Can Paris deal boost SDGs achievement? An assessment of climate-sustainability co-benefits or side-effects

Lorenza Campagnolo[1*], Marinella Davide[1]

[1]Fondazione Eni Enrico Mattei (FEEM) and Euro-Mediterranean Center on Climate Change (CMCC)

*Corresponding Author: lorenza.campagnolo@feem.it

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1. *Introduction*

At the end of 2015, two important summits took place, whose outcomes will potentially lead to a redefinition of the international policy environment in the near future. In September, the adoption of the Sustainable Development Goals (SDGs) by the United Nations, as the Millennium Development Goals follow-up, defined broader and more ambitious development targets for both developed and developing countries encompassing all sustainability dimensions (economic, social, and environmental) and designing the pathway towards an inclusive green growth. In December, the 21th UNFCCC Conference of Parties (COP 21) adopted the Paris Agreement, which aims at strengthening the global response to climate change through a new regime of country-driven emission targets. Synergies among these two landmark steps in international cooperation can directly affect countries' environmental performance, but also social and economic dimensions if we consider the possible use of climate policy revenues to reduce poverty prevalence (SDG 1) and inequality (SDG10).

This paper aims at giving an ex-ante assessment of the co-benefits and side effects of this new policy setting and, in particular, to shed some light on the influence of the Paris Agreement on achieving SDGs.

Our analysis relies on a recursive-dynamic Computable General Equilibrium (CGE) model developed and enriched with indicators representative of each SDGs. CGE models have a flexible structure, and can capture trade-offs and higher-order implications across sectors and countries that follows a shock or a policy. These models are well suited to assess the performance of economic indicators such as sectoral value added, GDP per capita, and public debt evolution; moreover, the CGE modelling literature of the past decades has highlighted that this is also a powerful tool to assess the evolution of some key environmental indicators, such as land use determined by land owners' revenues maximisation or GHG and CO2 emissions directly linked to agents' production and consumption choices (Böhringer and Löschel 2006).

Modelling social indicators in a CGE framework is a difficult task, especially when these imply dispersion measures such are poverty prevalence and inequality at the core of GOAL 1 and 10. In this case, we overcome the representative agent structure proper of CGE models empirically relying on the empirical literature and directly estimating the relations between indicators and endogenous variables of the model (Bourguignon et al. 2005; Ferreira et al. 2010; Montalvo and Ravallion 2010).

The analysis has world coverage, but for modelling reasons we aggregate the result in 45 countries/macro-regions. The historical records of indicators' values rely on international databases (Commission on Sustainable Development of the United Nations, EU Sustainable Development

Strategy, and World Development Indicators from World Bank) and are the starting point in our baseline scenario design.
We will mainly focus on characterising the future trend of some social indicators, i.e. poverty prevalence and inequality, in the SSP2 baseline scenario, in addition to the usual economic and environmental indicators. Then, this baseline scenario will be used as a term of comparison to assess the impact of climate policy and different recycling scheme on environmental, social and economic indicators.
Our framework that combine an empirical analysis with a modelling exercise allows considering economic, social and environmental dimensions in a CGE model, sheds some lights on the possible ancillary costs and benefits of mitigation policies, and assesses how the implementation of climate policy could help achieving SDGs or, rather, whether there is a trade-off between climate policy, and economic and social development.

2. *Inequality and poverty trends in the past*

Extreme poverty eradication and inequality reduction are among the most relevant priorities to ensure sustainability worldwide. Their achievement is a preliminary and necessary condition to address all other SDGs, including the environmental ones. Nevertheless, it is important to assess also how environmental regulation connects to the social dimension and can affect related indicators, and this crucially depends on the environmental policy design.
The United Nations devote two of the seventeen SDGs composing their post-2015 dashboard adopted in September 2015 on the topics: SDG 1) End Poverty in all its forms everywhere and SDG 10) Reduce Inequality within and among countries.
Both SDGs are then declined in more indicators, still under definition, and corresponding targets. More specifically, with reference to the poverty line, the UN suggest a very ambitious target as the fully eradication of the extreme poverty conditions. For inequality, the suggested target is sustaining “income growth of the bottom 40 per cent of the population at a rate higher than the national average” (United Nations 2014).
Despite the high variety of poverty measures available, we chose the poverty headcount ratio at 1.25$ a day (WB 2016) due to good data availability and because it allows to easily compare results across countries.

