4 explains the methodology, while Section 5 presents the results of the analysis. Section 6 discusses the policy implications and conclusions.

2. Background

2.1. Carbon taxes and compensatory mechanisms

Carbon taxes (and carbon pricing in general) are an important instrument to address climate change mitigation (Cramton et al., 2017). The reason lies in their higher economic efficiency compared to command and control instruments, as well as their ability to generate revenues. In recent years, the number of carbon pricing mechanisms has increased globally, reaching 61 initiatives by 2020 (World Bank, 2020). This number consists of 31 emission trading systems (ETSs) in regional, national and subnational jurisdictions, and 30 carbon taxes, primarily applied at a national level. Despite this overall trend, their use has been mainly limited to high-income countries (HICs); in addition, the few LMICs that employ carbon pricing mechanisms do so at relatively low levels of pricing. On the positive side, many LMICs are considering their use in the near future (World Bank, 2020).

While existing research on the distributional impacts of climate policies in HICs finds that in general carbon taxes are regressive (Wang et al., 2016),[1] such unequivocal evidence is lacking for LMICs. Given their different structure compared to HICs, more research in LMICs is needed as these policies need to be aligned also with social objectives. Simulation studies from Mexico and Indonesia (Renner, 2018; Saelim, 2019) seem to dispute the prediction that carbon pricing would be regressive also in LMICs. Using standardized data of 87 LMICs, Dorband et al. (2019) further investigate this relation in a first cross-country analysis. Although they consider just four income categories, they find no general patterns and conclude that contextual factors, and energy expenditure patterns in particular, matter. In addition, their analysis is based on a lower detail of consumption items compared to the current article. More importantly, looking at the effects on inequality gives a very partial picture. In fact, for both progressive and regressive carbon taxes, absolute impacts on the lowest income groups can significantly affect their living conditions and push households into poverty, especially in LMICs. Hence, fully understanding the winners and losers from a carbon tax is critical for the "leave no one behind" agenda (OECD, 2018).

Compensating losers can be achieved by redistributing the revenues from carbon pricing towards low-income households. Carl and Fedor (2016) and Klenert et al. (2018) show that, in HICs, revenues are allocated to different actors and purposes such as firms, households,

---

[1] Although the results depend on the design of the carbon tax, including the sectors considered.

government budget and green spending. The different shares mainly depend on the political economy. Carl and Fedor (2016) also show that on average more than one third of revenues is recycled towards households in the form of transfers to compensate for higher energy prices. There are good reasons to consider a more significant role of compensatory transfers in LMICs compared to HICs. First, in many LMICs there is a large informal labour market in which, moreover, the poor are concentrated (Ricciuti et al., 2018). Therefore, lowering labour and income taxes – as often recommended in HICs – will likely not benefit the lower income deciles much. Second, cash transfers are also better targeted at poor households compared to subsidies (Vogt-Schilb and Hallegatte, 2017). Third, the social protection architecture has been expanding in many LMICs, making this an administratively feasible option. The number of social assistance programs, defined as *non-contributory transfers from the general tax base* (Barrientos, 2013) reached 284 in 2015 compared to 89 in 2000 (Barrientos, 2018). They cover nearly one billion individuals in LMICs, and represent the main welfare institution (Barrientos, 2013). The spread of transfer schemes and their comparative advantages compared to other fiscal instruments hence represent a significant opportunity to use them as main compensatory mechanisms with carbon pricing mechanisms.[2]

But current social assistance programs have also drawbacks that could hinder their compensatory role in the context of carbon pricing. For example many programs have high exclusion errors, which implies that a large share of the poor do not benefit from these programs (Devereux et al., 2017). If this is the case, alternative program designs are needed. Yemtsov and Moubarak (2018) have shown that in the context of fossil fuel reforms, the majority of compensation programs used were new. In fact, the existing infrastructure of these programs was deemed insufficient for addressing increased needs arising from economy-wide higher prices. As compensating low-income households is crucial for the implementation of needed climate mitigation policies, we assess the potential need for new cash transfer programs and contribute to the current literature in two ways. First, we go beyond aggregate poverty statistics and focus on the poorest. Second, we simulate alternative transfer schemes based on the current architecture and targeting approaches to understand how to best compensate poorer households for the increase in prices from a carbon tax. To our knowledge this is the first detailed country study in relation to carbon taxes. The only other study related to LMICs that applied a comparable in-depth analysis (Schaffitzel et al., 2020) simulates the removal of fossil fuel subsidies and not a carbon tax.

2.2. *A carbon tax in Peru and the role of social protection*

The present article studies the aforementioned issues for the case of Peru. Peru's economy is growing fast and is heavily dependent on extractive industries, in particular mining (KPMG, 2013). The country represents an insightful case study for many reasons. First, Peru has planned to significantly cut its emissions, which have almost doubled since 1990.[3] But until now, the Peruvian government has discarded carbon pricing as an option (Jakob, 2018). Therefore, this paper explores the potential of a carbon tax. Second, Peru has gradually expanded its system and reach of social protection since the early 2000s, starting with the introduction of a social health insurance in 2002 (Jones et al., 2008). The two largest social assistance programmes in terms of coverage and expenditure are the conditional cash transfer (CCT) *Juntos* and the social pension *Pensión 65*. *Juntos* was introduced in 2005 and operates as a standard CCT: poor households with children receive a bimonthly income transfer of PEN 200 (approximately $PPP 133) as long as their children attend school regularly and make use of primary health care services. In the case of non-compliance, families are not automatically excluded but rather suspended temporarily from the programme. *Juntos* is available only in districts that have a local poverty rate of 40% and above.[4] *Pensión 65* was introduced in 2011 as a social pension that guarantees a bimonthly income transfer of PEN 250 (approximately $PPP 166) to the elderly aged 65 and above, that are identified as extremely poor and are not covered by contributory and private pension insurance.[5] Contrary to *Juntos*, there is no geographical targeting for *Pensión 65*.

Complementary to social protection targeted at individuals and households, the so-called canon-system aims to facilitate public social investment at the local level: parts of the revenues raised from taxes and royalties on extractive industries are paid into investment funds administered at the regional and municipal level to benefit local communities (Loayza and Rigolini, 2016). In practice, however, the lack of administrative and technical capacities to plan and disburse funds has hindered these objectives and rather contributed to socio-environmental conflicts (Jakob, 2018). Against this background and given the fact that *Juntos* and *Pensión 65* have been scaled up several times already in the past, using the existing cash transfer architecture to channel revenues towards lower income groups seems a more feasible strategy for promoting social and environmental goals than public infrastructure investment programs (Jakob, 2018).

While *Juntos* had positive impacts on poverty reduction (Perova and Vakis, 2009; Jaramillo, 2014), two drawbacks are critical for the current study and the link with a carbon tax. First, Peru's current social assistance architecture excludes large parts of the poor (Jaramillo, 2014; Gaentzsch, 2017). Second, transfer amounts and coverage are very low and thus achieve fairly little poverty reduction, a finding that applies to Peru's fiscal policy in general (Jaramillo, 2014).

3. Data and descriptive statistics

3.1. *GTAP and the resulting MRIO*

The macro-data comes from the GTAP 9 database, which we use for the consumption based emission analysis considers 140 regions and 57 sectors.[6] GTAP can be transferred into a multi-regional input-output model, following the procedure described by Andrew and Peters (2013). The calculations we apply are based on standard MRIO analysis (see e.g. (Miller and Blair, 2009)). It considers an inter-industry flow matrix $Z \in \mathbb{R}^{(m\cdot n)\times(m\cdot n)}$, where n is the number of regions and m is the number of sectors, as well as a final demand vector $Y \in \mathbb{R}^{m\cdot n\times n}$. Single entries of Z reflect the monetary value of flows from sector s_1 in region r_1 to sector s_2 in region r_2, with $r_1, r_2 \in \{1, \ldots, n\}$ and $s_1, s_2 \in \{1, \ldots, m\}$. Analogously, $y^{r_2}_{r_1,s_1}$ represents the sum of all monetary flows from sector s_1 of region r_1 into final demand of region r_2.

These can be used to calculate the technology matrix

---

[2] In addition, some major cash transfer programs were implemented as part of fossil fuel subsidies reforms, linking climate change mitigation and social policies (Vogt-Schilb and Hallegatte, 2017).

[3] Land use represents the biggest share of emissions; the largest growth occurred in industry, power and transportation.

[4] Except for (i) indigenous people in the Amazonas in target group; (ii) HH in districts hit by a natural disaster/emergency.

[5] To qualify for *Pensión 65*, individuals must live in a household that is qualified as poor or extremely poor (in addition to the individual criteria). To qualify for *Juntos*, households have to be poor or extremely poor and meet the following criteria: (i) have lived in a district of intervention for more than 6 months, (ii) contain at least one pregnant woman or a child/teenager between 0 and 19 years, (iii) have at least one adult that holds a valid ID card.

[6] In contrast to other IO databases, such as Exiobase (Stadler et al., 2018) or WIOD (Timmer et al., 2015) or EORA (Lenzen et al., 2013), GTAP does not have releases for every year. However, the database accounts for many non-industrialized economies, which are rarely considered in other databases and offers a homogenized sector resolution, which enables comparability with other, similar studies (Renner, 2018, Renner et al., 2018).

Table 1

Inclusion and exclusion errors, Juntos and Pension 65.

Poor (extreme and moderate)	(1) *Juntos*	(2) *Pension 65*	Extreme poor	(3) *Juntos*	(4) *Pension 65*
Beneficiaries (a)	36.56%	8.87%	Beneficiaries	55.02%	9.66%
Exclusion error (1-a)	63.44%	91.13%	Exclusion error (1-a)	44.98%	90.33%
Inclusion error	43.63%	57.35%	Inclusion error	84.16%	91.32%

Source: Authors' elaboration.

