MANCHESTER 1824

The University of Manchester
Global Development Institute

Global Development Institute

Working Paper Series

2018-032

August 2018

ISBN: 978-1-909336-68-1

How to reduce poverty and address climate change?

An empirical cross-country analysis and the roles of economic growth and inequality.

Daniele Malerba [1]

[1] daniele.malerba@die-gdi.de

German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE), Tulpenfeld 6, 53113 Bonn, Germany

Phone: +49 (0)228 94927-249

Fax: +49 (0)228 94927-130

Cite this paper as:

Malerba, Daniele (2018) How to reduce poverty and address climate change? An empirical cross-country analysis and the roles of economic growth and inequality. GDI Working Paper 2018-032. Manchester: The University of Manchester.

Abstract

How can countries eradicate poverty while also addressing climate change? Despite the necessity to deal with both issues simultaneously, no study has analysed the empirical relationship between the two aforementioned goals and the factors that drive these interlinkages. This paper addresses this gap in the literature, and the initial research question, by developing a framework to analyse this relationship and its drivers. It then econometrically tests the propositions derived from the framework, using data from 135 developed and developing countries. The paper's findings show that the carbon intensity of poverty reduction (CIPR), defined as the ratio between proportional changes in emissions levels and the share of the population above the poverty line, is heterogeneous across countries. This heterogeneity is partly explained by economic growth, which is found to have a negative effect on the CIPR up to a certain income level, defined here as a 'turning point'. Above that turning point, economic growth increases the CIPR. By contrast, inequality reduction is shown to have an unambiguous negative effect on the CIPR. The results are robust for different poverty lines and different model specifications. In addition, the research underlines the tension between policy perspectives at the national and global levels. Economic growth, despite the potential to reduce the national carbon intensity of poverty reduction for the numerous countries that lie below the estimated turning points, needs to confront global environmental boundaries. Given this tension, the paper concludes that, alongside developed countries drastically reducing their emissions, developing countries should follow alternative development paths. Among them, a stronger greening of economic growth or an increased use of cash transfers and inequality-reducing policies are discussed.

Keywords

Poverty, climate change, economic growth, inequality, cash transfers, turning points

JEL codes:

O11, I3, I38, Q01, Q54

Highlights

- Reductions in poverty are associated with heterogeneous proportional changes in emissions levels. This depends on many factors.
- Economic growth decreases the carbon intensity of poverty reduction up to a certain income level, after which the effect is positive.
- By contrast, inequality reduction makes poverty eradication always less carbon intensive, despite its level.
- A tension between policy levels is represented by the *national* carbon intensity of poverty reduction and the *global* environmental boundaries.
- Addressing global poverty and carbon budgets needs rich countries to cut emissions, and developing ones to follow different development paths.

Acknowledgements

I thank Armando Barrientos, Kunal Sen, Andy Sumner, Tilman Altenburg, Francesco Burchi, Hannah Janetschek, Babette Never and Anna Pegels for their useful suggestions and comments.

1. Introduction

How can countries eradicate poverty while also addressing climate change? Does economic growth improve the carbon intensity of poverty reduction? These questions are critical, as global poverty and climate change are two of the most pressing issues of our time. Despite a significant reduction in the past few decades, one billion people still live in extreme poverty (Sumner, 2016). On the other hand, emissions levels are crossing dangerous boundaries (Steffen et al., 2015). Given their urgency and relevance, poverty eradication and environmental goals need to be achieved jointly. This objective has, in fact, been recognised by the Sustainable Development Goals (SDGs), which bring together social, economic and environmental dimensions (Deacon, 2016).

In terms of the relationship between these three dimensions, economic growth and inequality have been identified as significant drivers of both poverty reduction and emissions levels. The poverty–growth–inequality triangle literature, for example, shows that, while economic growth reduces poverty, higher inequality has the opposite effect (Bourguignon, 2004). The environmental Kuznets curve (EKC) framework, by contrast, shows that growth has a positive effect on carbon emissions, while the effect on inequality depends on the income level of the country (Grunewald, Klasen, Martínez-Zarzoso, & Muris, 2017; Ravallion, Heil, & Jalan, 2000; Stern, 2004). The findings of these studies indicate that, over the past two centuries, economic development has resulted in a sharp decrease in absolute poverty at the global level, but also a significant increase in global emissions. They suggest, therefore, that a trade-off exists between reductions in poverty and increases in emissions. Little has been done, however, to directly analyse whether or not, or how, it is possible to eradicate poverty while maintaining emissions levels within sustainable levels.

In fact, evidence shown in this paper demonstrates that the trade-off between poverty reductions and emissions is heterogeneous across countries and time. Some countries, especially in Latin America, have significantly reduced poverty with a lower impact on, or even decreasing, emissions levels; the opposite is true for other countries, particularly in East Asia. This is in line with comparable research documenting heterogeneity in the efficiency of wellbeing, defined as “the amount of energy used per unit of human well-being” (Jorgenson, Alekseyko, & Giedraitis, 2014, p. 419). What factors, then, explain this heterogeneity across countries and time? Has economic development always meant that decreases in poverty have been accompanied by similar proportional increases in emissions? Or has its effect on the environmental efficiency of poverty reduction changed? This is a relevant issue because, in order to eradicate poverty and address emissions simultaneously, a better understanding of which development paths and policies, and when, are better positioned to achieve these ultimate goals is needed. Consequently, the role of economic growth and inequality, as the main macro policies of interest, in driving this trade-off needs to be empirically assessed. This implies also that the three pillars of sustainable development (economic, social and environmental) need to be better linked.

This paper addresses the previous research questions in two steps. First, it develops an analytical framework to formulate hypotheses on the possible effects of growth and inequality on the carbon intensity of poverty reduction (CIPR), defined as the proportional change in the ratio between per capita emissions and the proportion of the population above the poverty line (defined as *non-poverty*). The CIPR indicates whether emissions levels have increased proportionally more than wellbeing, in the form of *non-poverty;* and whether, therefore, poverty reduction has become more carbon-intensive. Second, it empirically tests the framework through an econometric analysis based on a derived dataset, from different sources, of 609 spells, defined as intervals of time, from 1981 to 2012. The countries included in the sample (135) represent the majority of global emissions producers and the majority in global poverty. Following the framework, the aim of the econometric analysis is to estimate the effects of economic growth and inequality, as well as the non-linearity of their effects, on the CIPR. This includes verifying the existence of turning points. This would mean, for the case of economic growth, estimating income levels after which further increases in such levels increase the carbon intensity of poverty reduction. This would imply the existence of an inverted Kuznets curve.

The results of the analysis show that, while the majority of countries witness both decreases in poverty and increases in emissions, the relationship between changes in poverty and changes in emissions levels shows different elasticity values across both countries and regions. The empirical estimation based on the proposed analytical framework confirms that, at the country level, the effect of economic growth on the CIPR is not linear. Up to a certain income level further growth has a negative effect (ie it reduces the carbon intensity), while, after a turning point, the effect becomes positive. On the other hand, reductions in inequality unambiguously reduce the CIPR. The results are robust for different poverty lines and different model specifications.

The paper concludes by underlining the tension between two policy levels – the national and the global. In fact, the national carbon intensity of poverty reduction needs to confront global environmental boundaries. This has two main implications. First, it is important to emphasise that high-income countries need to drastically decrease their emissions. On the other hand, it is also important to focus on the implications for developing countries, as they represent the majority of the global population. Indeed, despite decreasing the carbon intensity of poverty reduction at the national level, economic growth in large middle-income countries (which find themselves below the estimated turning points) would imply catastrophic effects on global emissions. Therefore the paper argues the need for a significant greening of economic growth, together with the increasing use of direct antipoverty policies. Green economic development can also be seen as an opportunity for developing countries. The paper further contributes to the literature by joining the three pillars of sustainable development – economic, social and environmental – considering poverty as the social dimension.[1]

The paper is organised as follows. Section 2 presents a preliminary analysis of the current and past trends of poverty and emissions levels. In Section 3 the extant literature on the factors that affect poverty and emissions is reviewed, with a particular emphasis on economic development and inequality. Section 4 develops an analytical framework unifying the literatures previously assessed. Section 5 then presents the data and the estimation methods used for the econometric analysis. The results of the estimations are presented in Section 6, while the conclusions and policy implications are discussed in Section 7.

2. Current and recent trends in global poverty and emissions

Much progress has been made towards income poverty eradication, especially over the past four decades.[2] Extreme poverty (US$1.90 a day in 2011 purchasing power parity – PPP) decreased from over 40% at the beginning of the 1980s to around 10.7% in 2013 (and 16% in 2010; World Bank (2016)). Yet it can be argued that such progress has been achieved at the expense of the environment, as measured by CO_2 emissions per capita.[3] Estimated annual CO_2 emissions per capita have in fact risen globally from 4.2 to 4.8 metric tons, representing a 16% increase over the past 30 years (from 1981 to 2010 (World Bank, 2016)).[4]

Nevertheless, these changes show significant variations by region, as shown by the elasticities in Table1. The East Asia and Pacific region witnessed a significant jump in emissions, while the Latin America and Caribbean region experienced only a slight increase. What is interesting, however, is that these two regions experienced similar decreases in the poverty headcount. This means that poverty reduction has been achieved in a more 'environmentally efficient' way (ie with fewer emissions) in Latin America than in East Asia. By contrast, in Sub-Saharan Africa poverty has been reduced (only in the past decade) in the presence of a nearly constant volume of per capita emissions. These trends show that, in the long run, while decreases in poverty are usually accompanied by increases in emissions, the elasticities between poverty reduction and changes in emissions levels are not homogeneous across regions. Such results indicate, therefore, that there may be important lessons to be learned from countries and regions that have addressed these goals in different ways.[5]

[1] There are many other social dimensions in the SDGs, such as health and education.
[2] The $1.90-a-day poverty line has been used as a global estimate was available. 'Moderate' poverty (measured with a higher poverty line of US$3.10 a day in 2011 PPP) followed a similar path, but no global estimate was available.
[3] As for the case of poverty as a social dimension, there are many other environmental dimensions included in the SDGs (and in the planetary boundaries framework) such as forest coverage, oceans or ecosystem services.
[4] Regional emissions estimates are sourced from the World Bank for comparability between emissions and poverty estimates using the same 'developing regions'. Data downloaded on 13t February 2017.
[5] See Ravallion (2016) for differences between China, India and Brazil.

Table 1: CO_2 emissions per capita and poverty headcount (US$1.90 a day) changes from 1993 to 2008, by region

Region	Emissions change (1)	Poverty change (2)	Elasticity (Ratio (1)/(2))
East Asia and Pacific	73.3%	-71.6%	-1.02
Europe and Central Asia	-8.3%[a]	-52.3%	0.16
Latin America and Caribbean	24.0%	-50.6%	-0.48
Middle East and North Africa	34.3%	-62.9%	-0.55
South Asia	66.0%	-34.5%	-1.91
Sub-Saharan Africa	7.1%	-19.5%	-0.36
World	17.3%	-46.8%	-0.37

Notes: 1993 has been used as the baseline year for this table as CO_2 emissions estimates for Europe and Central Asia are missing for previous years. 2008 has been used as the final year as 2010 estimates of poverty were missing for the Middle East and North Africa regions.