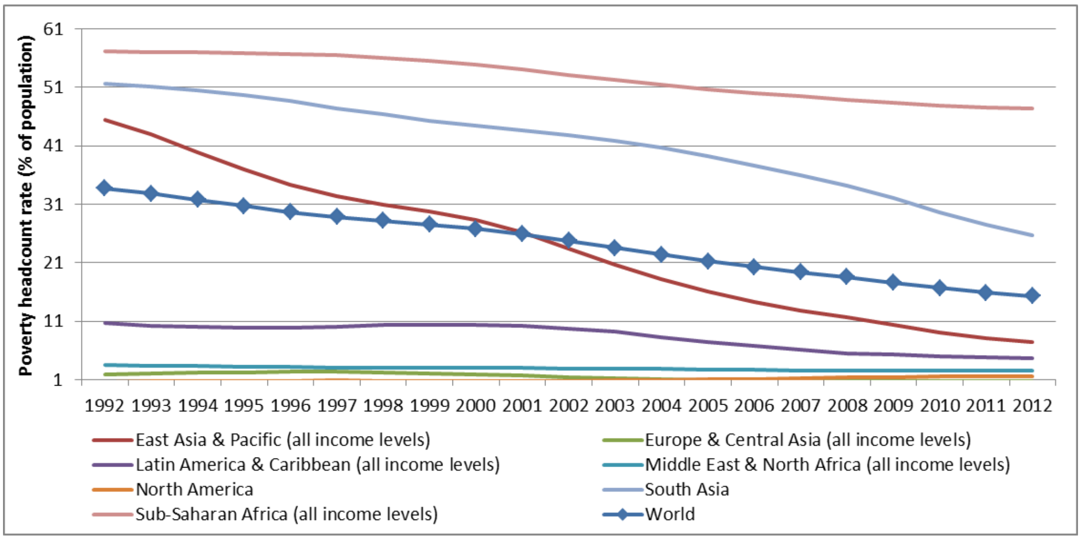

Figure 1 Poverty headcount ratio at 1.25$PPP a day for country aggregates and the World (5 year weighted average)

It is debated as well as challenging the definition of the right measure of equality within countries. While the Gini Index is the standard measure used by national statistics, there is now consensus on using the Palma Ratio as it is more appropriate to identify a desirable target. The Palma ratio is "the ratio of the top 10% of population's share of gross national income (GNI), divided by the poorest 40% of the population's share of GNI" (Cobham and Sumner 2013).

Looking at data from WDI from 1990 to 2012 (World Bank 2016), headcount ratio constantly lowered at the world level mainly due to large decreases in East and South Asian countries. On the contrary, the inequality, measured as country's weighted Palma ratio, is slightly increasing at world level.