$A \in \mathbb{R}^{(m \cdot n) \times (m \cdot n)}$, with single entries $a^{r_1 s_1}_{r_2 s_2} = z^{r_1 s_1}_{r_2 s_2} / o_{r_1, s_1}$, where $o_{r_1, s_1} = \sum_s \sum_r (z^{r,s}_{r_1 s_1}) + \sum_r y^r_{r_1, s_1}$ is the total output of a sector. These entries describe the amount of each input that is necessary to produce one unit of output. A enables the calculation of the Leontief inverse L, which accounts for all pre-products that have been used at some stage during the production process. It results as $L = (I - A)^{-1}$, where I denotes the identity matrix.

Let $F \in \mathbb{R}^{m \times n}$ denote the CO_2 emissions vector, whose elements $F_{r,s}$ refer to the total emissions released by sector s in region r. Let $F^* \in \mathbb{R}^{m \times n}$ denote the emission vector with the characteristic that it has non-zero entries in case of Peru, only, i.e. all entries referring to industries outside of Peru are zero. Dividing F and F^* entry-wise by the corresponding total sectoral outputs results in vectors f and f^* whose entries reflect CO_2 emissions associated with the production of one USD of output, i.e. the emissions intensity.

GTAP reports a separate final demand for households and accounts for households' direct emissions. Let $F^{dir}_{r1,s1}$ denote the direct emissions of households in region $r1$ for sector $s1$. Let Y^{HH} denote the final consumption that is due to households. The indirect emissions that are associated to the household consumption in region r_1 for sector (consumption item) $s1$ then result as

$$F^{ind}_{r1,s1} = \sum_{r'} \sum_{s'} \sum_{r} f_{r',s'} L^{r,s1}_{r',s'} y^{HH\ r1}_{r,s1}$$

Adding direct emissions gives the total amount of emissions associated with household consumption $F^{HH}_{r1,s1}$, which is $F^{HH}_{r1,s1} = F^{dir}_{r1,s1} + F^{ind}_{r1,s1}$. These emissions need to be assigned to household consumption, which is done in the next subchapter. When considering emissions originating from Peru only, f has to be replaced with f^* in the formula above.

For the case of Peru, our results are summarized in Table A1 in the Appendix. We calculate two different types of associated carbon emissions for Peru. First, the carbon footprint of Peruvian households arising from domestic production only (columns (b) and (c), where the latter corresponds to the embedded carbon intensity); and second, the carbon footprint considering the total carbon content of consumption (columns (d) and (e), with the latter being the embodied carbon intensity).[7] This serves as basis to simulate domestic and global carbon taxes. But, as previously specified, the analysis is based on a national carbon tax. Table A1 (column (b) and (d)) shows that the majority of emissions in Peru are related to the transport, petroleum and electricity sector. Conversely, the highest carbon intensity of consumption (column (c) and (e)) is found in the gas manufacturing, electricity and petroleum sectors.

3.2. ENAHO

The micro analysis draws on the National Household Survey ENAHO (*Encuesta Nacional de Hogares*), which is an annual nationwide survey administered by the Peruvian National Institute of Statistics and Informatics (INEI) that covers all regions of the country. It uses a geographic three-stage probabilistic sampling framework that is representative of the population living in private households at the level of the 24 departments in the country. It is further representative at the regional level, where geographic regions are divided by urban and rural areas of the Coast, the Jungle and the Highlands, respectively, and the metropolitan region of Lima (i.e. 7 regional units).

The sample size has increased over the past years, reaching approximately 33,400 households in 2015. The survey contains rich information on demographics, income sources of all household members aged 14 and above, consumption and expenditure patterns as well as receipt of public transfers. The extensive consumption module not only records detailed information on the type of product or service consumed, but also on the place of purchase, its price and the person or institution that paid for it. In the case of food items, both food consumed at home and outside is recorded as well as food (and other items) that derive from self-production. Moreover, given the absence of more detailed consumption surveys, ENAHO represents the best information on household consumption at the national level. Consumption information includes in total 324 items.

In line with the measurement of poverty in ENAHO and the fact that consumption better captures deprivation than income, we use consumption as the welfare measure of interest. We employ the poverty lines calculated by INEI to measure moderate (minimum well-being) poverty. These represent the monthly per capita value of locally representative food baskets and an additional lump-sum value of non-food expenditure to approximate moderate poverty. We also do robustness checks using extreme (nutritional) poverty lines. Overall, there are distinct extreme and moderate poverty lines for the 7 regional units outlined above that are calculated based on the median prices of the 110 items that enter the baskets.

Inequality as measured by the Gini coefficient lies high at 0.37 and around 22% of the population fall under the moderate poverty threshold (4% of the population is in extreme poverty). At the regional level, the coastal regions have a significantly lower poverty rate compared to the highlands. Lima presents the lowest poverty headcount value.

3.3. The reach of social assistance in Peru

We focus our analysis on the two largest social assistance schemes, *Juntos* and *Pensión 65*. For *Juntos*, we estimate its targeting accuracy in two ways:[8] we first look at actual receipt as declared by households; and second at eligibility as predicted by simulating the targeting algorithm. Overall, 14% of the population report to have received transfers from *Juntos* in the past year. Column (1) in Table 1 below shows that a large proportion of the poor (both extreme and moderate poor) are not receiving the program (36.6% are beneficiaries, with a 63.4% exclusion error), while a significant proportion of the beneficiaries are not poor (43.6% inclusion error).[9] When looking at social pensions, (column (2)), 8.9% of the poor live in a household receiving the pension but over 57% of recipients are not poor. Columns (3) and (4) take a narrower focus at

---

[7] The latter also accounts for re-imported emissions.

[8] We restrict the analysis of targeting efficiency to *Juntos* because ENAHO includes specific questions on *Juntos* receipt, which are not yet included for *Pensión 65*.

[9] The reasons for this are multiple: targeting specification; districts not reached by the program (including Lima); families having graduated out of poverty since joining *Juntos* but still enrolled; non-take up, including the fact that participants need to present birth certificates and apply to be a member and lack of adequate implementing capacity of municipalities.

extreme poverty. The fact that the share of the poor excluded from its transfer decreases suggests that, among the poor, *Juntos* disproportionately benefit the extreme poor. The parallel increase in the inclusion error can be attributed to the fact that the group of extreme poor is considerably smaller than the moderate poor (Hanna and Olken, 2018). Finally, around 3% of both the poor and extreme poor receive both *Juntos* and the pension; on the other hand, 57% of the poor and 39% of the extreme poor receive neither.

It is important to point out that this estimation of inclusion and exclusion errors measures the target group against monetary poverty, while the actual targeting of social transfers is based on the multidimensional SISFOH (*Sistema de Focalización de Hogares)* score. Although they strongly correlate, SISFOH aims to identify the chronic poor whereas monetary poverty also includes the transient poor.

To estimate *Juntos* eligibility at the household level, we simulate the targeting mechanism used by the program (Bernal et al., 2017; Hanna and Olken, 2018).[10] Peru adopts a unified targeting approach for social assistance, the *SISFOH*, which gives each household a score (*Índice de Focalización de Hogares*, IFH), that is then used to classify households as very extreme poor, poor or non-poor. This is based on a multidimensional proxy-means test (PMT) that takes into account *inter alia* the wealth of the household, the literacy of its members and dwelling characteristics.[11] Since the government does not disclose the exact targeting algorithm, we replicate it based on Linares García (2009) and Silva Huerta and Stampini (2018). Our calculations show that eligible beneficiaries (identified through the replication of the PMT) represent approximately 9% of the population, which is significantly lower than the incidence of moderate poverty of 22%. In addition, only around 6% of households that are not eligible according to our simulation based on the replication of the targeting mechanism report receiving *Juntos* benefits, while 43% report not receiving benefits despite being eligible. The *Juntos* eligibles represent 37% and 55% of the national poor and extreme poor. There may be several reasons that explain the divergence of actual beneficiaries and those that are eligible.[12] First, the government does not yet systematically reassess eligibility status of households. Hence, they may graduate out of poverty but continue to be enrolled in social programs for several more years. Second, there are reasons for non-take up among the eligible, such as lack of information, administrative barriers, non-compliance with conditionalities and/or opportunity costs of benefit take up, and stigma. In addition, our replication may not perfectly mimic the official one due to lack of complete information.

4. Methodology: carbon footprints, tax incidence and simulations

To address our research questions, we link the top-down macro data with bottom-up household information as described above. We then simulate different carbon tax levels, drawing conclusions on the incidence and distributional effects. For our analysis, we assume that all commodity price increases are handed over to the consumer. We then simulate different scenarios that comprise measures to increase the generosity of existing transfer schemes as well as their coverage to sufficiently compensate the poor.

4.1. The distributional effects of a carbon tax: merging ENAHO and MRIO

To calculate the effects of a carbon tax, we first need to estimate carbon footprints of households. We merge ENAHO household data of 2015 with the MRIO data of 2011 GTAP. Specifically, we categorize the 324 expenditure items from the household survey into the 57 sectors of GTAP. We then multiply the expenditure of the households for each category for the corresponding carbon intensity of the sector (as estimated in Table A1). The total carbon footprint (CF) of the household is the sum of the footprint from each sector:

$$CF = \sum_{i=1}^{n} c_i e_i$$

Where c_i is the amount of expenditure of item i, e_i is the corresponding carbon intensity, which is $F^{HH}_{Peru,i} / \sum_r y^{HH\ Peru}_{r,i}$, and n is the number of consumption items that are considered (we consider all available consumption items).

The amount of the carbon tax to be paid is then estimated by multiplying the carbon footprint (CF) by the tax rate. This tax liability is then subtracted from the household's total consumption. This calculation is based on expenditure both on the micro level capturing household spending and on the macro level capturing the carbon intensity of production through the MRIO. We measure poverty and inequality, however, against consumption and it is worth pointing out that a share of consumption is derived from self-production such as subsistence farming, especially among lower income deciles. We assume that this economic activity is not affected by the carbon tax because it is not traded in the market.