[a] *Eastern Europe and Central Asia represent an outlier thanks especially to "the transition period from socialism to market economies" (Ferreira & Ravallion, 2009).*

Source: Author's elaboration based on World Development Indicators (World Bank, 2016).

The short-term relationship between changes in poverty and emissions within countries appears to be even more heterogeneous. Table 2 divides the spells (defined as intervals of time of at least two years; a full explanation will be given in the data section) according to the direction of changes in both the poverty headcount (using the $3.10-a-day poverty line) and emissions per capita levels. The resulting 2x2 matrix shows that, among the four possible categories (a, b, c and d), the most frequent (272 out of 609 spells, around 45%) is the one identifying spells with increasing emissions and decreasing poverty (category b). This is expected, especially in the context of developing countries (which represent the majority of countries in the sample). In fact, recent achievements in terms of poverty reduction have largely been accompanied by economic growth and increased importance of the manufacturing sector, closely linked to increases in emissions (Ravallion, 2016).[6] Nonetheless the other categories (a, c and d) represent a significant share of the total spells. Therefore, it can be argued that there is no definitive relationship between changes in poverty and emissions in the sample at hand. One category of particular interest is d, the spells where both poverty and emissions have decreased. Among the 125 spells, the majority are in high-income European economies, which are lowering emissions through a transformation towards

[6] The opposite is also true. And it explains spells during which emissions decreased and poverty increased.

a service economy,[7] and in Sub-Saharan African countries, which have decreasing emissions per capita thanks to significant population growth and an underdeveloped manufacturing sector. Finally, 32 cases of category d are related to Latin American countries. In 23 of these cases, inequality has decreased. It seems that, for this region, simultaneous decreases in poverty and emissions have been achieved also through a reduction in inequality.

Table 2: Changes in poverty and per capita emissions, frequency

Sample = 609 total spells		*CO_2 emissions per capita, excluding LUCF*	
		Growth (>=0)	Decrease
Poverty headcount	Growth (>=0)	103 (a)	109 (c)
(US$3.10 a day, 2011 PPP)	Decrease	272 (b)	125 (d)

Source: Author's elaboration.

In summary, interesting and puzzling differences on the relationship between changes in poverty and emissions per capita levels exist. While part of the heterogeneity in the trade-off might depend on the starting points (ie the initial levels of poverty and emissions), other factors may be significant in explaining the differences. Their identification and analysis is crucial to making poverty eradication less carbon-intensive.

3. Review of the literature linking the three pillars of sustainable development

Sustainable development is a balance between economic, social and ecological goals (Redclift, 1991). To date, empirical research at the macro level has addressed only marginally the direct links between poverty (defined as the social goal) and environmental dimensions, such as emissions levels. Indeed, these two issues have traditionally been linked only indirectly in the economics literature through frameworks related to economic development and general macro policies.

Research on direct links has focused on alternative measures of wellbeing such as average life expectancy at birth (Dietz, Rosa, & York, 2012; Jorgenson et al., 2014; Knight & Rosa, 2011). These studies define the ratio between carbon emissions and a wellbeing indicator (or the inverse ratio) as efficiency, or carbon intensity, of wellbeing.[8] This literature showed how, for low levels of income, economic growth increases the

[7] These countries may have very low levels of poverty, but some of them have lowered them slightly.
[8] Called environmental or energy intensity of wellbeing (EIWB) and carbon intensity of well-being (CIWB). The inverse ratio is called environmental efficiency of wellbeing (EWEB).

efficiency of wellbeing, while environmental pressure per unit of wellbeing increases after a certain threshold (Dietz et al., 2012; Knight & Rosa, 2011). Jorgenson et al. (2014) also show that the relationship between average income and efficiency of wellbeing has changed over time, with an improved relationship between efficiency of wellbeing and economic development. Knight and Rosa (2011) also estimate the negative impacts of higher inequality on the efficiency of wellbeing. The use of these wellbeing indicators is also the result of better data availability compared with the scarcity of poverty data (Jean et al., 2016).

Despite being correlated and sharing similar drivers, different indicators represent different concepts (or dimensions) of wellbeing. Therefore an analysis that directly links poverty to the environmental and economic dimensions is crucial in the context of poverty eradication efforts. In order to do this, it is necessary to first critically review, and successively connect, the existing literatures linking economic development to emissions and poverty.

3.1. The environmental Kuznets curve: emissions, income and inequality

Empirical research on the determinants of emissions has focused on the relationship between income and emissions per capita across countries.[9] Most prominent in this literature are analyses of the EKC, which depicts the relationship between a country's mean income and environmental pressures (as defined by CO_2 emissions per capita as well as other greenhouse gas (GHG) concentrations). For most local pollutants, these analyses find an inverted-U shaped relationship; this means that, once a certain income threshold has been reached, emissions per capita actually decrease with increasing income per capita. For CO_2 emissions, on the other hand, turning points have been found at very high levels of income; the relationship between income and CO_2 levels increases monotonically, albeit not according to a strictly linear relationship (Stern, 2015).

Several different explanations have been proposed for these findings. Andreoni and Levinson (2001) suggest that declines in the rate of emissions at higher income levels result from changes in the composition of production and consumption. The former may be represented by different factors, such as the scale of production, the composition effect, changes in the input mix, technology and international reallocation (Copeland & Taylor, 2004; Stern, 2015). The latter reflects stronger preferences and behaviours towards the environment and the influence of the introduction of institutions that internalise external diseconomies (Dasgupta & Maler, 1995).

Empirical research has also begun to investigate the relationship between inequality and emissions levels (Grunewald et al., 2017; Ravallion et al., 2000). This research is closely linked to studies of political economy (Boyce, 1994; Torras & Boyce, 1998) in which it is suggested that greater power inequality leads to higher pollution levels through the preference for short-run benefits. These studies suggest that greater levels

[9] Empirical research has aimed to validate theories, such as those on modernisation or the treadmill of production.

of inequality may reduce the ability of societies to reach political agreements concerning the environment and to consider the environment as a public good to be protected. Other studies, by contrast, suggest that higher inequality could mean higher exclusion from the carbon economy and hence lower emissions (Ravallion et al., 2000): the poor lack access to modern energy and lead largely carbon-neutral lives. This is a mirror argument to the aggregation bias put forward by Heerink, Mulatu, and Bulte (2001); they suggest that lower levels of inequality may result in higher levels of emissions, depending on the redistribution of income and the marginal propensity to emit.

A final group of studies examines the interaction effects between income and inequality. Ravallion et al. (2000), for example, conclude that, for low-income countries, higher inequality decreases emissions, while the opposite is true for high-income countries. For low-income countries, there is a trade-off between inequality and emissions when mean income increases. The marginal impacts of economic growth on emissions decline as average income increases. Therefore, reducing between-country inequality will tend to increase emissions, as countries with a high marginal propensity to emit will have a higher share of global income. This work suggests that trade-offs exist between income and inequality regarding emissions levels.

3.2. The poverty–growth–inequality triangle

The poverty–growth–inequality triangle analyses inequality and growth as determinants of poverty. Since this literature has been summarised in depth by others (Bourguignon, 2004; Ravallion, 2016), only a brief overview of the main findings is presented here.

Much of the empirical research on poverty reduction indicates growth as the major determinant of poverty reduction (Deininger & Squire, 1998; Dollar, Kleineberg, & Kraay, 2016; Dollar & Kraay, 2002; Janvry & Sadoulet, 2000; Kraay, 2006; Ravallion, 2001; Ravallion & Chen, 1997). This is true even if different measures of poverty are used.[10] Estimates of the growth elasticity of poverty reduction find an average value of between minus 2 and minus 3 (Adams, 2004; Ravallion & Chen, 1997; Ravallion, Squire, & Bruno, 1999).

However, growth is not the only determinant of poverty reduction. In fact, it is common to decompose poverty reduction into changes in income and inequality (Bourguignon, 2003; Dollar et al., 2016; Fosu, 2017; Ravallion & Huppi, 1991).[11] Such decomposition allows an analysis of the effects of inequality, which can be made using different measures, such as the Gini index (Bourguignon, 2003) or the Lorenz curve (Datt & Ravallion, 1992). The latter estimates changes in poverty with precision (as it represents a mathematical identity), but it requires full information about income distribution. The former has fewer data requirements, but relies on significant

[10] In some cases they refer to absolute levels of poverty (Bourguignon, 2003; Kraay, 2006), while in others they refer to relative levels (Dollar et al., 2016).
[11] Channels for faster or better poverty eradication include direct transfers and inclusive growth.

assumptions concerning income distribution.[12] Studies that apply this decomposition find that growth remains the main determinant of poverty reduction, but changes in inequality play a statistically significant role as well (Adams, 2004; Bourguignon, 2003; Datt & Ravallion, 1992; Epaulard, 2003; Kalwij & Verschoor, 2007; Kraay, 2006).

Further, as in the case of the EKC literature, the interaction between growth and inequality has been found to be relevant for poverty reduction (Bourguignon, 2003; Datt & Ravallion, 1992). Studies on the growth elasticity of poverty find that such elasticities are heterogeneous and vary by country.[13] One of the main elements explaining the heterogeneity of growth elasticities is the initial level of inequality, which is important for two main reasons (Bourguignon, 2003).[14] First, it is an impediment to growth. Second, it hinders the effects of growth on poverty.[15] Although growth has been found to reduce poverty more significantly in less unequal societies, there is less evidence of a systematic relationship between economic growth and changes in inequality. In fact, studies suggest that it is not the interaction between economic growth and changes in inequality, but more the latter's initial level, that is significant for poverty reduction (Bourguignon, 2003; Dollar et al., 2016; Dollar & Kraay, 2002).

4. A model linking changes in poverty and emissions and their determinants

4.1. Carbon intensity of poverty reduction and trade-offs

Let us consider a policy maker who is concerned with reducing poverty and addressing environmental degradation, defined by emissions levels per capita. Poverty (P) is conceptualised as "substantial deficits in *well-being*" (Barrientos, 2013, p. 36).[16] Using a 'non-welfarist approach', instead of maximising social welfare (which considers individual utilities and aggregates them), the social planner addresses poverty and emissions levels as joint and simultaneous goals. Ideally, the policy maker would like to eradicate (reduce) poverty and lower emissions. In practice, however, this is problematic, especially in the short-term; therefore the policy maker needs to confront a trade-off. Previous literature (Dietz et al., 2012; Jorgenson, 2014; Jorgenson et al., 2014; Knight & Rosa, 2011) used as a metric the energy intensity of wellbeing, defined as the ratio between emissions per capita (E) and wellbeing (WB) and (therefore $\frac{E}{WB}$).[17] In contrast to this literature, the paper employs the proportion of population above the poverty line (1-P), also defined as *non-poverty,* as the measure of national wellbeing.