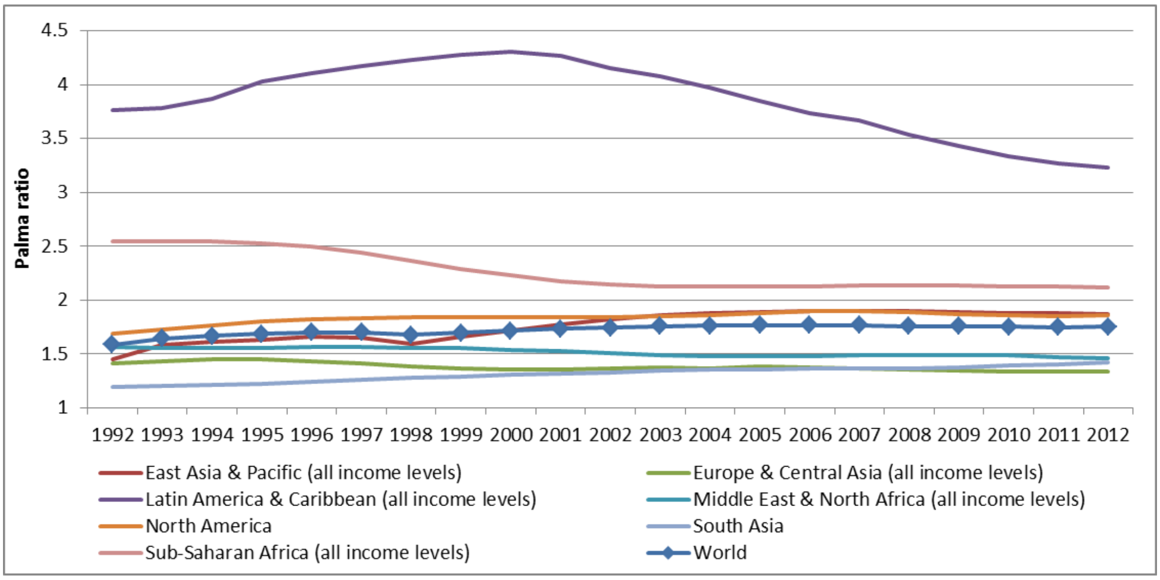

Figure 2 Palma ratio trend for country aggregates and the World (5 year weighted average)

Assessing the impact of environmental policies on social indicators, i.e. poverty and inequality, from an ex-ante and quantitative perspective, is particularly challenging and implies understanding the determinants of these two indicators and linking them to our macro-economic framework.

3. Inequality and poverty determinants in empirical and modelling literature

A wide empirical literature has looked at the determinants of the **poverty** reduction from a cross-country perspective. While Ravallion and Chen (1997) consider as the main driver the growth of average income per capita, Ravallion (1997, 2001) and Heltberg (2002) highlight the importance of the change in the distribution of income that may undermine the inclusiveness of economic growth. The concept of growth elasticity of poverty is central in this branch of literature; this measures the responsiveness of poverty prevalence to a change in average income per capita, and it is directly estimated from data or derived from an approximation of poverty distribution (Bourguignon, 2007). Other country-specific empirical analyses highlight also the relevance of sectoral growth patterns in explaining the differentiated poverty reduction rates across regions (Ferreira et al. 2007; Montalvo and Ravallion 2010).

On the other hand, examples from the macro-economic modelling literature are much more scattered and in general focus on single-country analyses. Two strands can be identified: the Microsimulation approach that elaborates the outcome of the CGE model using a microsimulation module that downscale the macro-economic result at individual or group-level (Lofgren et al. 2013; Hilderink et al. 2009; Hertel et al. 2011; Bussolo and Lay 2003), and the Multi-Household approach

that directly integrates microdata in the macro-economic model and allows an endogenous poverty evolution (Boccanfuso et al. 2003).
The choice of modelling approach depends strongly on data availability. The lack of country-specific data on the different composition of income sources (and consumption expenditure) by income quantile makes impracticable to use a Multi-Household approach and even a complex Microsimulation module as in Bussolo and Lay (2003).
Building upon Lofgren et al. (2013) and Hilderink et al. (2009) as well as the empirical literature on the topic, we run a panel regression in order to understand the link between the widely used measure of poverty prevalence (Poverty headcount ratio at 2005$1.25 a day), the average income per capita (GDP PPP per capita) and an indicator of unequal distribution of income (Palma ratio). Furthermore, we included a time trend (t) and country and year fixed effects.

$$\ln(POV_{i,t}) = \beta_1 \ln(GDPPPPpc_{i,t}) + \beta_2 \ln(Palma_{i,t}) + t + \varepsilon_{i,t}$$

In order to account for heteroskedasticity and autocorrelation that characterise our panel, we use a linear regression model with panel corrected standard errors, including a first order correlation within each panel. The data source is the World Development Indicator database (WB 2016); the panel considers 95 countries, both developed and developing, in the period 1990-2013.