4.2. Scenarios: targeting and carbon tax values

We simulate different scenarios, modelled taking into account two dimensions of interest: the level of the carbon tax; and the design of the transfer program. In relation to the first dimension, estimating the actual monetary costs of carbon emissions is empirically challenging and there is no agreed price offered by the literature. We apply a carbon tax with three different rates to test different scenarios. Stiglitz et al. (2017) suggest a tax rate in the range of US$40–80 per ton of CO2 by 2020. Carattini et al. (2019) estimate that a global tax of US$80/$tCO_2$ would achieve a reduction of one third; therefore we use this value as our upper bound. By 2030 a tax of at least US$50/$tCO_2$ would be needed to reach the goals of the Paris agreement (Stiglitz et al., 2017). We hence simulate the impacts of a Peruvian carbon tax of US$50/$tCO_2$ as the baseline scenario. We chose a lower bound of US$20/$tCO_2$, as it is close to some estimates of the social cost of carbon by Tol (2019). The lower bound is also motivated by the assumption that in the beginning, the government may opt to choose a low tax rate that can gradually be increased. It may be noted that the social cost of carbon increases substantially when inequality at the sub-national level is taken into account (Dennig et al., 2015; Adler et al., 2017; Kornek et al., 2019).

We simulate a national carbon tax, compared to other studies that simulate global carbon taxes. We acknowledge that governments may be reluctant to implement national carbon taxes due to the potential losses in competitiveness of their industries (Fullerton and Muehlegger, 2019; Ward et al., 2019) and carbon leakage (Elliott and Fullerton, 2014). However, as there are high barriers to international agreements on a global carbon tax, which would be the first best solution (Edenhofer et al., 2015; Cramton et al., 2017; Stiglitz et al., 2017), national policies are of high relevance to keeping a global tax on the political agenda and make progress towards achieving the ambitious Paris goals. By employing appropriate policy mixes, national policies can deliver social alongside environmental improvements. In addition, governments can implement solutions, such as Border Carbon Adjustments, to partially

---

[10] Eligibility is an important criterion for our analysis since we assume it may be possible to reduce non-take up.

[11] *Juntos* also features two additional stages: geographical targeting (which also excludes the capital Lima); and a consultative assembly at the district level that verifies whether identified households are actually those in need.

[12] Targeting errors could be decomposed into errors by design and errors in implementation (Devereux et al., 2017).

Table 2
Scenarios for redistributing carbon tax revenues through cash transfers.

Scenario	Main dimension of interest	Description
Baseline		Status Quo
Poverty eradication		Poverty gap is perfectly closed (scenario used to estimate the tax revenues as a share of the expenditures needed to close the poverty gap)
1a	Increase generosity – *vertical expansion*	Double current *Juntos* transfer
1b		Double current *Juntos* and *Pensión 65* transfers
1c		Extend *Juntos* coverage at twice the current transfer levels to all eligible (in addition to current beneficiaries)
2a	Extend coverage – *horizontal expansion*	Extend *Juntos* coverage to all eligible at national level
2b		Grant a universal child benefit of 25PEN/month to all children up to the age of 17
2c		Grant a universal basic income (UBI) of 50PEN/month per household
3a	Redistribute all carbon tax revenues	Distribute all revenues to current *Juntos* beneficiaries
3b		Distribute all revenues to all households eligible for *Juntos* at the national level
3c		All revenues shared on a p.c. basis to all population (UBI with all revenues)

Source: Authors' elaboration.

address these issues of carbon leakage and loss of competitiveness (Cosbey et al., 2019).

In terms of design of the transfer programs, we simulate different scenarios to show the potential compensatory effects of different *credible* policy designs. We then compare the funding needed for these policies with the revenues raised from the carbon tax. We assess these scenarios against the baseline of the status quo, i.e. a household's consumption as reported in ENAHO that includes current transfer receipts (including *Juntos* and *Pension 65)*. The simulated scenarios can be divided into different groups (see Table 2 below). The first set of scenarios is built around *vertical expansion*; this means keeping the current beneficiary group, but increasing the transfer amount. We estimate the effects of doubling transfer levels to current *Juntos* beneficiaries (scenario (1a)), as well as both *Juntos* and *Pension 65* beneficiaries (scenario (1b)). In addition, scenario (1c) models *Juntos* coverage at twice the current transfer levels to all potential eligible individuals, in addition to the current beneficiaries. The second set of scenarios simulates *horizontal expansion* through credible policy scenarios, inspired by current programs. These scenarios model increases in beneficiary numbers that could address the high exclusion errors witnessed by the current *Juntos* and *Pension 65*. Scenario (2a) scales up *Juntos* nationwide; scenario (2b) considers a universal child benefit of 25PEN/month. In scenario (2c) we simulate a transfer of 50PEN/month to all households. Such universal transfer is discussed as a feasible option for LMICs, due to ease of implementation and political economy reasons (Macauslan and Riemenschneider, 2011).

The third, and final set of scenarios, starts from the available revenues. It estimates the effects of redistributing all revenues raised by the carbon tax on equal per capita terms to: the current *Juntos* beneficiaries (scenario (3a)); to the potential beneficiaries in the case of an expansion of *Juntos* at the national level (scenario (3b)); to all citizens (scenario (3c)). Distributing all the revenues may not be politically feasible as no revenue would be left to be recycled in other ways, such as compensating powerful interest groups (Klenert et al., 2018). But it makes results comparable as each targeting mechanism receives the same amount (Vogt-Schilb et al., 2019).

Finally, we estimate the funds needed to close the poverty gap as a benchmark in the scenario "Poverty eradication".[13]

5. Results

5.1. Footprints by percentiles

The first step of the analysis is to calculate the carbon footprints of households. Fig. 1 presents the carbon footprints along the total consumption distribution.[14] It shows that the footprints increase linearly for the first nine deciles, and exponentially for the highest 10% of the distribution. The top decile, in fact, has a footprint almost two times the one of the 9th decile, and six times the one of the lower half of the distribution. It is also interesting to notice that inequality of footprints is slightly higher than the monetary inequality in consumption. The former's Gini Index is 0.42, the second is 0.37.

These results confirm that income[15] acts as the main driver of carbon footprints, mainly due to increases in overall consumption. Moreover, both average footprints and expenditures are three times higher in urban areas compared to rural areas.

5.2. Distributional impacts of a carbon tax

To understand the distributional effects, we compute the changes in poverty and relative inequality[16] arising from a carbon tax, following the assumption that households were to pay for a carbon tax on their current consumption baskets. To estimate poverty, we rely on the FGT indices (Foster et al., 2010) while for inequality, we measure the Gini index and the ratio between the welfare shares of the top 10 and the bottom 10% of the population, as well as between the top 25% and the bottom 25% (Cobham et al., 2016). Table 3 presents the estimated effects of the different carbon tax rates on poverty and inequality. In the case of the US\$50/tCO_2 tax rate, the poverty headcount (FGT0) would proportionally increase by 7.2% (from 0.218 to 0.233), with lower

---

[13] Apart from scenarios using the current program infrastructure ((a), (b), (3a)), the other scenarios will likely additional administration costs. These are usually not large in relation to the overall budget (around 5% (Fiszbein and Schady, 2009)) and are not included in the analysis.

[14] We use the carbon footprints of expenditure (not total consumption), arising from national emissions, as consumption from self-production is not relevant for the carbon tax.

[15] Following the government of Peru and the literature (Deaton, 2016), we use consumption (instead of income) as our welfare variable as this better captures welfare of lower deciles. Expenditure is the part of consumption that has been paid for, and that we consider in the estimation of the tax amount liability as the majority of other studies.

[16] The analysis in this study uses relative measures to estimate inequality, which compare the ratios of income between individuals (or groups). The main example is the commonly employed Gini Index. In contrast, absolute inequality measures compare the absolute income differences between individuals. Examples are the Absolute Gini Index or the variance. While both are important for informing policy analysis, this study focuses on relative inequality as it favors the comparability with other studies and it is arguably better suited to complement poverty analysis (Niño-Zarazúa et al., 2017).

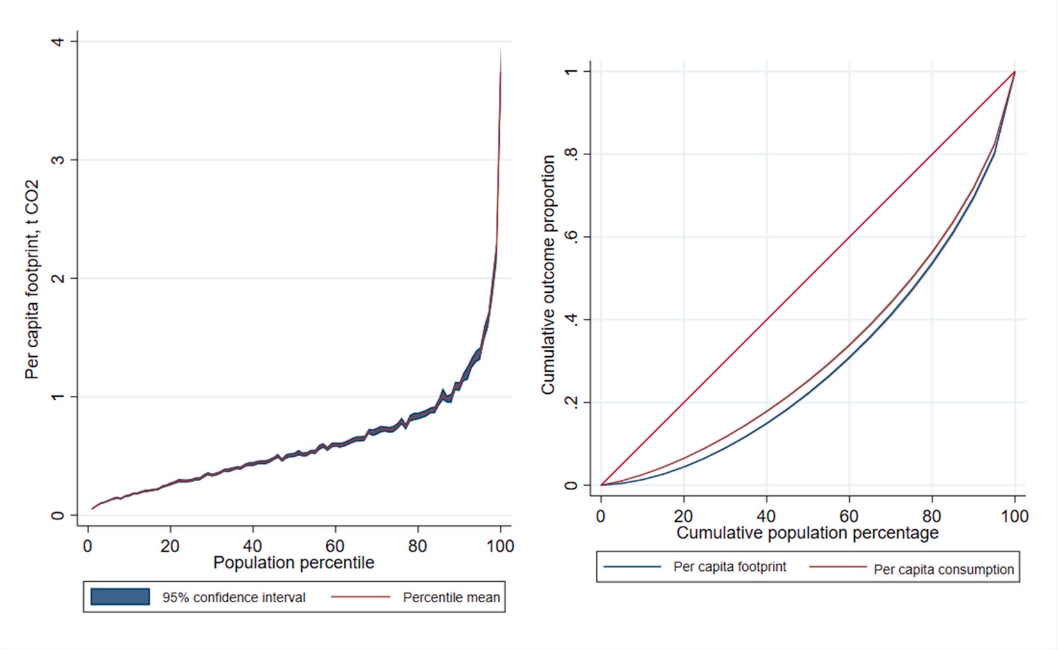

Fig. 1. Distribution of footprints, and inequality of consumption and footprints. Source: Authors' elaboration.