[12] A middle ground methodology (Kraay (2006)) is used to estimate Lorenz curves from shares of income deciles.
[13] Kraay (2006, p. 201) identifies one of the drivers of pro-poor growth as "the sensitivity of poverty to growth in average incomes". On the other hand, Ravallion (2012); Thorbecke (2013) show the significance of initial poverty levels.
[14] The size of the middle class or the initial level of poverty can be also used (Ravallion, 2016).
[15] Bourguignon (2003) calls these two reasons the "double dividend".
[16] And measured with the F-G-T index $P(x, z, \alpha) = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{z-x_i}{z}\right)^{\alpha}$ (Foster, Greer, & Thorbecke, 1984).
[17] Dietz et al. (2012); Knight and Rosa (2011) used the inverse ratio (the environmental efficiency of wellbeing).

The environmental efficiency of poverty can therefore be thought of as the percentage of the population above the poverty line for each unit of carbon emissions per capita. As we are interested in the proportional change, the CIPR between t and $t-1$ can be represented as the proportional change of the ratio between per capita emissions and *non-poverty*:[18]

$$CIPR_{t,t-1} = \left(\frac{\left(\frac{E_t}{1-P_t}\right)}{\left(\frac{E_{t-1}}{1-P_{t-1}}\right)}\right) - 1 = \ln\left(\frac{E_t}{1-P_t}\right) - \ln\left(\frac{E_{t-1}}{1-P_{t-1}}\right) \quad (1)$$

A positive value of the CIPR indicates that *non-poverty* for each unit of emissions per capita has increased, indicating efficiency in poverty reduction. Rearranging the terms, the CIPR can also be described as the trade-off (Tr) between proportional changes (Δ) in emissions levels and *non-poverty*. In fact:

$$CIPR_{t,t-1} = \ln\left(\frac{E_t}{1-P_t}\right) - \ln\left(\frac{E_{t-1}}{1-P_{t-1}}\right) = (\ln(E_t) - \ln(E_{t-1})) - (\ln(1-P_t) - \ln(1-P_{t-1})) = \Delta_{t,t-1}E - \Delta_{t,t-1}(1-P) = Tr\left(E_{t,t-1}, 1-P_{t,t-1}\right) \quad (2)$$

$Tr\left(E_{t,t-1}, 1-P_{t,t-1}\right)$ is therefore represented as the difference between the proportional changes of per capita emissions ($\Delta_{t,t-1}E$) and *non-poverty* ($\Delta_{t,t-1}(1-P)$). This second notation and conceptualisation is useful in the next section when the effects of growth and inequality are analysed. In the remainder of the paper, as they both indicate the same thing, the term ‘carbon intensity of poverty reduction’ (CIPR) is mainly used, but in a few instances the concept of trade-off is also employed.

4.2. Growth and inequality as drivers of poverty reduction and emissions: an analytical and graphical representation

The extant literature suggests that both the poverty and the emissions levels of countries (as measured in terms of both absolute amounts and changes over time) may be represented as a non-linear function of mean incomes and inequality.[19] The non-linearity is related to the fact that the effects of income and inequality (especially the former) depend on their levels. For example, emissions rise rapidly when income is at lower levels than inequality, while this relationship becomes flatter at higher income levels. The non-linearity includes interactions between the two determinants.

To integrate this in the equations (1) and (2), the income of individual i in country *c,* and at time *t* can be defined through the following non-linear relationship:

[18] Percentage changes can be expressed by difference in logarithms.
[19] This is true especially in the case of poverty, as shown by Bourguignon (2003); Datt and Ravallion (1992). Many scholars like Datt and Ravallion (1992) use the ratio between the poverty line and the mean income instead of the mean income. Datt and Ravallion (1992) also use the full Lorenz curve instead of inequality, as they do not work with the assumption of log-normal distribution as Bourguignon (2003) does.

$$x_{i,c,t} = x(\bar{x}_{c,t}, \emptyset_{c,t}) \quad (3)$$

where $\bar{x}_{t,c}$ and $\emptyset_{c,t}$ are the average income and the inequality in country *c* at time t. Adding (3) as a determinant in (1), the CIPR between t and $t-1$ can be rewritten as:

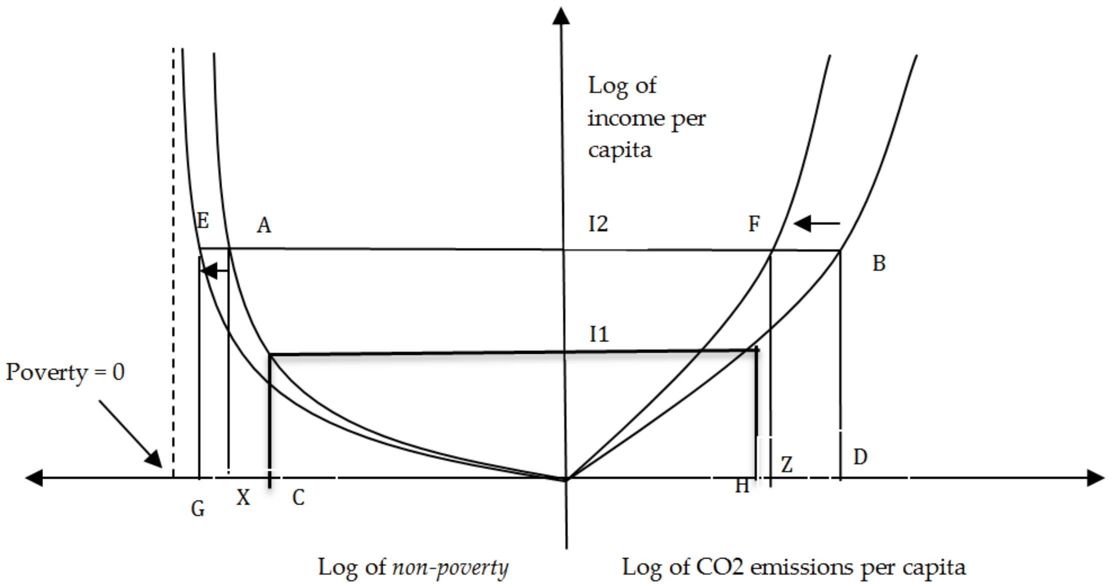
$$CIPR_{t,t-1} = Tr\left(E_{t,t-1}, 1 - P_{t,t-1},\right) = \left(\left(\ln\left(E_{c,t}(\bar{x}_{c,t}, \emptyset_{c,t})\right) - \ln\left(E_{c,t-1}(\bar{x}_{c,t-1}, \emptyset_{c,t-1})\right)\right) - \left(\ln\left(1 - P_{c,t}\left(x(\bar{x}_{c,t}, \emptyset_{c,t}), z, \alpha\right)\right) - \ln\left(1 - P_{c,t-1}\left(x(\bar{x}_{c,t-1}, \emptyset_{c,t-1}), z, \alpha\right)\right)\right)\right) = f(\bar{x}_{c,t}, \emptyset_{c,t}, \bar{x}_{c,t-1}, \emptyset_{c,t-1}) \quad (4)$$

Equation (4) formally defines the CIPR as a function of mean income and inequality. Non-linearity remains a feature of the relationship and includes interactions between income and inequality (and their changes), as well as changes and levels of the two determinants.

Equation (4) is represented graphically in Figure 1 showing the relationship between income per capita (vertical axis, in logarithmic terms), and both emissions per capita (right side of the horizontal axis, in logarithms as well) and *non-poverty* (left side of the horizontal axis, in logarithms as well). For simplicity, relationships shown in Figure 1 follow three assumptions from the literature (Section 3). First, the concave curve on the left-hand side of the figure considers diminishing returns of increases in income for poverty reduction *(non-poverty* increases).[20] This is consistent with the literature, which finds that the growth-elasticity of poverty reduction is heterogeneous across countries (Sumner (2016), among many others). Second, the relationship between income and CO_2 emissions is represented by a monotonically increasing (concave) curve. This follows the EKC literature, which focuses on CO_2 emissions.[21] Third, these graphical relationships aim to describe the dynamics *within* countries.

[20] Estimates vary between minus 2 and minus 3 for developing countries (Bourguignon, 2003), meaning that a 10% income growth decreases poverty by 20% or 30%. Other studies found even higher elasticity (Sumner, 2016).
[21] It must be noted that, when local pollutants are considered, an inverted U shape is found.

Figure 1: *Non-poverty*, emissions and income within countries



Source: Author's elaboration.

An increase in income from $I1$ to $I2$ (two points on the vertical axis) simultaneously affects poverty and emissions. The (logarithm of) *non-poverty* increases from C to X. Emissions, on the other hand, increase from H to D. These are proportional changes, as logarithms are used. If $\overline{HD}$ is larger than $\overline{XC}$ it means that, proportionally, the increase in emissions is larger than the one for *non-poverty* ($CIPR_{t,t-1} = Tr\left(E_{t,t-1}, 1 - P_{t,t-1}\right) > 0$). Thus income growth results in a positive effect on the CIPR. If, on the other hand, the percentage increase in emissions is smaller than the *non-poverty* one (ie if $\overline{HD} < \overline{XC}$ and $CIPR_{t,t-1} = Tr\left(E_{t,t-1}, 1 - P_{t,t-1}\right) < 0$, income growth decreases the carbon intensity of poverty reduction. But, given the different concavity of the two curves in Figure 1, the effect of income increase might be non-linear, describing the following first proposition to be tested:

> *Economic growth decreases the carbon intensity of poverty reduction (CIPR) for low income levels, turning to a positive effect for higher mean incomes.*

Focusing now on inequality, lower levels of inequality are associated with lower poverty headcount values (for the same level of income). Similarly, it is assumed that lower inequality means lower emissions.[22] Keeping mean income constant ($I2$), a decrease in inequality would raise the logarithm of *non-poverty* from X to G, while emissions per

[22] The literature was not definitive for emissions levels (see Section 3).

capita would decrease from D to Z (in logarithms).[23] Thus the second proposition to be tested is:

Decreasing inequality unequivocally decreases the carbon intensity of poverty reduction (CIPR).

In order to keep the graphical analysis simple, the interaction effects between income growth and inequality (changes) are not taken into account in the figure, but are considered in the econometric analysis.[24]

5. Data and methodology

5.1. Data

The data used in the analysis are drawn from two main sources. The main poverty, inequality and mean income data (presented in US$ using 2011 PPP) have been sourced from *PovcalNet*.[25] This source is used because the data are estimated from the most comprehensive collection of household surveys from developing countries. Moreover, these data are employed by the majority of studies on cross-country poverty in the literature. These data also allow the estimation of alternative poverty and inequality measures with different absolute poverty lines.[26] Robustness checks for income data are conducted using data from the *Penn World Tables*,[27] which include GDP estimates from national accounts and derived expenditure-side real GDP (Feenstra, Inklaar, & Timmer, 2015), and GDP estimates sourced from World Bank (2016), following the EKC literature.