Table 1 Linear regression model for panel corrected standard errors for Poverty headcount ratio at $1.25 a day.

	$\ln(\mathrm{POV}_{i,t})$
$\ln(GDPPPPpc_{i,t-1})$	-1.4362***
	(0.000)
$\ln(Palma_{i,t-1})$	1.0814***
	(0.000)
t	0.0079***
	(0.000)
Observations	501
Number of country	95

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The regression results are in line with the literature and show a negative correlation between poverty prevalence and income per capita, i.e. the number of people below poverty line shrinks as the GDP increases on average; however, the increase of Palma ratio, which means a wider distance between the income share detained by the richest 10% and the poorest 40% of the population (larger dispersion of income), works in the opposite direction leading more people below poverty line.

The determinants of **income inequality** are even more complex to disentangle. From empirical studies, there is evidence since the 1980s of reduction in income inequality within and among countries, especially in the developing ones (Ravallion 2003; 2014). The determinants of this pattern can be various: in country-specific analyses, differential in labour productivity between agricultural and non-agricultural sectors (Bourguignon and Morrison 1998), reforms in the labour market, expansion of education and changes in population dynamics (Bourguignon et al. 2005) play a major role. In cross-country analyses, sectoral wage differentials between skilled and un-

skilled labour, globalization, education rates, market reforms and policy interventions are the principal variables considered (Alvaredo and Gasparini 2015).
Regarding the macro-economic modelling literature (in particular CGE frameworks), income distribution is generally assumed constant through time or exogenously imposed (van der Mensbrugghe 2015). Another option for tackling the possible evolution of within-country inequality is the Multi-Household approach allowing for heterogeneous response of households' income and consumption choices to macro-sectoral dynamics.
However, given the global perspective of our analysis and the lack of data availability, modelling inequality with a Multi-Household approach is unfeasible.
Therefore, following the empirical strand of the literature, we run an unbalanced panel regression for 120 countries (both developed and developing) in the period 1990-2013.
The share of GDP detained by the richest 10% of the population and that owned by the poorest 40% are our dependent variables given their key role in the computation of Palma ratio, adopted in this paper as the measure of inequality within a country. As explanatory variables, we consider some macroeconomic variables drawn from World Development Indicator database and World Governance Indicators (World Bank 2016), which are consistent with the literature, characterised by a good country and year coverage and directly linkable to endogenous variables in ICES model.
We ran two independent regressions with the following specification:

$$\begin{aligned}\ln\left(\mathrm{y}_{i,t}^{p}\right) = {} & \beta_0 + \beta_1 \ln\left(PEduExp_{sh}{}_{i,t-1}^{p}\right) + \beta_2 \ln\left(AgriVA_{sh}{}_{i,t-1}^{p}\right) + \beta_3 \ln\left(IndVA_{sh}{}_{i,t-1}^{p}\right) \\ & + \beta_4 \ln\left(ServVA_{sh}{}_{i,t-1}^{p}\right) + \beta_5\, CorruptCtrl_{i,t}^{p} + \beta_6 \ln\left(Unempl_{i,t-1}^{p}\right) + \beta_7 d\_c\_i_{i,t}^{p} \\ & + \beta_8 d\_inc_{i,t}^{p} + t + \varepsilon_{i,t} \qquad\qquad p = \{low40, high10\}\end{aligned}$$

where $\mathrm{y}_{i,t}^{low40}$ and $\mathrm{y}_{i,t}^{high10}$ are the shares of GDP owned by the poorest 40% and the richest 10% of the population. The explanatory variables are: the share of Public Education Expenditure ($PEduExp\_sh$), the sectoral composition of the Value Added, i.e. the share of VA from agriculture ($AgriVA\_sh$), industry ($IndVA\_sh$) and services ($ServVA\_sh$); an indicator on corruption control perception ($CorruptCtrl$), the unemployment rate ($Unempl$), a dummy distinguishing whether the dependent variable derives from a consumption or income distribution (d_c_i), and a dummy using the World Bank Income classes (d_inc). In addition, we included a time trend (t) and country and year fixed effects. Also in this case, we use a linear regression model with panel corrected standard errors accounting for heteroskedasticity.