Table 3
Effects of a carbon tax on poverty and inequality.

	Poverty measures					Inequality measures				
		Pre-tax	Post-tax	change (abs)	change (%)		Pre-tax	Post-tax	change (abs)	change (%)
US\$20/tCO$_2$	**FGT0**	0.218	0.223	0.005	2.43%	**Gini**	0.368	0.368	−0.000	−0.02%
	FGT1	0.054	0.055	0.001	1.64%	**p90p10**	5.457	5.451	−0.006	−0.10%
	FGT2	0.020	0.020	0.000	1.77%	**p75p25**	2.388	2.386	−0.002	−0.09%
US\$50/tCO$_2$	**FGT0**	0.218	0.233	0.016	7.21%	**Gini**	0.368	0.368	−0.001	−0.04%
	FGT1	0.054	0.057	0.002	4.26%	**p90p10**	5.457	5.454	−0.003	−0.05%
	FGT2	0.020	0.021	0.001	4.52%	**p75p25**	2.388	2.384	−0.004	−0.19%
US\$80/tCO$_2$	**FGT0**	0.218	0.241	0.024	10.81%	**Gini**	0.368	0.368	−0.001	−0.07%
	FGT1	0.054	0.058	0.004	7.02%	**p90p10**	5.457	5.444	−0.013	−0.23%
	FGT2	0.020	0.021	0.001	7.38%	**p75p25**	2.388	2.384	−0.005	−0.19%

Source: Authors' elaboration.

increases for the poverty gap (FGT1) and the poverty gap squared (FGT2). In terms of proportional impacts on consumption, the carbon tax represents around 1.1% of the consumption of the lower decile, and 1.5% of the consumption of the highest deciles. In the case of the lower tax rate, the poverty headcount would increase by 2.4% (0.5 percentage point increase), while it would increase by 10.8% for the higher tax rate.[17]

Apart from that, the carbon tax would not significantly impact inequality measured in relative terms at any of the modelled rates. The Gini coefficient would show a relatively modest decrease of just 0.04% at the US\$50/tCO$_2$ tax rate. Similar results are found when considering other relative inequality measures. These estimates show very modest signs of progressivity of a national carbon tax.

Table 4 shows the geographical heterogeneity of the impacts, focusing on differences between urban and rural areas, and also between regions. In general, while the Gini coefficient is confirmed to remain substantially unchanged in both urban and rural areas, the effects on poverty are significantly different. In the case of the US\$50/tCO$_2$ tax rate for example, urban poverty rates would increase by 11.4%, compared to an increase of nearly 2% in rural areas. The highest proportional increases in poverty would be witnessed in the coastal regions and in Lima, which are also the regions with the lowest poverty rates.

The distributional effects of a carbon tax can thus be summarized in three main findings. First, a carbon tax would be distribution neutral, as the estimated decrease in relative inequality is very small. Second, poverty would increase, with some of the estimated changes being sizeable. Third the effects are geographically heterogeneous. Especially, poverty would increase proportionally more in urban areas, and some regions would be hit harder from a carbon tax of any level. These heterogeneous effects need to be analyzed in the context of cash transfer programs design.

5.3. *Compensatory effects of different scenarios*

Table 5 presents results of the simulations of the scenarios presented in Table 2 for the main case of the US\$50/tCO$_2$ tax. The table shows the absolute values for each scenario (upper part) and the proportional

---

[17] These changes in the poverty headcount are all statistically significant. On the other hand, the changes in inequality presented in the next paragraph and in the table are not statistically significant. To assess whether changes in poverty and inequality associated with the tax are statistically significant, we compare the confidence intervals of the poverty/inequality estimator before and after the tax. If the two confidence intervals overlap, we conclude that the difference between the two estimators is not significant.

Table 4
Effects of a carbon tax, by region.

	FG0							Gini						
	Pre-tax	US$20/tCO$_2$		US$50/tCO$_2$		US$80/tCO$_2$		Pre-tax	US$20/tCO$_2$		US$50/tCO$_2$		US$80/tCO$_2$	
		Post-tax	Change (%)	Post-tax	Change (%)	Post-tax	Change (%)		Post-tax	Change (%)	Post-tax	Change (%)	Post-tax	Change (%)
Urban	0.15	0.156	3.79%	0.167	11.41%	0.175	16.75%	0.335	0.335	0.02%	0.336	0.05%	0.336	0.08%
Rural	0.472	0.476	0.80%	0.482	2.18%	0.489	3.71%	0.298	0.297	−0.10%	0.297	−0.24%	0.297	−0.38%
Costa Norte	0.209	0.214	2.70%	0.233	11.71%	0.245	17.10%	0.32	0.320	0.02%	0.320	0.06%	0.320	0.10%
Costa Centro	0.127	0.143	12.82%	0.146	14.96%	0.148	16.92%	0.26	0.260	0.04%	0.260	0.11%	0.260	0.18%
Costa Sur	0.115	0.126	8.87%	0.134	15.63%	0.141	21.98%	0.306	0.306	0.03%	0.306	0.08%	0.306	0.13%
Sierra Norte	0.532	0.535	0.65%	0.541	1.69%	0.552	3.86%	0.399	0.399	−0.08%	0.399	−0.19%	0.398	−0.30%
Sierra Centro	0.322	0.325	0.96%	0.336	4.25%	0.344	6.77%	0.353	0.353	−0.05%	0.353	−0.13%	0.352	−0.20%
Sierra Sur	0.231	0.237	2.62%	0.246	6.36%	0.257	11.11%	0.344	0.344	−0.03%	0.344	−0.07%	0.344	−0.11%
Selva	0.289	0.293	1.13%	0.303	4.71%	0.309	6.78%	0.346	0.346	−0.08%	0.346	−0.20%	0.345	−0.33%
Lima Metrop.	0.11	0.114	3.83%	0.124	12.96%	0.130	18.43%	0.32	0.320	0.03%	0.320	0.09%	0.320	0.15%

Source: Authors' elaboration.

changes (lower part) compared to the pre-tax values. The last line of the table shows how much of the revenues would be used in each scenario.

Starting with the scenarios modelling vertical expansion, column (1a) shows that doubling the *Juntos* transfer to current beneficiaries would compensate for the increase in poverty caused by the tax (shown in the post-tax column); overall it would slightly increase poverty rates compared to the pre-tax situation (first column of Table 5). Conversely, the poverty gap and poverty gap squared would be reduced, while inequality would decrease by 1.3%. By doubling also *Pension 65* (1b), or implementing a perfectly targeted *Juntos* with double amounts (1c), the decrease both in poverty gaps and in inequality are larger compared to scenario (1a), while they also reduce the poverty headcount.

Moving to the policy scenarios considering horizontal expansion (columns (2a) -(2c)), the policy reform would reduce the poverty headcount by between 5.3% and 6.2% compared to the pre-tax value. Among the three cases, the nationwide rollout of *Juntos* (column (2a)) would have similar effects to the child grant (2b).[18] Reductions in inequality would be in the range of 1.7%–2% for all three scenarios.

The effects are linked to the share of revenues (see last line of Table 5). Doubling *Juntos* will use 34.1% of total carbon tax revenues, increasing to 63.6% if also the pension amount is doubled. The former share is similar to what has been found in the case of HICs (Carl and Fedor, 2016; Klenert et al., 2018). On the other extreme, a national rollout of *Juntos* (scenario (2a)) and a UBI to all households (2c) would exceed the total amount of revenues collected by the carbon tax. This is also the case for the poverty eradication scenario (where the poverty gap is closed).

What would happen if all tax revenues were to be redistributed? Poverty would reduce significantly in the case of revenue redistribution to the current or an expanded group of beneficiaries. Columns (3a) in Table 6 show that, if revenues are distributed among current *Juntos* beneficiaries, the poverty headcount would reduce by around 10%, while the poverty gap and the poverty gap squared would have reductions of 25% and 33% in proportional terms. On the other hand, redistributing revenues through an equal transfer to all nationwide eligible (3b) or all citizens (3c) would have a smaller effect on poverty and inequality compared to scenario (3a).

We now compare these findings with those of different tax rates. Fig. 2 shows that for scenarios (1a) to (2c), the poverty headcount decreases less for a higher tax rate of US$80. This is because increases in poverty due to the tax exceed what transfers compensate. Note that for these scenarios, the tax liabilities of households increase with the tax rate while transfer amounts remain fixed across all rates. These results underline that the generosity of cash transfer programs needs to be adjusted to the size of distributional effects of the corresponding tax to compensate negative effects on poorer households. Therefore, understanding the distributional effects is crucial. For the last set of scenarios ((3a)-(3c)), a higher tax rate causes larger decreases in the poverty headcount because they imply that larger budgets are redistributed. Similar results are found when considering the poverty gap.[19]

As a last step, Fig. 3 draws a comparison between scenarios considering the significant policy trade-off between their poverty reduction potential and the relative amount of revenues spent.[20] We define the relationship between the two dimensions as the *efficiency of expenditure*. The left panel evaluates the poverty headcount, the right one the poverty gap. No scenario is located in the upper right quadrant, meaning that no scenario uses more than all revenues while increasing poverty. The lower left quadrant is the one that policy makers should aim for:

---

[18] Other scenarios have also been modelled but are not presented in the paper for space reasons.

[19] Not presented here for space reasons.

[20] This is crucial as part of the revenues would probably be needed to be recycled towards different actors to take care of political economy issues (Fullerton and Muehlegger, 2019; Ward et al., 2019).

Table 5
Simulation of the different scenarios, US$50/tCO$_2$.