Emissions data come from the Climate Analysis Indicators Tool (CAIT).[28] The reason CAIT is used as a data source is that it includes historical CO_2 emissions and emissions from different sources, sectors and pollutants. More specifically, a major advantage of CAIT data is the availability of estimates of GHG and CO_2 emissions, including land-use change and forestry (LUCF), estimated from 1990 to 2012, which are employed in some of the quantitative analyses. Since poverty eradication is the main focus of this paper, it was important to test for the inclusion of emissions sources closely linked to poverty reduction, such as agriculture and changes in land use. Nonetheless, the number of available estimates for CO_2 (and GHG) emissions

[23] This is a simplification, as decreases in inequality might actually increase emissions. But, as this is less common, for simplicity it has not been considered in this graphical representation.
[24] Section 3 has pointed out that that economic growth has a much higher poverty reduction capacity if initial inequality is low. A similar reasoning applies for emissions. On the other hand, no systematic correlation has been found between changes in income and inequality.
[25] http://iresearch.worldbank.org/PovcalNet/povOnDemand.aspx. Accessed: December 2016.
[26] However, there are significant drawbacks in using these data. See Ravallion (2016), for a detailed summary and explanations. For China, India and Indonesia national inequality (the Gini Index) for the missing values has been derived from different sources.
[27] http://cid.econ.ucdavis.edu/pwt.html. Accessed: December 2016.
[28] http://cait.wri.org/. Unlike in the *PovcalNet* data, there are no CAIT estimates for Kosovo, Micronesia, South Sudan, Saint Lucia, Timor Leste, Tuvalu, West Bank and Gaza.

excluding LUCF is significantly greater than that including LUCF. Robustness checks using CDIAC data are still performed, as these data are used in many studies in the literature. Data on carbon footprints is not considered as there are missing values for relevant country-years observations in the existing datasets.

Additional variables are used as covariates in the regressions. Data are sourced mainly from the World Bank (2016). They include trade as a percentage of GDP, the share of employment in agriculture, industry and services, urbanisation rate, population size and population density, the sources of electricity production, forest cover and literacy rates. Two additional data sources have also been used. Data on legal origins have been sourced from La Porta, Lopez-de-Silanes, and Shleifer (2008), while data on average temperatures have been taken from Mitchell, Hulme, and New (2002).These variables have been used in studies related to the EKC. Moreover, as estimates were not available for all countries and all years, interpolation techniques have been implemented for missing values.

The final dataset consists of 609 spells from 135 countries. Following the literature, percentage changes are calculated as the difference between logarithms. Trimming of the original data has been performed following the literature (especially Adams (2004); Bourguignon (2003)), to improve the robustness of the estimations. First, spells have been kept if the same welfare indicator (income or consumption) was used at both ends (initial and final year of the spell). Second, spells of at least two years have been considered. Finally, the spells in which the annual proportional and absolute changes in the poverty headcounts, per capita emissions, and mean incomes are too large, are considered as outliers and dropped.[29]

[29] In this process 55 spells have been discarded. Annual changes larger than 100% in proportional terms, or annual absolute changes of the poverty headcount of over 10 have been excluded. Adams (2004) also excludes observations from non-nationally representative surveys and considered excluding countries from Eastern Europe and Central Asia because of the effect of the collapse of the Soviet Union. Bourguignon (2003) refers to spells with abnormal changes. An alternative would have been to follow Dollar et al. (2016) for outliers.

5.2. Summary statistics

Table 3 shows the unweighted averages of the annual proportional changes in the main variables for all spells. Annual average (compound) growth rates for each variable are calculated as the difference between logarithmic values of two consecutive points in time, divided by the length of the spell in years. Income per capita increased on average by 1.9% annually. Poverty headcounts decreased on average for all poverty lines. For the poverty estimates, different poverty lines were considered, based on (Hoy & Sumner, 2016). Each line represents a different concept of poverty. Considering the poverty lines of $1.90, $3.10, $5 and $10 a day, the annual average decrease has been of 4.9%, 3%, 2.1% and 1%, respectively. Inequality, represented by the Gini index, exhibits an average decrease of 0.2%, while still exhibiting significant variance. Finally, emissions increased annually by 1.2% on average (when considering total CO_2 emissions from CAIT excluding LUCF).

Table 3: Average annual percentage change of the main variables

	(1) **count**	**(2)** **mean**	**(3)** **sd**	**(1)** **min**	**(1)** **max**
Poverty headcount (1.90)	609	-4.89%	23.88%	-95.21%	93.59%
Poverty headcount (3.10)	609	-3.04%	17.35%	-89.59%	80.47%
Poverty headcount (5)	609	-2.05%	13.52%	-63.65%	82.43%
Poverty headcount (10)	609	-1.04%	7.91%	-38.59%	46.26%
Gini Index	609	-0.16%	2.77%	-13.50%	12.76%
Mean income (HH surveys)	609	1.90%	5.10%	-19.73%	19.11%
CO_2 emissions per cap, excl LUCF	609	1.20%	5.37%	-21.55%	18.91%

Source: Author's elaboration.

Figure 3, in Appendix 1, shows the relationships between the values of *non-poverty* (top half) and emissions (bottom part), represented on the vertical axes, and mean income (horizontal axes). The description of the figure seems to give a preliminary validation of the relationships outlined in the framework. But, as this figure employs static data and not the values of the changes, which is the primary interest of the paper, Figure 3 is merely employed as a descriptive tool.

5.3. Econometric strategy

The aim of the econometric analysis is to estimate the effects of different dependent variables on the CIPR defined in (1), which is also expressed as the trade-off between proportional changes in emissions and *non-poverty*. To achieve this, spells (defined as the period between two points in time) are used. As in both empirical literatures previously analysed (the EKC and the poverty–growth–inequality triangle), the use of spells allows us to overcome methodological limitations (Bourguignon, 2003; Dollar et al., 2016; Kraay, 2006).[30] These limitations include the highly unbalanced nature of the panel at hand (especially as a result of missing poverty estimates for many countries and years), as well as the low number of observations available for each country in the sample. In relation to poverty, one major issue is that surveys can differ between countries in several important aspects, such as the use of income or consumption, the items of consumption and income included in the survey countries, the coverage (national or sub-national level), and the unit of observation (households or individuals) (Dollar & Kraay, 2002). The use of spells enables consideration only of the changes between comparable estimates, such as those using similar surveys (Iradian (2005). Although panel data methods are still dominant (Uchiyama, 2016), the use of spells has recently started to be employed also in the EKC literature (Sanchez & Stern, 2016; Stern, Gerlagh, & Burke, 2017).[31] These models are inspired by Ordás Criado, Valente, and Stengos (2011), who studied beta convergence of emissions and income.

In addition, literature already discussed (Dietz et al., 2012; Jorgenson, 2014; Knight & Rosa, 2011) has pointed out possible estimation issues when the analysis employs a composite dependent variable, such as the CIPR. One major problem is that, if the value and variability of the numerator and denominator differ substantially, a ratio may be dominated by one or the other. Alternative solutions may be implemented, such as constraining the coefficient of variation of the numerator and denominator to be equal, or employing as a dependent variable the unstandardised residuals obtained from regressing the wellbeing measure on the environmental variable. As the CIPR uses proportional changes, the issue previously described does not affect the analysis in this case. Nonetheless, the second method has also been used for robustness checks, delivering similar results.

The independent variables include growth in mean incomes, changes in inequality, and their respective interactions, as well as the additional explanatory variables previously outlined.[32] The choice of the specific additional variables is driven by the difficulty of finding instrumental variables at the macro level (according to Bazzi and Clemens (2013)).

[30] The main concern with unbalanced panel data is whether observations could be missing at random.
[31] Panel data methods are desirable when estimating the original EKC, as data on GDP and per capita emissions are usually available for the majority of countries and years, resulting in a very balanced panel.
[32] Using the Gini index, instead of the more technical decomposition approach used by Datt and Ravallion (1992); Kraay (2006), this paper follows the approach of Bourguignon (2003) discussed in Section 3.

The final equation to be estimated is:[33]

$$CIPR_{t,t-1} = Tr\left(E_{i,t,t-1}, 1 - P_{i,t,t-1}\right) = \beta_0 + \beta_1 \hat{x}_{it} + \beta_2 \hat{x}_{it} \ln(x_{i,t-1}) + \beta_3 \ln(x_{i,t-1}) + \beta_4 \ln(EI_{i,t-1}) + \beta_5 \ln(P_{i,t-1}) + \beta_6 \widehat{\emptyset}_{it} + \beta_7 \ln(\emptyset_{i,t-1}) + \beta_8 \widehat{\emptyset}_{it} \ln(\emptyset_{i,t-1}) + \beta_9 \ln(\emptyset_{it-1}) \hat{x}_{it} + \beta_{10} \widehat{\emptyset}_{it} \ln(x_{i,t-1}) + \sum_{j=11}^{J} \beta_j \, \pi_{it} + \varepsilon_{it} \quad (5)$$

where $CIPR_{t,t-1} = Tr(E_{i,t,t-1}, 1 - P_{i,t,t-1})$ is the annualised CIPR between times *t* and *t-1*; $\hat{x}_{it}$ and $\widehat{\emptyset}_{it}$ are the annual average growth rates in mean incomes and inequality; $ln(x_{i,t-1})$ and $ln(\emptyset_{i,t-1})$ are the natural logarithms of the mean income and the Gini coefficient at time $t-1$; $ln(P_{i,t-1})$ and $\ln(EI_{i,t-1})$ are the logarithms of the *non-poverty* rate and of emissions intensity at time *t-1*; and finally $\sum_{j=11}^{J} \pi_{i,t-1}$ is the set of additional control variables. Turning to the coefficients, β_1 represents the income growth elasticity of the CIPR. The interactions between income growth rates and initial mean income (β_2), and between the annual percentage change in the Gini coefficient and the initial Gini coefficient (β_8) capture the non-linear effect of inequality changes and growth on the CIPR. On the other hand β_9 and β_{10} represent the interaction between growth and initial inequality, and between the initial income level and the change in inequality. All the variables in levels are demeaned to simplify the interpretation of the coefficients. A positive value of a coefficient indicates that an increase in the variable has a positive effect on the CIPR.

If β_1 is positive and β_2 negative, an important issue is the possible presence of a turning point related to income, which can be calculated as $\mu = \exp\left(\frac{-\beta_1}{\beta_2}\right)$.[34] This would mean that higher income levels do not always have the same effect on the dependent variable. I have also estimated a further specification of the above model, allowing for a cubic relationship between the CIPR and income (Uchiyama, 2016). But the second turning point that I found was nonetheless very high and significantly outside the sample. For simplicity the model with the quadratic relationship is employed.