Table 2 Linear regression model for panel corrected standard errors for GDP share owned by the poorest 40% and richest 10% of the population.

	$\mathrm{y}_{i,t}^{low40}$	$\mathrm{y}_{i,t}^{high10}$
$\ln\left(PEduExp\_sh_{i,t-1}\right)$	0.0608***	-0.0651***
	(0.004)	(0.000)
$\ln\left(AgriVA\_sh_{i,t-1}\right)$	0.0526**	-0.0314*
	(0.011)	(0.067)
$\ln\left(IndVA\_sh_{i,t-1}\right)$	0.1161**	-0.1020***
	(0.018)	(0.009)
$\ln\left(ServVA\_sh_{i,t-1}\right)$	-0.1608**	0.1581***
	(0.011)	(0.001)
$Corrupt\_cntr_{i,t}$	0.0356**	-0.0240*
	(0.033)	(0.075)
$Unempl_{i,t-1}$	-0.0038***	0.0027***
	(0.000)	(0.007)
$d\_c\_i_{i,t}$	0.0199	0.0122

	(0.103)	(0.349)
t	0.0079***	-0.0054***
	(0.000)	(0.000)
Constant	-12.7870***	13.9773***
	(0.001)	(0.000)
Observations	659	659
Number of country1	120	120

pval in parentheses
*** p<0.01, ** p<0.05, *p<0.1

The GDP share of the poorest 40% of the population is positively correlated with public education expenditure, the VA share generated in agriculture and industry and a high level of corruption control[1]. The share of VA coming from services shows a negative sign; this result is in contrast with the literature on poverty which generally identifies the growth of tertiary sector output as a factor benefiting the poor layers of population (Ferreira et al. 2010). However, these results can be motivated by the cross country perspective of the analysis: the countries experiencing the highest levels of inequality are the emerging economies, e.g. China and India, clearly the high economic growth goes along with the development of tertiary sector and the slow-down of agricultural production. For the richest 10% of the population the explanatory variables show opposite signs and similar magnitude.

4. The CGE modelling framework

Projecting the evolution of inequality and poverty prevalence, and assessing the impact of environmental policies on these social indicators require some assumptions on future socio-economic scenario and a modelling framework to recreate it. The Intertemporal Computable Equilibrium System (ICES) model (Parrado and De Cian 2014; Eboli et al. 2010) is used for this purpose. ICES is a recursive dynamic CGE model: a multi-market model linked to current real economy data observed in the benchmark year, based upon the merging of national social accounting matrices (sophisticated input-output tables) into a global economic database (GTAP8). The ICES framework is characterised by perfect competitiveness in all markets, stylized behaviours of economic agents that maximize profits (firms) and consumption (households) respectively, and the explicit inter-connections among domestic and international markets allow highlighting higher-order costs and benefits at global and country level, going beyond the perspective of the sector/country/indicator originally impacted by the policy/shock. In addition ICES model has a recursive-dynamic engine: the model finds a new general (worldwide and economy-wide) equilibrium in each period by solving at yearly steps. All subsequent periods/years are interconnected through the process of accumulating physical capital stock in each country, net of its deterioration. The matching between savings and investments only holds at world level, while the allocation process of worldwide savings across countries in each year follows a rule of "countries with higher return of capital take more".

The exogenous drivers that contribute to the dynamic are socio-economic (e.g. population, primary factors stocks and productivity) as well as (economic, social and environmental) policy-driven changes occurring in the economic system, agents are allowed to modify their decisions in terms of input mix (firms) and consumption basket (households). Decisions depend upon changes in relative prices in all (national and international) markets according to pre-determined behavioural and physical constraints (elasticities of substitution/transformation).