	Pre-tax	Post-tax	Vertical expansion			Horizontal expansion		
Scenario			1a	1b	1c	2a	2b	2c
			absolute value					
FGT0	0.218	0.233	0.220	0.211	0.214	0.206	0.206	0.204
FGT1	0.054	0.057	0.051	0.048	0.048	0.050	0.048	0.048
FGT2	0.020	0.021	0.018	0.017	0.016	0.018	0.016	0.017
Gini	0.368	0.368	0.363	0.360	0.361	0.362	0.361	0.362
			% change compared to pre-tax					
FGT0	0.218	7.21%	1.00%	−2.98%	−1.90%	−5.32%	−5.43%	−6.21%
FGT1	0.054	4.26%	−6.81%	−11.55%	−11.75%	−8.65%	−12.22%	−11.66%
FGT2	0.020	4.52%	−11.22%	−16.60%	−17.90%	−10.67%	−18.22%	−16.24%
Gini	0.368	−0.04%	−1.33%	−2.17%	−2.00%	−1.79%	−2.00%	−1.70%
% revenues used			34.05%	63.55%	56.12%	144.63%	90.93%	153.24%

Source: Authors' elaboration.

Table 6
Simulation of different scenarios, using all revenues (US$50/tCO$_2$).

Scenario	Pre-tax	3a	3b	3c
		absolute value		
FGT0	0.218	0.195	0.212	0.209
FGT1	0.054	0.040	0.052	0.049
FGT2	0.020	0.013	0.019	0.017
Gini	0.368	0.354	0.364	0.363
		% change compared to pre-tax		
FGT0	0.218	−10.41%	−2.67%	−4.03%
FGT1	0.054	−25.34%	−4.44%	−8.76%
FGT2	0.020	−32.93%	−5.52%	−13.08%
Gini	0.368	−3.77%	−1.28%	−1.51%

Source: Authors' elaboration.

poverty is reduced and 100% or less of the revenues are used. Overall, the heterogeneity between scenarios indicate that it is critical for policy makers to fully understand the trade-offs between the amount of the revenues that needs to be saved and the poverty reduction potential to make an informed decision.

5.4. Poverty transitions and fiscal impoverishment of the poor

While the impact of a carbon tax on poverty can be documented by monitoring changes in aggregate, and most commonly used, poverty statistics (such as the FGT measures), critical policy information may be missed. For example, even with aggregate poverty measures unchanged or even improving, some individuals may still be made poorer by the tax reforms (Higgins and Lustig, 2016).[21] The FGT poverty measures cannot capture these dynamics as they respect the anonymity axiom, implying that they do not take into account the initial positions of individuals. This is particularly important in the context of the current analysis in Peru. For example, the many poor households that do not receive *Juntos* will face a decrease in real incomes due to higher prices from the tax without being compensated through higher transfers channelled through existing programmes.

How to empirically go beyond aggregate poverty estimates? One main approach is to decompose changes of the main FGT poverty measures previously employed. One can decompose changes in the poverty headcount into entries into and exits from poverty, based on the pre-tax status. This has been done traditionally by researchers looking at chronic poverty (Baulch and Hoddinott, 2000). Table 7 shows that, for the case of the US$50/tCO$_2$ tax, in all scenarios some individuals transition into poverty (column (c)). And, in many scenarios, transitions into poverty are non-negligible. For example, scenario (1b) shows a significantly higher proportion of transitions both in and out of poverty than the aggregate reduction in poverty. Redistributing the revenues on an equal per capita basis shows the lowest transitions into poverty (3c).

Table 7 also presents the decomposition of the poverty gap into the fiscal impoverishment (FI) and the fiscal gains of the poor (FGP), as proposed by Higgins and Lustig (2016). FI happens when some of the post-reform poor pay more in taxes than they receive in transfers; and it measures by how much the post-reform poor are worse-off. The FGP

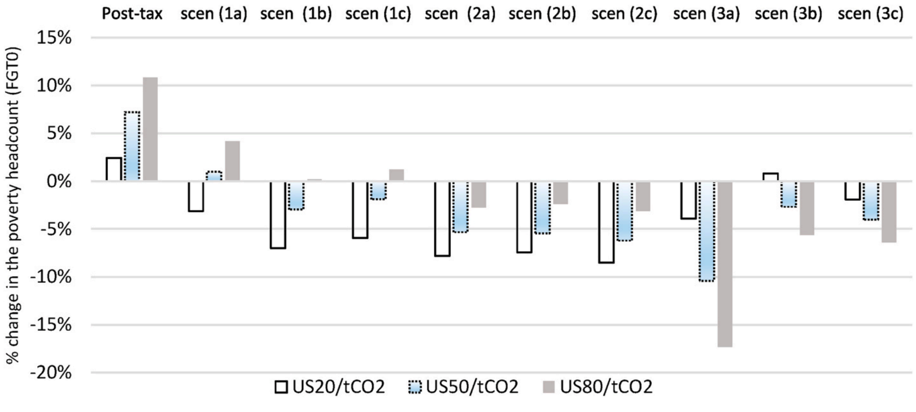

Fig. 2. Relative change in poverty headcount by tax rates (US$/tCO$_2$). Source: Authors' elaboration.

---

[21] Stochastic dominance tests (Atkinson, 1987, Foster and Shorrocks, 1988), are also inadequate in this case.

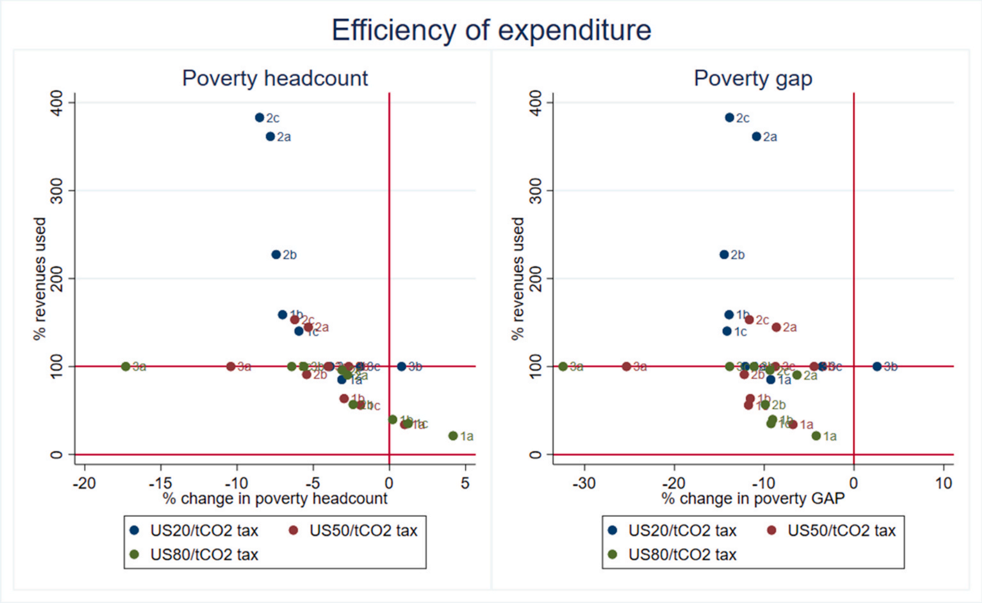

Fig. 3. Efficiency of expenditure, by scenario and tax rate. Source: Authors' elaboration.

Table 7
Poverty transitions and fiscal impoverishment of the poor, US\$50/tCO$_2$ tax.

	Change in poverty headcount (p.p.)[a]	Transitions into poverty (p.p.)	Trans. out of poverty (p.p.)	Change in poverty gap ratio (p.p.)	Per capita FI as share of poverty line (p.p.)	Per capita FGP as share of poverty line (p.p.)	FGP/FI	Changes in extreme poverty			
								Extreme Poverty headcount (p.p)	Extreme Poverty headcount, %	Extreme Poverty gap (p.p)	Extreme Poverty gap, %
Scenario	(a) = (b) - (c)	(b)	(c)	(d) = (e) - (f)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
1a	0.22	1.29	1.07	−0.37	0.17	0.54	3.18	−0.71	−17.45%	−0.19	−24.72%
1b	−0.65	1.21	1.85	−0.63	0.16	0.78	5.02	−0.97	−23.81%	−0.24	−31.24%
1c	−0.41	1.21	1.62	−0.64	0.15	0.79	5.21	−1.08	−26.60%	−0.28	−35.60%
2a	−1.16	0.43	1.59	−0.47	0.09	0.56	6.18	−0.42	−10.45%	−0.11	−13.79%
2b	−1.18	0.16	1.34	−0.66	0.03	0.69	22.26	−1.00	−24.57%	−0.26	−33.40%
2c	−1.35	0.05	1.40	−0.63	0.00	0.63	573.65	−0.85	−20.87%	−0.22	−28.59%
3a	−2.27	1.26	3.53	−1.37	0.17	1.54	9.14	−1.88	−46.33%	−0.39	−50.08%
3b	−0.58	0.67	1.25	−0.24	0.25	0.49	1.98	−0.23	−5.60%	−0.04	−5.36%
3c	−0.88	0.00	0.88	−0.47	0.00	0.48	486.47	−0.68	−16.75%	−0.19	−24.61%

[a] P. p. is the percentage point change, calculated as the difference between absolute values, then multiplied by 100.
Source: Authors' elaboration.