To estimate equation (5) Ordinary Least Squares (OLS) regression methods are employed (Bourguignon, 2003), but several issues must be taken into account. These estimations can, in fact, be affected by measurement errors, omitted variables and reverse causation.[35] The use of robust standard errors accounts just for heteroscedasticity heteroscedasticity. On the other hand, fixed effects (and first differences) or random effects control for the presence of unobserved country-specific effects, and account for serial correlation and heteroscedasticity.[36] But the use of fixed

[33] The interaction between changes in income and inequality has not been included in the regression, as it has not been found to be significant in the literature. Dollar et al. (2016).
[34] The calculation of the turning points is performed with estimates from regressions where variables are not demeaned. But caution needs to be exercised as different countries use surveys that are methodologically distinct.
[35] See Ravallion (2016) for a summary of these issues.
[36] The fixed effects estimations attenuate the bias by eliminating the time-invariant characteristics.

effects has been associated with coefficients biased towards zero thanks to a low signal to noise ratio (Hauk & Wacziarg, 2009; Ravallion, 2016). In the literature OLS estimations with robust standard errors are usually employed when dealing with spells. However, I also estimate panel methods (fixed and random effects, not presented here) as robustness checks.[37]

What about the assumption of the exogeneity of the regressors and the causality claims? For example, simultaneity, together with heteroscedasticity , omitted variables bias, and co-integration, constitutes a standard criticism of the econometric methods employed in the EKC (Stern, 2004). Therefore, the choice of the variables to use in the regression needs further clarification. When considering emissions levels, there is no strong evidence of causality running from emissions to income, except in the case of more developed countries.[38] However, these countries represent a small share of the sample. As a result, simultaneity between income, inequality and emissions should not be of concern (Grunewald et al., 2017; Stern, 2004). On the other hand, within the empirical literature on poverty reduction, Ravallion (2012); Thorbecke (2013) make the case for controlling for the initial level of poverty, which is included in equation (5).[39] Nonetheless, some bias might still be of concern; to address this, I further estimate equation (5) with Generalized Method of Moments (GMM) estimators. The results are similar to the OLS regressions.[40]

6. Results

6.1. Regression results

Table 4 shows the results for the econometric estimation of equation (5), when the poverty line of $3.10 a day in 2011 PPP is used. It presents regression estimates by OLS controlling for hetero-scedastic and clustered standard errors.[41] Different gradual models are estimated, to test the significance of the inclusion of different variables. Model (1) includes only the growth in mean incomes as a regressor. This gives an initial indication of the average effect of growth on the CIPR. Model (2) considers the non-linearity of the effect of economic growth, through the inclusion of the interaction between the growth rate and the level of mean incomes (in logarithmic terms), as well as the level of mean income on its own. If the coefficient of the interaction term has a different sign compared to the coefficient of income growth, non-linearity in the effects of income growth is assessed. In model (3) variables related to inequality are added.

[37] Grunewald et al. (2017) use a group fixed effects estimator (GFE) and time-varying inequality estimates; they underline the problem of dealing with time-varying unobserved heterogeneity.
[38] Dinda and Coondoo (2006) show no causality, or causality from income to CO2 emissions, in developing countries, as well as causality from CO2 emissions to income in advanced countries.
[39] Ravallion (2012) also uses the growth rate in private consumption per capita from the national accounts as the instrument for the growth rate in the survey mean, to address common measurement errors.
[40] Seemingly unrelated regression equations (SURE) have been also performed. But there was no correlation between the residuals of the equation estimating poverty reduction and those estimating emissions changes. Pooled Mean Group (PMG) estimators could not be employed because of the structure of the data.
[41] All the models also include year fixed effects.

As for the case of income, the possibility of non-linearity in the effects of inequality changes is addressed. In model (4) the initial levels of poverty and emissions intensity are added as further controls. Model (5) includes the interactions between initial inequality levels and income growth, as well as the interaction between changes in inequality and the initial level of income. Finally, in model (6) the additional control variables previously discussed are added.

Table 4: Regression results using the US$3.10 a day poverty line, all models

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CIPR	CIPR	CIPR	CIPR	CIPR	CIPR
Mean income, growth	-0.34***	-0.24***	-0.26***	-0.26***	-0.26***	-0.24***
	(0.07)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)
Mean income, log		-0.01*	-0.01**	-0.03***	-0.03***	-0.03***
		(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
(Mean income, growth)*(Mean income, log)		0.68***	0.71***	0.58***	0.60***	0.59***
		(0.08)	(0.07)	(0.06)	(0.06)	(0.06)
(Gini index, growth)*(Gini index, log)			2.02***	1.83***	1.66***	1.51***
			(0.32)	(0.32)	(0.34)	(0.34)
Gini index, growth			0.28***	0.26***	0.24***	0.22**
			(0.09)	(0.08)	(0.08)	(0.09)
Gini index, log			0.04***	0.02*	0.01	0.00
			(0.01)	(0.01)	(0.01)	(0.01)
Emiss intens, log				-0.01***	-0.01***	-0.01***
				(0.00)	(0.00)	(0.00)
Non-pov $3.10, log				0.05***	0.05***	0.05***
				(0.01)	(0.01)	(0.01)
(Gini index, growth)*(Mean income, log)					-0.07	-0.11
					(0.09)	(0.10)
(Mean income, growth)*(Gini index, log)					0.27	0.25
					(0.19)	(0.19)
Constant	-0.07	-0.05	-0.04	-0.02	-0.02	-0.02
	(0.05)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)
Additional controls	No	No	No	No	No	Yes
Observations	609	609	609	609	609	609
R-squared	0.16	0.35	0.41	0.47	0.47	0.49
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

*Notes: *** p<0.01, ** p<0.05, * p<0.1*

Source: Author's elaboration based on different data sources.

The results of model (1) show that growth in mean incomes decreases, on average, the CIPR with a coefficient of -0.34. This means that, for the average country in the sample, economic growth makes poverty reduction less carbon intensive. Turning to model (2), the coefficient of income growth is still negative and significant (but lower); conversely its interaction with the income level is positive. This means that, where higher–income countries are concerned, the effect of income growth is higher and will turn positive after a certain income value. This confirms the first proposition derived from the framework and will be further explored in the next section.

Model (3) shows that the effect of inequality is unambiguous. The coefficients for the level, the proportional change and the interaction between the level and the proportional change are all positive and statistically significant. This seems to confirm the suppposition derived from the framework that lower inequality has been described as decreasing both poverty and emissions. Therefore, the unambiguous positive effect of decreasing inequality on the efficiency of poverty reduction does not come as a surprise. In model (4), controlling for the initial levels of poverty and per capita emissions does not change the sign or the significance of the coefficients previously analysed. The initial values of *non-poverty* and emissions intensity are both significant, as expected. One interesting finding is that, contrary to the arguments advanced in Ravallion (2012), both the coefficients of initial inequality and initial poverty are significant. But the significance of the former is much lower. Finally, the interactions between income and inequality, introduced in model (5), do not appear significant.

In model (6) the addition of further control variables does not change the size, sign or significance of the previous coefficients. Moreover, in this last model, the R-squared value is the highest, equal to 49%. From the full regression tables presented in Appendix 1 (Table 7), it is interesting to note that the coefficient related to the share of the labour force in the services sector is positive and significant. This may be linked to the fact that growth in the services sector tends to have a lower impact on poverty reduction (Ravallion, 2016; Sumner, 2016). A similar positive impact can be found with higher electricity production from oil, while higher electricity production from renewable sources has a positive effect. The main finding of Table 4 is that the non-linear effect of income growth on the CIPR is significant and robust in all the models. The same can be said of the positive effect of increases in inequality on the CIPR.

Table 5 presents estimations of model (6), but with different poverty lines, to test the robustness of the results and to analyse the different dynamics associated with different poverty lines. More specifically, models (7), (9) and (10) employ poverty lines of $1.90, $5 and $10 a day, respectively. As a benchmark, model (8) is the same as model (6) in Table 4, using a poverty line of $3 a day.

Table 5: Regression results using all poverty lines, final model

	(7)	(8)	(9)	(10)
VARIABLES	CIPR	CIPR	CIPR	CIPR
Poverty line	US$1.90	US$3.10	US$5	US$10
Mean income, growth	-0.03	-0.24***	-0.56***	-1.24***
	(0.04)	(0.04)	(0.05)	(0.09)
Mean income, log	-0.02***	-0.03***	-0.05***	-0.06***
	(0.01)	(0.01)	(0.01)	(0.02)
(Mean income, growth)*(Mean income, log)	0.42***	0.59***	0.74***	0.77***
	(0.06)	(0.06)	(0.08)	(0.12)
(Gini index, growth)*(Gini index, log)	1.33***	1.51***	2.00***	2.91***
	(0.32)	(0.34)	(0.38)	(0.61)
Gini index, growth	0.22***	0.22**	0.08	-0.44***
	(0.08)	(0.09)	(0.11)	(0.14)
Gini index, log	0.01	0.00	-0.01	-0.03
	(0.01)	(0.01)	(0.02)	(0.02)
Emiss intens, log	-0.01**	-0.01***	-0.01***	-0.01*
	(0.00)	(0.00)	(0.00)	(0.01)
(Gini index, growth)*(Mean income, log)	-0.32***	-0.11	0.29**	1.09***
	(0.08)	(0.10)	(0.14)	(0.20)
(Mean income, growth)*(Gini index, log)	0.10	0.25	0.48**	1.00***
	(0.17)	(0.19)	(0.22)	(0.34)
Constant	-0.00	-0.02	-0.02	0.01
	(0.01)	(0.02)	(0.02)	(0.03)
Initial poverty rates	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	609	609	609	609
R-squared	0.41	0.49	0.59	0.63
Year FE	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's elaboration based on different data sources.

The results highlight the following points. First, the non-linearity in the effects of income growth is generally confirmed. The size of the coefficients changes between models using different poverty lines, but the significance and the sign of the coefficients related to income growth and its interaction with the logarithm of the initial income level remain the same for most estimations. The only exception is given by the coefficient for income growth in model (7), when the $1.90 a day poverty line is employed. In this case the coefficient is not significant, thanks to the use of demeaned variables in the regression. Second, the effect of changes in inequality was found not to be significant in the final model (6) in Table 4. By contrast, Table 5 shows that, in the case of the highest poverty line – $10 a day in model (10) – the effect of inequality is non-linear. In fact, the coefficient of the growth in the Gini index is significant and negative, while its interaction with the level of inequality is positive. This is because $10 a day is a much higher poverty line, where different dynamics are in place. Third, different results can be found in the interactions between economic growth and initial inequality and between changes in inequality and the initial income, compared to the benchmark model (8). Both interactions are positive and significant when the two highest poverty lines ($5 and $10 a day) are used. This underlines again the different dynamics in place with higher poverty lines. Despite these exceptions, the propositions put forward from the framework seem to be confirmed also when different poverty lines are considered.