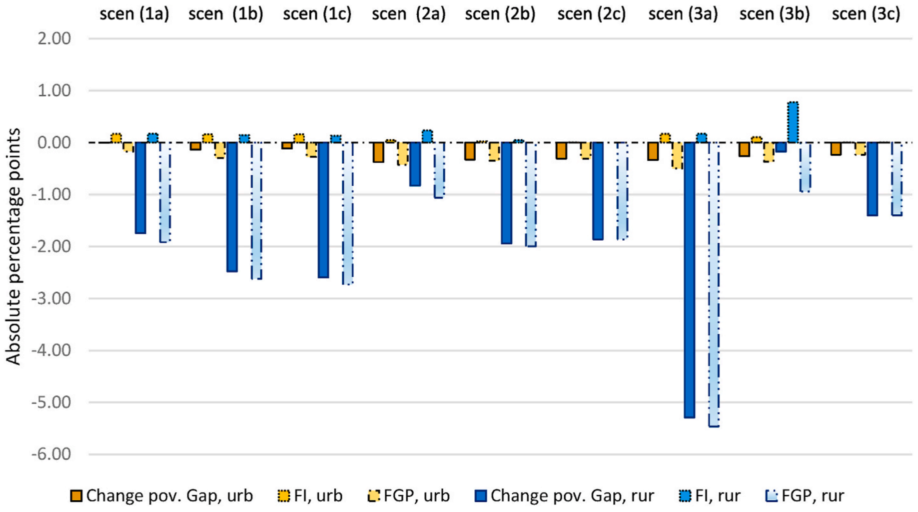

Fig. 4. FI and FGP by rural/ur**ban, tax of US\$50/tCO$_2$.** Source: Authors' elaboration.

represents the opposite case, measuring by how much the pre-reform poor are better-off. First, as for the case of poverty transitions, all scenarios show some fiscal impoverishment (column (e)) (scenarios (2c) and (3c) witness vey low values as redistributing revenues to all households and citizens does not suffer from targeting errors). On a positive note, the total amount of FI is small (on average around 0.10% of the poverty line). Second, FI and FGP strongly depend on the compensation mechanism. For example, scenarios modelled around the current *Juntos* infrastructure would decrease poverty significantly. But this would include some fiscal impoverishment. FI would be the same between scenarios (1a), (1b), (1c) and (3a), but FGP (column (f)) would be much higher in the latter. As an additional example, scenario (1b) achieves the same poverty gap reduction as scenario (2c), but with more FI and FGP.

A complementary approach to further analyse winners and losers is to look at the bottom of the distribution, i.e. at changes in extreme poverty (columns (h) to (k)). All scenarios decrease extreme poverty, and poverty transitions are not too large. When looking at the poverty gap, all scenarios witness a decrease also in this case.

Finally, as in the previous section, heterogenetiy can be looked at, for example by comparing urban and rural areas. Fig. 4 shows that absolute FI and FGP are considerably higher in rural areas, with scenarios modelling more universal programs showing also lower values.

6. Conclusions and policy implications

As means to achieve progress on reducing Greenhouse Gas Emissions, carbon pricing will likely become a preferred policy option. For its successful implementation, it is crucial that social goals are not violated, as advocated by the call for sustainable development in both the SDGs and the Paris agreement; these international frameworks imply that social and environmental goals should be met jointly. This paper analyses this issue, for the case of Peru, by simulating a policy reform consisting of two elements: a carbon tax; and cash transfers to compensate the losers of the tax. It does so by combining micro and macro data and by assessing the short-term distributional implications of a national carbon tax.

Our results show that a carbon tax, without compensation, would increase poverty but leave relative inequality unchanged. Most importantly, the simulations indicate that by recycling tax revenues through transfer schemes poverty can be decreased compared to the pre-tax scenario. By simulating different transfer programs, we also show that different policy options present a trade-off between poverty reduction effects and the share of revenues used. Our results underline some of the points made by previous qualitative research (Jakob, 2018). This paper adds to the inconclusive literature in relation to the implementation of socially just climate policies in LMICs.

In particular, our findings have relevant policy implications for how to design and combine carbon taxes with revenue recycling in Peru and other countries. First, our analysis shows that a carbon tax in Peru is not regressive. In addition, the simulations show that by recycling revenues through transfer programs, poverty can be decreased. Hence, combining the tax with transfer schemes will likely make the policy package even more progressive. Therefore, a carbon tax can improve social goals alongside environmental ones, and it can be politically motivated on the grounds of poverty reduction efforts.

A second policy implication is the need to go beyond aggregate measures of poverty and inequality to fully understand distributional implications of carbon pricing. We show, for example, that despite the poverty headcount having decreased, some of the poor are worse-off (*fiscal impoverishment*). This is caused mainly by exclusion of these individuals from the cash transfer infrastructure. This may also be the case for many cash transfer programs in MICs and LICs, which use PMT targeting. The decomposition used in the paper enables a substantially richer analysis than the typical comparison of poverty before and after taxes and transfers. Therefore, the leave no one behind principle of the SDGs requires focusing on additional measures such as fiscal impoverishment and fiscal gains of the poor, alongside increasing administrative capacity and extending programs to areas and households currently not covered.

In this regard, a third implication is the importance of policy design. As seen in previous sections, each design faces a trade-off between reducing poverty and inequality on one hand, and satisfying different budget constraints on the other. This is a relevant information for policymakers as most likely not all of the revenues can be recycled through transfers (Carl and Fedor, 2016; Klenert et al., 2018). Therefore, adequately mapping possible solutions is a critical research task. Moreover, it is important to understand whether the current architecture of cash transfer can sufficiently compensate losers from carbon taxes, or if these programs need to be adjusted to cover wider target groups.

Finally, compared to existing studies (Dorband et al., 2019), we analyse the case of a national carbon tax, as it is easier to implement given that it requires no cooperation between countries. We show that even unilateral climate action can bring social benefits alongside environmental ones.[22]

Our analytical framework has some inherent limitations. We perform an incidence analysis without assessing general-equilibrium (GE) effects, such as behavioral responses, changes in consumption patterns, labor supply, health effects or firm adjustments. Our analysis gives an upper bound estimate of the short-term effects and impacts that are crucial for a successful policy implementation, as well as social and public acceptance, as recently seen in France and other countries (Carattini et al., 2018; Klenert et al., 2018; Vogt-Schilb et al., 2019).[23] In fact, through the analysis of the tax incidence, it is possible to understand the potential personal costs (higher energy prices and less purchasing power), and their distribution, both critical for the acceptability of carbon taxes (Maestre-Andrés et al., 2019). Nevertheless, other research approaches and GE models are important when assessing overall impacts on a longer time scale. They can also provide important supplementary information for policy makers. Depending on the research set-up, chosen modelling approach and assessed impact dimensions, different insights can be revealed. For instance, there is evidence that employment effects due to a transition towards cleaner energy systems might be rather small and even positive (Montt et al., 2018). Also, general investment patterns could be impacted. Using a GE approach, Fullerton and Heutel (2007) show that measures controlling for pollution can harm the remuneration of capital relatively more than labour. Dissou and Siddiqui (2014) show, using a multisector computable GE (CGE) model for the Canadian economy, that changes in factor prices and changes in commodity prices can have opposing effects on inequality. Hence, considering changes in commodity prices alone can be misleading for long-term effects. For a recent extensive investigation

---

[22] Nonetheless, a global carbon tax, alongside stronger environmental outcomes would bring more significant improvements in poverty and inequality to a middle-income country as Peru Carattini et al. (2019) found that, given revenues are distributed equally to global citizens, a global carbon tax of US \$50/tCO$_2$ would mean a UBI of US\$189 per person. This is higher than the value found in this paper.

[23] Despite being advocated on the ground that they suffer less from corruption, other transfer schemes such as in-kind transfers and food vouchers were out of the scope of the paper. There are different reasons for this, and they especially relate to computational limitations. In addition, Juntos beneficiaries also receive free health insurance (denominated as SIS). SIS covers a range of illnesses and conditions outlined in the PEAS (Plan Esencial de Aseguramiento en Salud, or Essential Health Insurance Plan). But funds towards health witness significant shortcomings (Francke, 2013). Therefore, investing revenues in health systems could increase long (and short term) health outcomes. The same applies for investments in the education system. Peru is last in the PISA test (OECD, 2012), and using some of the tax revenues for investment in education could further poverty reduction in the long-term.

of internalizing the climate externality in a CGE setting for the US and its implications for economic efficiency, see Goulder and Hafstead (2017). Even Cobb-Douglas approaches (Fullerton and Ta, 2019) allow to assess long-term outcomes of different policy options and can reveal changes in economic efficiency when a carbon tax is introduced.

In conclusion, the paper provides a detailed analysis of how to design a policy reform constituted by a carbon tax and compensatory transfer schemes. The analysis has shown that it is feasible to jointly achieve social and environmental goals, whilst also generating additional tax revenues for other objectives. These positive social effects are critical as they could favour implementation of carbon pricing. Moving forward, critical further research avenues include comparable detailed analyses for other countries, given the sensitivity of results to country-specific factors, in particular consumption patterns and the reach of existing social protection systems. Further, research is also needed on questions of implementation. This includes issues of suitable and feasible policy sequencing, found critical for decarbonisation (Meckling et al., 2017) and the implementation of carbon pricing. Similarly, analysing countries' institutional capacities can address the question of whether these will be overstretched by the proposed reform and what policy mix may be adequate. Finally, we recognize that political economy issues are crucial. Notwithstanding the potential of a carbon tax for reducing poverty and furthering environmental goals, the political economy in Peru might make the introduction of a carbon tax difficult. The private sector opposition against higher taxes as well as concerns about the distributional implications are seen as major barriers towards carbon pricing policies (Jakob, 2018). The recent political turmoil, caused by corruption scandals, the more deep-rooted division between the Government and Congress, as well as the economic recession caused by the current COVID-19 pandemic may further increase opposition towards tax reforms in the near future in Peru (Zarate and Casey, 2019).[24] However, Peru has implemented very significant fiscal and economic reforms in the first decade of this century, enabled *inter alia* through strong political leadership and the emergence from a deep economic crisis that rendered reforms indispensable (Carranza, 2012). The potential social co-benefits of a reform including a carbon pricing scheme coupled with transfers to households, as highlighted from this research, can also increase the public acceptability and address concerns about the distributional implications (Jakob, 2018). As other countries may consider carbon pricing to combine economic recovery from the current economic downturn with their climate-and emission goals (Burke and Bowen, 2020; Hepburn et al., 2020), further research is needed on the political economy actors and their stakes in the implementation of these reforms.

CRediT authorship contribution statement

Daniele Malerba: Conceptualization, Data curation, Methodology, Validation, Visualization, Investigation, Writing - original draft, Supervision. **Anja Gaentzsch:** Conceptualization, Methodology, Investigation, Writing - review & editing. **Hauke Ward:** Conceptualization, Methodology, Software, Validation, Writing - review & editing.

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.

Acknowledgements

The authors would like to thank the editor and one anonymous referee for their comments and constructive suggestions which have significantly improved the paper. The authors are also grateful to the participants in the 2019 PEGNet Conference in Bonn, the 2020 Leibniz Environment and Development Symposium in Berlin, the 2020 The ICTA-UAB International Conference 2020 on Low-Carbon Lifestyle Changes, and the 2020 EAERE Annual Conference in Manchester for their comments. Finally, the authors also would like to thank Jann Lay, Babette Never, Miguel Jaramillo, Hanna Fuhrmann, Jean Carlo Rodriguez de Francisco, Tilman Altenburg for their suggestions and fruitful discussions.

Daniele Malerba gratefully acknowledges funding by the Federal Ministry for Economic Cooperation and Development (BMZ), through the Project "SDG-2" (Projektnr. 9002003).

Hauke Ward gratefully acknowledges funding by the German Federal Ministry of Education and Research (BMBF) grant "Klimapolitische Maβnahmen und Transformationspfade zur Begrenzung der globalen Erwärmung auf 1,5 °C (PEP 1p5)", funding code 01LS1610B.

Appendix

Table A1
Virtual emissions of peruvian households and expenditures according to GTAP derived from own calculations.

	Consumption spending of Peruvian HH in Mio USD	Associated emissions to Peruvian HH consumption originating from Peru in kt of CO_2		All associated emissions to HH consumption in Peru in kt of CO_2	
		(national tax)		(Global tax)	
	(a)	(b)	(c) = (b)/(a)	(d)	(e) = (d)/(a)
Paddy rice	1	0.04	0.037	0.05	0.046
Wheat	512	18.5	0.036	155.69	0.304
Cereal grains nec	928	34.43	0.037	189.63	0.204
Vegetables, fruit, nuts	2538	206	0.081	330.04	0.130
Oil seeds	34	1.39	0.041	6.24	0.183
Sugar cane, sugar beet	0	0	0.000	0.01	0.238
Plant-based fibers	142	5.93	0.042	45.01	0.317
Crops nec	3086	285.56	0.093	372.24	0.121
Bovine cattle, sheep and goats, horses	332	20.92	0.063	34.61	0.104
Animal products nec	1266	80.53	0.064	140.64	0.111
Raw milk	2	0.14	0.060	0.28	0.119

(*continued on next page*)

---

[24] See also https://www.economist.com/the-americas/2020/01/30/the-difficulty-of-reforming-peru.

Table A1 (*continued*)

	Consumption spending of Peruvian HH in Mio USD	Associated emissions to Peruvian HH consumption originating from Peru in kt of CO_2		All associated emissions to HH consumption in Peru in kt of CO_2	
		(national tax)		(Global tax)	
	(a)	(b)	(c) = (b)/(a)	(d)	(e) = (d)/(a)
Wool, silk-worm cocoons	0	0.03	0.120	0.03	0.120
Forestry	174	9.49	0.054	15.65	0.090
Fishing	2037	324.13	0.159	413.87	0.203
Coal	–	0	–	0	–
Oil	–	0	–	0	–
Gas	0	0	0.000	0	0.000
Minerals nec	1	0.08	0.094	0.3	0.351
Bovine meat products	1273	148.01	0.116	210.8	0.166
Meat products nec	2980	245.74	0.082	367.62	0.123
Vegetable oils and fats	2381	208.44	0.088	671.71	0.282
Dairy products	2350	223.36	0.095	376.52	0.160
Processed rice	1074	79.13	0.074	164.85	0.153
Sugar	1717	152.54	0.089	232.33	0.135
Food products nec	3678	382.54	0.104	579.77	0.158
Beverages and tobacco products	4991	272.34	0.055	419.7	0.084
Textiles	908	6.98	0.008	639.85	0.705
Wearing apparel	7474	668.58	0.089	1312.08	0.176
Leather products	1960	146.57	0.075	387.59	0.198
Wood products	2740	214.94	0.078	368.73	0.135
Paper products, publishing	2590	244.74	0.094	623.66	0.241
Petroleum, coal products	2450	7048.12	2.877	7597.71	3.101
Chemical, rubber, plastic products	5423	499.08	0.092	3041.5	0.561
Mineral products nec	479	129.2	0.270	364.49	0.761
Ferrous metals	446	128.12	0.287	646.97	1.450
Metals nec	0	0	0.000	0.03	0.545
Metal products	372	144.34	0.389	301.23	0.811
Motor vehicles and parts	672	24.03	0.036	244.56	0.364
Transport equipment nec	76	3.21	0.042	39.82	0.526
Electronic equipment	2284	130.17	0.057	841.42	0.368
Machinery and equipment nec	526	24.55	0.047	178	0.338
Manufactures nec	4529	844.63	0.186	1209.07	0.267
Electricity	804	2752.63	3.425	2794.35	3.477
Gas manufacture, distribution	2	27.1	10.884	27.15	10.904
Water	43	4.85	0.112	7.66	0.178
Construction	141	17.68	0.125	24.26	0.172
Trade	10,270	1913.09	0.186	2492.1	0.243
Transport nec	7982	7308.14	0.916	8124.73	1.018
Water transport	401	68.42	0.171	355.58	0.887
Air transport	1255	663.37	0.529	1413.09	1.126
Communication	2215	101.48	0.046	155.24	0.070
Financial services nec	1092	42.71	0.039	55.66	0.051
Insurance	1568	81.23	0.052	131.96	0.084
Business services nec	1301	59.77	0.046	114.1	0.088
Recreational and other services	9227	1702.36	0.184	2072.52	0.225
Public Administration, Defense, Education, Health	96	13.48	0.141	15.73	0.164
Dwellings	568	18.28	0.032	24.7	0.043
Total	101,391	27,731.13	0.274	40,333.12	0.398

Source: Authors' elaboration.

References

Eclac, Oecd, 2016. Environmental Performance Reviews. Peru 2016: Highlights and Recommendations.

Niño-Zarazúa, M., Roope, L., Tarp, F., 2017. Global inequality: relatively lower, absolutely higher. Rev. Income Wealth 63, 661–684.

Adler, M., Anthoff, D., Bosetti, V., Garner, G., Keller, K., Treich, N., 2017. Priority for the worse-off and the social cost of carbon. Nat. Clim. Change 7, 443–449.

Aguiar, A., Narayanan, B., Mcdougall, R., 2016. An overview of the GTAP 9 data base. J. Global Econ. Anal. 1, 181–208.

Andrew, R.M., Peters, G.P., 2013. A multi-region input–output table based ON the global trade analysis project database (GTAP-MRIO). Econ. Syst. Res. 25, 99–121.

Atkinson, A.B., 1987. On the measurement of poverty. Econometrica: J. Econom. Soc. 749–764.

Barrientos, A., 2013. Social Assistance in Developing Countries, 1 edition ed. Cambridge University Press.

Barrientos, A., 2018. In: Manchester, U.O. (Ed.), Social Assistance in Developing Countries Database.

Baulch, B., Hoddinott, J., 2000. Economic mobility and poverty dynamics in developing countries. J. Dev. Stud. 36, 1–24.

Bernal, N., Carpio, M.A., Klein, T.J., 2017. The effects of access to health insurance: evidence from a regression discontinuity design in Peru. J. Publ. Econ. 154, 122–136.

Brenner, M., Riddle, M., Boyce, J.K., 2007. A Chinese sky trust?: distributional impacts of carbon charges and revenue recycling in China. Energy Pol. 35, 1771–1784.

Burke, S.F., Bowen, A., 2020. Pricing Carbon during the Economic Recovery from the COVID-19 Pandemic. Grantham Research Institute on Climate Change and the Environment Policy Brief.

Carattini, S., Carvalho, M., Fankhauser, S., 2018. Overcoming public resistance to carbon taxes. Wires Climate Change 9, e531.

Carattini, S., Kallbekken, S., Orlov, A., 2019. How to Win Public Support for a Global Carbon Tax. Nature Publishing Group.

Carl, J., Fedor, D., 2016. Tracking global carbon revenues: a survey of carbon taxes versus cap-and-trade in the real world. Energy Pol. 96, 50–77.

Carranza, L., 2012. Politics of fiscal reforms in Peru. In: Dayton-Johnson, J., Santiso, J. (Eds.), The Oxford Handbook of Latin American Political Economy. Oxford University Press, Oxford, pp. 43–67.

Cobham, A., Schlögl, L., Sumner, A., 2016. Inequality and the tails: the Palma proposition and ratio. Global Policy 7, 25–36.

Cosbey, A., Droege, S., Fischer, C., Munnings, C., 2019. Developing guidance for implementing border carbon Adjustments: lessons, cautions, and research needs from the literature. Rev. Environ. Econ. Pol. 13, 3–22.

Cramton, P., Mackay, D.J., Ockenfels, A., Stoft, S., 2017. Global Carbon Pricing: the Path to Climate Cooperation. The MIT Press.

Deaton, A., 2016. Measuring and understanding behavior, welfare, and poverty. Am. Econ. Rev. 106, 1221–1243.

Dennig, F., Budolfson, M.B., Fleurbaey, M., Siebert, A., Socolow, R.H., 2015. Inequality, climate impacts on the future poor, and carbon prices. Proc. Natl. Acad. Sci. Unit. States Am. 112, 15827–15832.

Devereux, S., Masset, E., Sabates-Wheeler, R., Samson, M., Rivas, A.-M., Te Lintelo, D., 2017. The targeting effectiveness of social transfers. J. Dev. Effect. 9, 162–211.

Dissou, Y., Siddiqui, M.S., 2014. Can carbon taxes be progressive? Energy Econ. 42, 88–100.