6.2. Turning points

Turning points identify the point after which the effect of a variable on the outcome of interest switches from positive (negative) to negative (positive). For example, in the case of the EKC, the turning point indicates the income level below which further economic growth increases emissions. If a country is at a higher income level, further growth would, on the other hand, decrease emissions. Table 6 shows the estimated turning points for the gradual models seen in Table 4, and considering all four poverty lines. The results of the different models are similar, but for simplicity the last column of the table, which considers model (3) from Table 4 with the addition of the regression controls ($\sum_{j=11}^{J} \pi_{it}$), is considered. Starting with the $3.10-a-day poverty line, the turning point is around $5,000 a year. Therefore it can be said that, if a country has an income per capita below $5,000 a year, economic growth will, on average, decrease the carbon intensity of poverty reduction, at $3 a day poverty. Turning points increase with higher poverty lines, reaching a value of almost $15,000 a year with the $10 a day poverty line. On the other hand, for the international extreme poverty line, the turning point is at $3,750.

Table 6: Turning points, income per capita (US$, 2011 PPP)

Regression model	Model (1)	Model (2)	Model (3)	-
Poverty line	**Covariates:** **only income**	**Covariates:** **Model (1) + inequality**	**Covariates:** **Model (2) + initial poverty and emiss intensity**	**Covariates:** **Model (3) + regression controls**
US$ 1.90	3,561.64	3,784.85	3,820.29	3,750.54
US$3.10	4,719.83	4,816.71	5,130.61	5,037.01
US$5	6,441.28	6,207.98	6,800.94	6,796.03
US$10	16,097.78	12,447.09	15,185.35	14,959.32

Source: Author's elaboration.

How do these results relate to the sample at hand and to global poverty and emissions? A turning point of $5,000 a year would mean that around 66% of the countries in the sample are below that threshold. The mean income of the sample is, in fact, around $5,700 a year; while the median is $3,269.[42] Thus median income level will still be higher than the turning point when the extreme poverty line is used. What this means in general terms is that many countries could still promote the use of economic growth, as it reduces the carbon intensity of poverty reduction. In addition, the results can be compared with previous research. For example, Dietz et al. (2012) estimated a turning point of around $2,500 when using life expectancy and carbon footprints (instead of *non-poverty* and emissions levels) as the wellbeing and environmental indicators. But, contrary to this paper, they use GDP (and not mean incomes), and local currencies are converted to US dollars using exchange rates and not PPP. Therefore the estimates are not fully comparable.[43] Nonetheless it can be inferred that the non-linear effect of economic growth on the environmental efficiency of both *non-poverty* and life expectancy presents similar turning points.

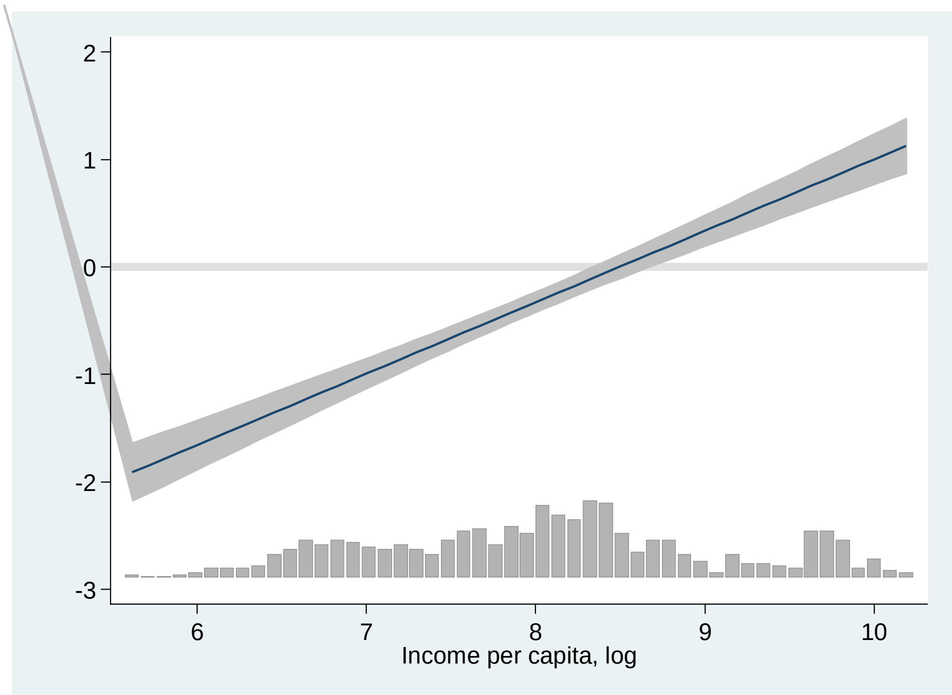
Finally, additional estimations were performed to check the existence of a third turning point (Uchiyama, 2016). This would mean an income level after which economic growth would again decrease the carbon intensity of poverty reduction. This could be exemplified by those countries at very high income levels that have no (or very low and stable) poverty, and where emissions are decreasing. But, as this second turning point was estimated at a very high-income level, significantly outside the sample values, it was not included in the previous analysis.

In summary, the results from the analysis of the effects of economic growth can be described in Figure 2, showing the marginal effects of economic growth on the CIPR by

[42] Using the latest observations for each country.
[43] Moreover, the value of the turning points is higher for GDP than for mean incomes (Ravallion, 2016).

income level (in logarithms). The decreasing marginal effects, crossing the horizontal axis (meaning no effect), confirm the proposition of a U-shaped relationship between economic levels and the carbon intensity of poverty reduction (as shown in Appendix Figure 4).

Figure 2: The marginal effect of income growth on CIPR, by income level



Source: Author's elaboration.

7. Conclusions and policy implications

In the past few decades, the significant decrease in poverty has been mirrored by a rise in global emissions, underlying a strong trade-off between the two goals. This can be regarded as bad news, since both goals need to be achieved jointly as well as urgently. Despite this overall negative picture, the degree of this trade-off varies significantly across countries, indicating that it might be possible to identify cases and policies that are able to eradicate poverty in less carbon-intensive, therefore more environmentally efficient, ways.

The results of the analysis presented here show that, in the short-term, there are examples of countries that have been able to achieve reductions in both poverty and emissions levels simultaneously. These positive examples belong mainly to two different groups. High-income countries in Europe represent the first group, while the second group consists of low-income countries in Sub-Saharan Africa. This is noteworthy given that middle-income countries represent the majority of global poverty and emissions levels; here countries at either extreme of the income distribution spectrum seem to have performed the best. The results also indicate that the effect of economic growth on the CIPR is non-linear, following a U-shape relationship, similar to an inverted Kuznets curve.[44] Up to a certain income per capita value (turning point), it can be argued that the pursuit of economic growth is a carbon-efficient strategy for poverty reduction. After this turning point, economic growth increases the carbon intensity of poverty reduction. The second main finding is that reducing inequality is an efficient way to achieve both poverty reduction and emissions standards at all levels of inequality. The findings are in line with previous research on the efficiency of wellbeing that concluded that wellbeing goals should be achieved directly rather than through economic development in order to be sustainable (Dietz et al., 2012; Knight & Rosa, 2011).

As a consequence of these results, one may ask if the pursuit of economic growth in the short term is the best policy for developing countries aiming to address poverty reduction within the global context of environmental sustainability. In fact, the majority of low and middle income countries lie below the estimated turning points. And the findings from the quantitative analysis imply that governments of these countries may argue that economic growth is an efficient way to deal with the national trade-off between changes in poverty and emissions levels represented by the CIPR. On the other hand, despite reducing the carbon intensity of poverty reduction, economic growth will have a significant impact on global emissions in absolute terms. This is particularly true if such economic growth is obtained in the same way as in the past. For example, the two main polluters in absolute terms, China and India, lie below the line, as their mean income is around $3,000 and $1,350, respectively (compared with the turning point of $3,750 for the lowest poverty line).[45] And it has been estimated that globally we would need to have an annual carbon emissions mitigation rate of around 4.4% to have a 66% chance of staying below a 2°C global warming by the end of the century (Hubacek, Baiocchi, Feng, & Patwardhan, 2017). Therefore a tension between the national carbon intensity of poverty reduction and global environmental boundaries exists.

Given the previous findings, what are the prospects for global poverty eradication within environmental boundaries, and within the carbon budget more specifically? One thing that is clear is that high-income economies need to drastically decrease their emissions levels. This is on both equity and sufficiency grounds (Peters, Andrew, Solomon, & Friedlingstein, 2015; Raupach et al., 2014). For example, the per capita emissions in the US are 13 times the level of India's. Having said that, it is also important that developing countries do not grow along the same path as other advanced economies; otherwise, including populous countries, global emissions will increase substantially, passing dangerous thresholds (Steffen et al., 2015).[46] If the current type of economic growth, despite reducing the CIPR, is not compatible with global environmental limits, what can be done especially in relation to middle-income

[44] The analysis has found evidence of a second turning point, but the estimations of this were significantly outside the sample values.
[45] From the data used in the analysis.
[46] Steffen et al. (2015) indicate 350 ppm as the planetary boundary for the atmospheric concentration of CO_2. The value in 2015 was already 398 ppm.

countries, which represent the majority producers of global emissions and poverty? One solution advanced is to focus on inequality and redistributive policies to address poverty, rather than focusing on economic growth. This viewpoint is supported by the results of the econometric analysis in this paper, and also by studies that show that middle-income countries potentially have the fiscal capacity to implement such policies, like the removal of fossil fuel subsidies (Hoy & Sumner, 2016). A shift towards greater equality, redistribution and structural change is also supported by the argument that these countries are witnessing a low growth elasticity of poverty reduction because of increasing inequality, an insufficient structural transformation of their economies and spatial poverty traps (Sumner, 2016). These issues may be further exacerbated if environmental issues are considered. A second alternative is a significant shift towards greener growth. Green economic development can represent an opportunity for many developing countries not locked into polluting industries. But, while greener growth would lower emissions levels, the potential effects on poverty are uncertain and will depend on how it is achieved (Dercon, 2014). Therefore a combination of greener growth and distributive policies seems the best policy mix to achieve poverty eradication within environmental limits. More research is therefore needed to understand what kinds of structural transformations and development paths are necessary to make such approaches work, especially in the large middle-income countries. This implies also the importance of considering jointly the three dimensions of sustainable development (economic, social and environmental), as done in this paper, and the need to employ more interdisciplinary and holistic approaches.

References

Adams, R. H. (2004). Economic Growth, Inequality and Poverty: Estimating the Growth Elasticity of Poverty. *World Development, 32*(12), 1989-2014. doi:https://doi.org/10.1016/j.worlddev.2004.08.006

Andreoni, J., & Levinson, A. (2001). The simple analytics of the environmental Kuznets curve. *Journal of Public Economics, 80*(2), 269-286. doi:10.1016/S0047-2727(00)00110-9

Barrientos, A. (2013). *Social assistance in developing countries* (1 edition ed.): Cambridge University Press.

Bazzi, S., & Clemens, M. A. (2013). Blunt Instruments: Avoiding Common Pitfalls in Identifying the Causes of Economic Growth. *American Economic Journal: Macroeconomics, 5*(2), 152-186. doi:doi: 10.1257/mac.5.2.152

Bourguignon, F. (2003). *The growth elasticity of poverty reduction: explaining heterogeneity across countries and time periods* (28104). Retrieved from http://documents.worldbank.org/curated/en/503161468780002293/The-growth-elasticity-of-poverty-reduction-explaining-heterogeneity-across-countries-and-time-periods. Accessed in November 2016.

Bourguignon, F. (2004). *The Poverty-growth-inequality triangle* (125). Retrieved from https://ideas.repec.org/p/ind/icrier/125.html. Accessed in November 2016.

Boyce, J. K. (1994). Inequality as a cause of environmental degradation. *Ecological Economics, 11*(3), 169-178. doi:10.1016/0921-8009(94)90198-8

Copeland, B. R., & Taylor, M. S. (2004). Trade, Growth, and the Environment. *Journal of Economic Literature, 42*(1), 7-71. doi:10.1257/002205104773558047

Dasgupta, P., & Maler, K.-G. (1995). *Poverty, institutions, and the environmental resource-base*. Retrieved from http://econpapers.repec.org/bookchap/eeedevchp/3-39.htm. Accessed in November 2016.

Datt, G., & Ravallion, M. (1992). Growth and redistribution components of changes in poverty measures: A decomposition with applications to Brazil and India in the 1980s. *Journal of Development Economics, 38*(2), 275-295.

Deacon, B. (2016). SDGs, Agenda 2030 and the prospects for transformative social policy and social development. *Journal of International and Comparative Social Policy, 32*(2), 79-82. doi:10.1080/21699763.2016.1200112

Deininger, K., & Squire, L. (1998). New ways of looking at old issues: inequality and growth. *Journal of Development Economics, 57*(2), 259-287. doi:10.1016/S0304-3878(98)00099-6

Dercon, S. (2014). Is Green Growth Good for the Poor? *World Bank Research Observer, 29*(2), 163-185. doi:10.1093/wbro/lku007

Dietz, T., Rosa, E. A., & York, R. (2012). Environmentally efficient well-being: Is there a Kuznets curve? *Applied Geography, 32*(1), 21-28. doi:https://doi.org/10.1016/j.apgeog.2010.10.011

Dinda, S., & Coondoo, D. (2006). Income and emission: A panel data-based cointegration analysis. *Ecological Economics, 57*(2), 167-181. doi:10.1016/j.ecolecon.2005.03.028

Dollar, D., Kleineberg, T., & Kraay, A. (2016). Growth still is good for the poor. *European Economic Review, 81*(Supplement C), 68-85. doi:https://doi.org/10.1016/j.euroecorev.2015.05.008

Dollar, D., & Kraay, A. (2002). Growth is Good for the Poor. *Journal of Economic Growth, 7*(3), 195-225. doi:10.1023/a:1020139631000

Epaulard, A. (2003). *Macroeconomic Performance and Poverty Reduction* (03/72). Retrieved from https://ideas.repec.org/p/imf/imfwpa/03-72.html

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *The American Economic Review, 105*(10), 3150-3182.

Ferreira, F., & Ravallion, M. (2009). Poverty and Inequality: The Global Context. In W. Salverda, B. Nolan, & T. M. Smeeding (Eds.), *The Oxford Handbook of Economic Inequality*. Oxford: Oxford University Press.

Foster, J., Greer, J., & Thorbecke, E. (1984). A Class of Decomposable Poverty Measures. *Econometrica, 52*(3), 761-766. doi:10.2307/1913475

Fosu, A. K. (2017). Growth, inequality, and poverty reduction in developing countries: Recent global evidence. *Research in Economics, 71*(2), 306-336. doi:10.1016/j.rie.2016.05.005

Grunewald, N., Klasen, S., Martínez-Zarzoso, I., & Muris, C. (2017). The Trade-off Between Income Inequality and Carbon Dioxide Emissions. *Ecological Economics, 142*(Supplement C), 249-256. doi:https://doi.org/10.1016/j.ecolecon.2017.06.034

Hauk, W. R., & Wacziarg, R. (2009). A Monte Carlo study of growth regressions. *Journal of Economic Growth, 14*(2), 103-147. doi:10.1007/s10887-009-9040-3

Heerink, N., Mulatu, A., & Bulte, E. (2001). Income inequality and the environment: aggregation bias in environmental Kuznets curves. *Ecological Economics, 38*(3), 359-367. doi:10.1016/S0921-8009(01)00171-9

Hoy, C., & Sumner, A. (2016). Global Poverty and Inequality: Is There New Capacity for Redistribution in Developing Countries? *Journal of Globalization and Development* (Vol. 7).

Hubacek, K., Baiocchi, G., Feng, K., & Patwardhan, A. (2017). Poverty eradication in a carbon constrained world. *Nature Communications, 8*(1). doi:10.1038/s41467-017-00919-4

Iradian, G. (2005). *Inequality, poverty, and growth: cross-country evidence* (Vol. 5): International Monetary Fund.

Janvry, A. d., & Sadoulet, E. (2000). Growth, Poverty, and Inequality in Latin America: A Causal Analysis, 1970–94. *Review of Income and Wealth, 46*(3), 267-287. doi:10.1111/j.1475-4991.2000.tb00843.x

Jean, N., Burke, M., Xie, M., Davis, W. M., Lobell, D. B., & Ermon, S. (2016). Combining satellite imagery and machine learning to predict poverty. *Science, 353*(6301), 790-794. doi:10.1126/science.aaf7894

Jorgenson, A. K. (2014). Economic development and the carbon intensity of human well-being. *Nature Climate Change, 4*, 186. doi:10.1038/nclimate2110

https://www.nature.com/articles/nclimate2110#supplementary-information

Jorgenson, A. K., Alekseyko, A., & Giedraitis, V. (2014). Energy consumption, human well-being and economic development in central and eastern European nations: A cautionary tale of sustainability. *Energy Policy, 66*, 419-427. doi:https://doi.org/10.1016/j.enpol.2013.11.020

Kalwij, A., & Verschoor, A. (2007). Not by growth alone: The role of the distribution of income in regional diversity in poverty reduction. *European Economic Review, 51*(4), 805-829. doi:10.1016/j.euroecorev.2006.06.003

Knight, K. W., & Rosa, E. A. (2011). The environmental efficiency of well-being: A cross-national analysis. *Social Science Research, 40*(3), 931-949. doi:https://doi.org/10.1016/j.ssresearch.2010.11.002

Kraay, A. (2006). When is growth pro-poor? Evidence from a panel of countries. *Journal of Development Economics, 80*(1), 198-227. doi:10.1016/j.jdeveco.2005.02.004

La Porta, R., Lopez-de-Silanes, F., & Shleifer, A. (2008). The Economic Consequences of Legal Origins. *Journal of Economic Literature, 46*(2), 285-332. doi:10.1257/jel.46.2.285

Mitchell, T. D., Hulme, M., & New, M. (2002). Climate data for political areas. *Area, 34*(1), 109-112.

Ordás Criado, C., Valente, S., & Stengos, T. (2011). Growth and pollution convergence: Theory and evidence. *Journal of Environmental Economics and Management, 62*(2), 199-214. doi:https://doi.org/10.1016/j.jeem.2010.10.009

Peters, G. P., Andrew, R. M., Solomon, S., & Friedlingstein, P. (2015). Measuring a fair and ambitious climate agreement using cumulative emissions. *Environmental Research Letters, 10*(10), 105004.

Raupach, M. R., Davis, S. J., Peters, G. P., Andrew, R. M., Canadell, J. G., Ciais, P., . . . Le Quéré, C. (2014). Sharing a quota on cumulative carbon emissions. *Nature Climate Change, 4*, 873. doi:10.1038/nclimate2384

https://www.nature.com/articles/nclimate2384#supplementary-information

Ravallion, M. (2001). Growth, Inequality and Poverty: Looking Beyond Averages. *World Development, 29*(11), 1803-1815. doi:10.1016/S0305-750X(01)00072-9

Ravallion, M. (2012). Why Don't We See Poverty Convergence? *The American Economic Review, 102*(1), 504-523.

Ravallion, M. (2016). *The Economics of Poverty: History, Measurement, and Policy*. Oxford, New York: Oxford University Press.

Ravallion, M., & Chen, S. (1997). What Can New Survey Data Tell Us about Recent Changes in Distribution and Poverty? *World Bank Economic Review, 11*(2), 357-382. doi:10.1093/wber/11.2.357

Ravallion, M., Heil, M., & Jalan, J. (2000). Carbon emissions and income inequality. *Oxford Economic Papers, 52*(4), 651-669. doi:10.1093/oep/52.4.651

Ravallion, M., & Huppi, M. (1991). Measuring Changes in Poverty: A Methodological Case Study of Indonesia during an Adjustment Period. *The World Bank Economic Review, 5*(1), 57-82.

Ravallion, M., Squire, L., & Bruno, M. (1999). Equity and Growth in Developing Countries: Old and New Perspectives on the Policy Issues. *Policy Research Working Papers*, 40. doi:doi:10.1596/1813-9450-1563

Redclift, M. (1991). The Multiple Dimensions of Sustainable Development. *Geography, 76*(1), 36-42.

Sanchez, L. F., & Stern, D. I. (2016). Drivers of industrial and non-industrial greenhouse gas emissions. *Ecological Economics, 124*(Supplement C), 17-24. doi:https://doi.org/10.1016/j.ecolecon.2016.01.008

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., . . . Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855. doi:10.1126/science.1259855

Stern, D. I. (2004). The Rise and Fall of the Environmental Kuznets Curve. *World Development, 32*(8), 1419-1439. doi:10.1016/j.worlddev.2004.03.004

Stern, D. I. (2015). *The environmental Kuznets curve after 25 years* (1514). Retrieved from https://ideas.repec.org/p/een/ccepwp/1514.html

Stern, D. I., Gerlagh, R., & Burke, P. J. (2017). Modeling the emissions–income relationship using long-run growth rates. *Environment and Development Economics, 22*(6), 699-724. doi:10.1017/S1355770X17000109

Sumner, A. (2016). *Global poverty: Deprivation, distribution, and development since the cold War*: Oxford University Press.