Dollar, D., Kleineberg, T., Kraay, A., 2016. Growth still is good for the poor. Eur. Econ. Rev. 81, 68–85.

Dorband, I.I., Jakob, M., Kalkuhl, M., Steckel, J.C., 2019. Poverty and distributional effects of carbon pricing in low- and middle-income countries – a global comparative analysis. World Dev. 115, 246–257.

Edenhofer, O., Jakob, M., Creutzig, F., Flachsland, C., Fuss, S., Kowarsch, M., Lessmann, K., Mattauch, L., Siegmeier, J., Steckel, J.C., 2015. Closing the emission price gap. Global Environ. Change 31, 132–143.

Elliott, J., Fullerton, D., 2014. Can a unilateral carbon tax reduce emissions elsewhere? Resour. Energy Econ. 36, 6–21.

Fiszbein, A., Schady, N.R., 2009. Conditional Cash Transfers: Reducing Present and Future Poverty. The World Bank.

Foster, J.E., Shorrocks, A.F., 1988. Poverty orderings. *Econometrica*. J. Econom. Soc. 173–177.

Foster, J., Greer, J., Thorbecke, E., 2010. The Foster–Greer–Thorbecke (FGT) poverty measures: 25 years later. J. Econ. Inequal. 8, 491–524.

Francke, P., 2013. Peru's Comprehensive Health Insurance and New Challenges for Universal Coverage.

Fullerton, D., Heutel, G., 2007. The general equilibrium incidence of environmental taxes. J. Publ. Econ. 91, 571–591.

Fullerton, D., Muehlegger, E., 2019. Who bears the economic burdens of environmental Regulations? Rev. Environ. Econ. Pol. 13, 62–82.

Fullerton, D., Ta, C.L., 2019. Environmental policy on the back of an envelope: a Cobb-Douglas model is not just a teaching tool. Energy Econ. 84, 104447.

Gaentzsch, A., 2017. Do conditional cash transfers (CCT) raise educational attainment? A Case Study of Juntos in Peru.

Goulder, L., Hafstead, M., 2017. Confronting the Climate Challenge: US Policy Options. Columbia University Press.

Hanna, R., Olken, B.A., 2018. Universal basic incomes versus targeted transfers: anti-poverty programs in developing countries. J. Econ. Perspect. 32, 201–226.

Hepburn, C., Stern, N., Stiglitz, J.E., 2020. "Carbon pricing" special issue in the European economic review. Eur. Econ. Rev. 127, 103440.

Higgins, S., Lustig, N., 2016. Can a poverty-reducing and progressive tax and transfer system hurt the poor? J. Dev. Econ. 122, 63–75.

Jakob, M., 2018. Can carbon pricing jointly promote climate change mitigation and human development in Peru? Energy for Sustain. Dev. 44, 87–96.

Jakob, M., Edenhofer, O., 2015. Green growth, degrowth, and the commons. Oxf. Rev. Econ. Pol. 30, 447–468.

Jaramillo, M., 2014. The incidence of social spending and taxes in Peru. Publ. Finance Rev. 42, 391–412.

Jones, N., Vargas, R., Villar, E., 2008. Cash transfers to tackle childhood poverty and vulnerability: an analysis of Peru's Juntos Programme. Environ. Urbanization 20, 255–273.

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., Stern, N., 2018. Making carbon pricing work for citizens. Nat. Clim. Change 8, 669–677.

Kornek, U., Klenert, D., Edenhofer, O., Fleurbaey, M., 2019. The Social Cost of Carbon and Inequality: when Local Redistribution Shapes Global Carbon Prices.

KPMG, 2013. Peru Mining Guide.

Lenzen, M., Moran, D., Kanemoto, K., Geschke, A., 2013. Building EORA: a global multi-region input–output database at high country and sector resolution. Econ. Syst. Res. 25, 20–49.

Linares García, I., 2009. Descripción y diagnóstico de los instrumentos y procesos vigentes de focalización yregistro de beneficiarios del programa Juntos.

Loayza, N., Rigolini, J., 2016. The local impact of mining on poverty and inequality: evidence from the commodity boom in Peru. World Dev. 84, 219–234.

Macauslan, I., Riemenschneider, N., 2011. Richer but resented: what do cash transfers do to social relations? IDS Bull. 42, 60–66.

Maestre-Andrés, S., Drews, S., Van Den Bergh, J., 2019. Perceived fairness and public acceptability of carbon pricing: a review of the literature. Clim. Pol. 1–19.

Malerba, D., 2020. The trade-off between poverty reduction and carbon emissions, and the role of economic growth and inequality: an empirical cross-country analysis using a novel indicator. Social Indicat. Res. 1–29.

Meckling, J., Sterner, T., Wagner, G., 2017. Policy sequencing toward decarbonization. Nature Energy 2, 918–922.

Miller, R.E., Blair, P.D., 2009. Input-Output Analysis: Foundations and Extensions, 2 ed. Cambridge University Press, Cambridge.

Montt, G., Wiebe, K.S., Harsdorff, M., Simas, M., Bonnet, A., Wood, R., 2018. Does climate action destroy jobs? An assessment of the employment implications of the 2-degree goal. Int. Lab. Rev. 157, 519–556.

Oecd, 2012. PISA 2012 database. In: Oecd (Ed.).

OECD, 2018. Delivering the Sustainable Development Goals for All: Policy Priorities for Leaving No One behind. Development Co-Operation Report 2018: Joining Forces to Leave No One behind. OECD Publishing, Paris.

Perova, E., Vakis, R., 2009. Welfare impacts of the "Juntos" program in Peru: evidence from a non-experimental evaluation. The World Bank, pp. 1–59.

Pradhan, P., Costa, L., Rybski, D., Lucht, W., Kropp, J.P., 2017. A systematic study of sustainable development goal (SDG) interactions. Earth's Future 5, 1169–1179.

Renner, S., 2018. Poverty and distributional effects of a carbon tax in Mexico. Energy Pol. 112, 98–110.

Renner, S., Lay, J., Schleicher, M., 2018. The effects of energy price changes: heterogeneous welfare impacts and energy poverty in Indonesia. Environ. Dev. Econ. 24, 180–200.

Ricciuti, R., Savoia, A., Sen, K., 2018. How do political institutions affect fiscal capacity? Explaining taxation in developing economies. J. Inst. Econ. 15, 351–380.

Saelim, S., 2019. Carbon tax incidence on household consumption: heterogeneity across socio-economic factors in Thailand. Econ. Anal. Pol. 62, 159–174.

Schaffitzel, F., Jakob, M., Soria, R., Vogt-Schilb, A., Ward, H., 2020. Can government transfers make energy subsidy reform socially acceptable? A case study on Ecuador. Energy Pol. 137, 111120.

Silva Huerta, R., Stampini, M., 2018. ¿Cómo funciona el Programa Juntos? Mejores Prácticas en la Implementación de Programas de Transferencias Monetarias Condicionadas en América Latina y el Caribe.

Stadler, K., Wood, R., Bulavskaya, T., Södersten, C.-J., Simas, M., Schmidt, S., Usubiaga, A., Acosta-Fernández, J., Kuenen, J., Bruckner, M., Giljum, S., Lutter, S., Merciai, S., Schmidt, J.H., Theurl, M.C., Plutzar, C., Kastner, T., Eisenmenger, N., Erb, K.-H., De Koning, A., Tukker, A., 2018. Exiobase 3: developing a time Series of detailed environmentally extended multi-regional input-output tables. J. Ind. Ecol. 22, 502–515.

Stiglitz, J.E., 2019. Addressing climate change through price and non-price interventions. Eur. Econ. Rev. 119, 594–612.

Stiglitz, J.E., Stern, N., Duan, M., Edenhofer, O., Giraud, G., Heal, G.M., La Rovere, E.L., Morris, A., Moyer, E., Pangestu, M., 2017. Report of the High-Level Commission on Carbon Prices. World Bank, Washington D.C.. Carbon Pricing Leadership Coalition.

Timmer, M.P., Dietzenbacher, E., Los, B., Stehrer, R., De Vries, G.J., 2015. An illustrated user Guide to the world input–output database: the case of global automotive production. Rev. Int. Econ. 23, 575–605.

Tol, R.S.J., 2019. A social cost of carbon for (almost) every country. Energy Econ. 83, 555–566.

Vogt-Schilb, A., Hallegatte, S., 2017. Climate policies and nationally determined contributions: reconciling the needed ambition with the political economy. Wiley Interdiscipl. Rev.: Energy Environ. 6, e256.

Vogt-Schilb, A., Walsh, B., Feng, K., Di Capua, L., Liu, Y., Zuluaga, D., Robles, M., Hubaceck, K., 2019. Cash transfers for pro-poor carbon taxes in Latin America and the Caribbean. Nature Sustain. 2, 941–948.

Wang, Q., Hubacek, K., Feng, K., Wei, Y.-M., Liang, Q.-M., 2016. Distributional effects of carbon taxation. Appl. Energy 184, 1123–1131.

Wang, Q., Hubacek, K., Feng, K., Guo, L., Zhang, K., Xue, J., Liang, Q.-M., 2019. Distributional impact of carbon pricing in Chinese provinces. Energy Econ. 81, 327–340.

Ward, H., Steckel, J.C., Jakob, M., 2019. How global climate policy could affect competitiveness. Energy Econ. 84, 104549.

World Bank, 2020. State and Trends of Carbon Pricing 2020. World Bank, Washington, DC.

Yemtsov, R., Moubarak, A., 2018. Assessing the Readiness of Social Safety Nets to Mitigate the Impact of Reform. Washington, D.C.

Yusuf, A.A., Resosudarmo, B.P., 2015. On the distributional impact of a carbon tax in developing countries: the case of Indonesia. Environ. Econ. Pol. Stud. 17, 131–156.

Zarate, A., Casey, N., 2019. How a Political Crisis Seized Peru: Boom Times, Corruption and Chaos at the Top *the New York Times*.