Thorbecke, E. (2013). The Interrelationship Linking Growth, Inequality and Poverty in Sub-Saharan Africa. *Journal of African Economies, 22*(suppl_1), i15-i48. doi:10.1093/jae/ejs028

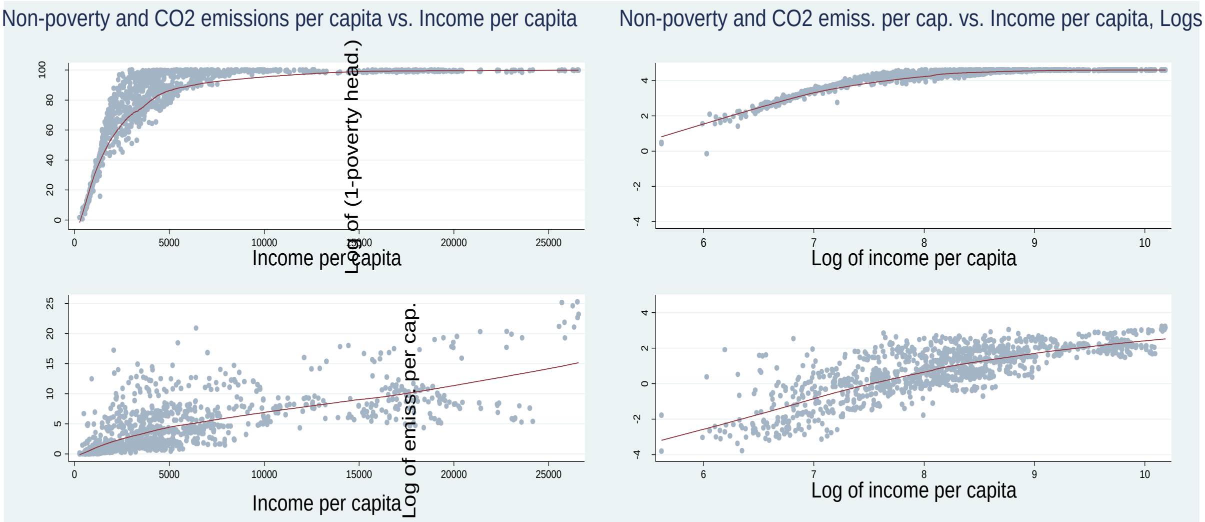
Torras, M., & Boyce, J. K. (1998). Income, inequality, and pollution: a reassessment of the environmental Kuznets Curve. *Ecological Economics, 25*(2), 147-160. doi:10.1016/S0921-8009(97)00177-8

Uchiyama, K. (2016). *Environmental Kuznets Curve Hypothesis and Carbon Dioxide Emissions*: Springer.

World Bank. (2016). *World Development Indicators*.

Appendix 1

Figure 3: Relationship between poverty, emissions and mean income



Source: Author's elaboration.

Table 7: Full regression results using the US$3.10 a day poverty line

VARIABLES	(1) EEPR	(2) EEPR	(3) EEPR	(4) EEPR	(5) EEPR	(6) EEPR
Mean income, growth	0.34***	0.24***	0.26***	0.26***	0.26***	0.24***
	(0.07)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)
Mean income, log		0.01*	0.01**	0.03***	0.03***	0.03***
		(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
(Mean income,		-0.68***	-0.71***	-0.58***	-0.60***	-0.59***
		(0.08)	(0.07)	(0.06)	(0.06)	(0.06)
(Gini index, growth)*(Gini index, log)			-2.02***	-1.83***	-1.66***	-1.51***
			(0.32)	(0.32)	(0.34)	(0.34)
Gini index, growth			-0.28***	-0.26***	-0.24***	-0.22**
			(0.09)	(0.08)	(0.08)	(0.09)
Gini index, log			-0.04***	-0.02*	-0.01	-0.00
			(0.01)	(0.01)	(0.01)	(0.01)
Emiss intens, log				0.01***	0.01***	0.01***
				(0.00)	(0.00)	(0.00)
Non-pov $3.10, log				-0.05***	-0.05***	-0.05***
				(0.01)	(0.01)	(0.01)
(Gini index, growth)*(Mean income, log)					0.07	0.11
					(0.09)	(0.10)
(Mean income,					-0.27	-0.25
					(0.19)	(0.19)
Avg temperature						0.00
						(0.00)
Legal origin						-0.00
						(0.01)
Trade, log % GDP						-0.00
						(0.01)
Forest, log % land						-0.00
						(0.00)
Pop density, log						-0.00
						(0.00)
Literacy, log						-0.00
						(0.01)
Population, million						-0.00
						(0.00)
Elect prod coal, log %						-0.00*
						(0.00)
Elect prod hydro, log %						-0.00
						(0.00)
Elect prod gas, log %						-0.00
						(0.00)
Elect prod nucl, log %						0.00

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	EEPR	EEPR	EEPR	EEPR	EEPR	EEPR
						(0.00)
Elect prod oil, log %						-0.00**
						(0.00)
Elect prod renew, log %						0.00**
						(0.00)
Employment in ind, log %						0.01
						(0.01)
Employment in agric, log %						-0.00
						(0.00)
Employment in services,						-0.03***
						(0.01)
Constant	0.07	0.05	0.04	0.02	0.02	0.02
	(0.05)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)
Observations	609	609	609	609	609	609
R-squared	0.16	0.35	0.41	0.47	0.47	0.49
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses.

**** p<0.01, ** p<0.05, * p<0.1*

Source: Author's elaboration based on different data sources.

Table 8: Full regression results using all poverty lines, final model

VARIABLES	(7) EEPR	(8) EEPR	(9) EEPR	(10) EEPR
Poverty line	US$1.90	US$3.10	US$5	US$10
Mean income, growth	0.03	0.24***	0.56***	1.24***
	(0.04)	(0.04)	(0.05)	(0.09)
Mean income, log	0.02***	0.03***	0.05***	0.06***
	(0.01)	(0.01)	(0.01)	(0.02)
(Mean income, growth)*(Mean income, log)	-0.42***	-0.59***	-0.74***	-0.77***
	(0.06)	(0.06)	(0.08)	(0.12)
(Gini index, growth)*(Gini index, log)	-1.33***	-1.51***	-2.00***	-2.91***
	(0.32)	(0.34)	(0.38)	(0.61)
Gini index, growth	-0.22***	-0.22**	-0.08	0.44***
	(0.08)	(0.09)	(0.11)	(0.14)
Gini index, log	-0.01	-0.00	0.01	0.03
	(0.01)	(0.01)	(0.02)	(0.02)
Emiss intens, log	0.01**	0.01***	0.01***	0.01*
	(0.00)	(0.00)	(0.00)	(0.01)
Non-pov $1.90, log	-0.05***			
	(0.01)			
(Gini index, growth)*(Mean income, log)	0.32***	0.11	-0.29**	-1.09***
	(0.08)	(0.10)	(0.14)	(0.20)
(Mean income, growth)*(Gini index, log)	-0.10	-0.25	-0.48**	-1.00***
	(0.17)	(0.19)	(0.22)	(0.34)
Avg temperature	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Legal origin	-0.00	-0.00	-0.00	-0.01
	(0.00)	(0.01)	(0.01)	(0.01)
Trade, log % GDP	-0.00	-0.00	-0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
Forest, log % land	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Pop density, log	-0.00	-0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Literacy, log	-0.01	-0.00	0.01	0.02
	(0.01)	(0.01)	(0.01)	(0.02)
Population, million	-0.00	-0.00	-0.00	-0.00

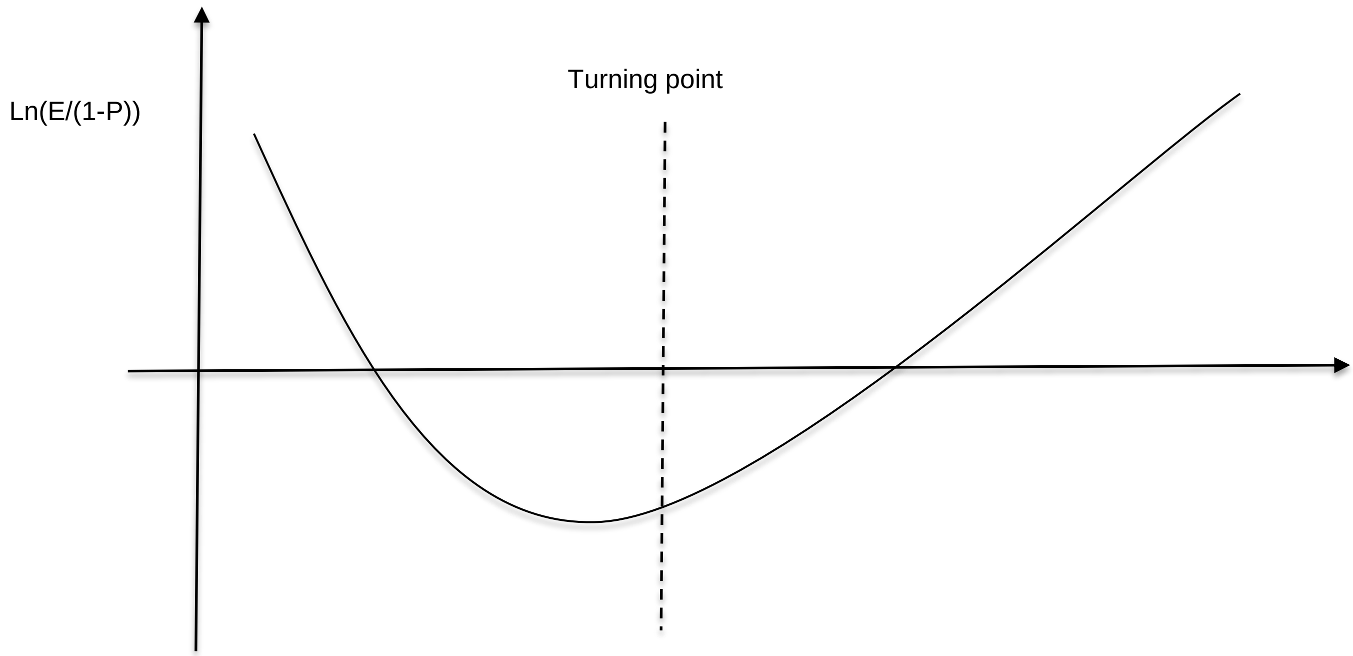
VARIABLES	(7) EEPR	(8) EEPR	(9) EEPR	(10) EEPR
Poverty line	US$1.90	US$3.10	US$5	US$10
	(0.00)	(0.00)	(0.00)	(0.00)
Elect prod coal, log %	-0.00	-0.00*	-0.00**	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)
Elect prod hydro, log %	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Elect prod gas, log %	-0.00	-0.00	-0.00	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)
Elect prod nucl, log %	0.00	0.00	0.00	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)
Elect prod oil, log %	-0.00***	-0.00**	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Elect prod renew, log %	0.00**	0.00**	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Employment in ind, log %	0.01	0.01	0.02	-0.00
	(0.01)	(0.01)	(0.01)	(0.02)
Employment in agric, log %	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Employment in services, log %	-0.02**	-0.03***	-0.04***	-0.02
	(0.01)	(0.01)	(0.01)	(0.02)
Non-pov $3.10, log		-0.05***		
		(0.01)		
Non-pov $5, log			-0.04***	
			(0.01)	
Non-pov $10, log				-0.03**
				(0.01)
Constant	0.00	0.02	0.02	-0.01
	(0.01)	(0.02)	(0.02)	(0.03)
Observations	609	609	609	609
R-squared	0.41	0.49	0.59	0.63
Year FE	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses.

**** p<0.01, ** p<0.05, * p<0.1*

Source: Author's elaboration based on different data sources.

Figure 4: Kuznets curve between the carbon intensity of non-poverty and income



Source: Author's elaboration.