[1] The indicator on control of corruption (WB 2016) ranges from approximately -2.5 (weak control) to 2.5 (strong control).

The current exercise considers 2007 as the benchmark year and has time horizon up to 2030. The economy in each country is described by 22 sectoral aggregates listed in **Error! Reference source not found.**. Figure 3 gives a snapshot of the chosen country aggregation in 45 macro regions.

Table 3 Sectoral aggregation

ICES sectors	
Agriculture	*Fossil Fuel Electricity*
Livestock	*Clean Electricity*
Processed Food	*Heavy Industries*
Forestry	*Light Industries*
Fishing	*Transport*
Other Mining	*Water*
Coal	*R&D*
Oil	*Market Services*
Gas	*Health*
Oil products	*Education*
Nuclear Fuel	*Public Services*

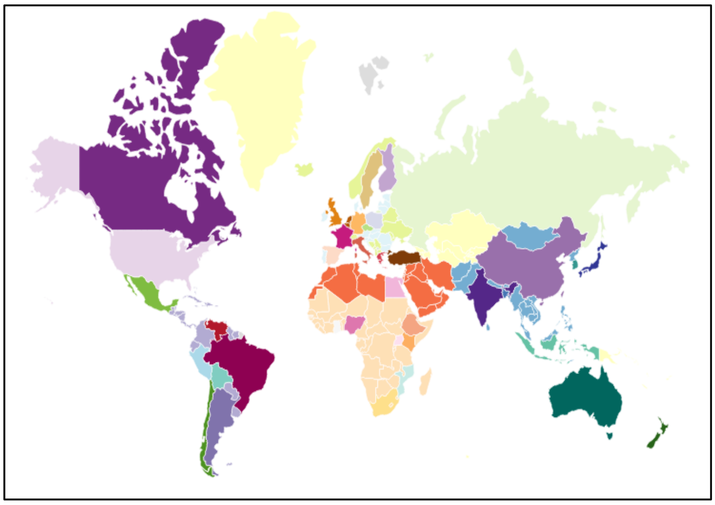

Figure 3 Regional aggregation

ICES model is commonly used to assess world-wide and economy-wide implications of environmental as well as other policies and/or economic shocks on variables such as income per capita, commodities outputs and demand, commodities prices, international trade.
Extending the model with social and environmental indicators allows assessing in an internally consistent framework how and at which extent changes in macro-economic variables may affect the achievement of SDGs all around the world. This approach is particularly suited as it considers the actual response of economic agents to the perturbation occurred in the socio-economic system (market-driven or autonomous adaptation) and the interactions among SDGs (synergies and/or trade-offs), such to mimic more realistically the likely future outcomes of all sustainability indicators in different scenarios (e.g. reference and policy).

5. *Baseline scenario*

As a reference source for scenarios, we use those developed by the climate change community and known as Shared Socioeconomic Pathways (SSPs). They are connected to different mitigation/adaptation challenges and, more extensively, to sustainable pathways of future economic development. Scenarios are based upon specific assumptions on both exogenous and endogenous variables at the national/regional level. SSPs provide future patterns for population as well as labour force and cropland area. Other trends for exogenous drivers such as primary factor productivity, sector-specific efficiency, total factor productivity and energy prices are then used in order to calibrate given endogenous variables, namely GDP, energy use, emissions and value added shares.
The baseline reproduces a Shared Socio-Economic Pathways 2 (SSP2), consistent with a RCP4.5, and it is used as a benchmark to assess the effects of mitigation scenario arising from the outcome of COP21. SSP2 is defined as the “Middle of the road” scenario and is characterised by similar dynamics observed in recent decades. Income per capita grows globally at a medium pace and also population follows the UN medium projection scenario.

Using the results from the SSP2 scenario, we ran an off-sample post-estimation procedure in order to compute the change in the Palma ratio up to 2030 (Figure 4).

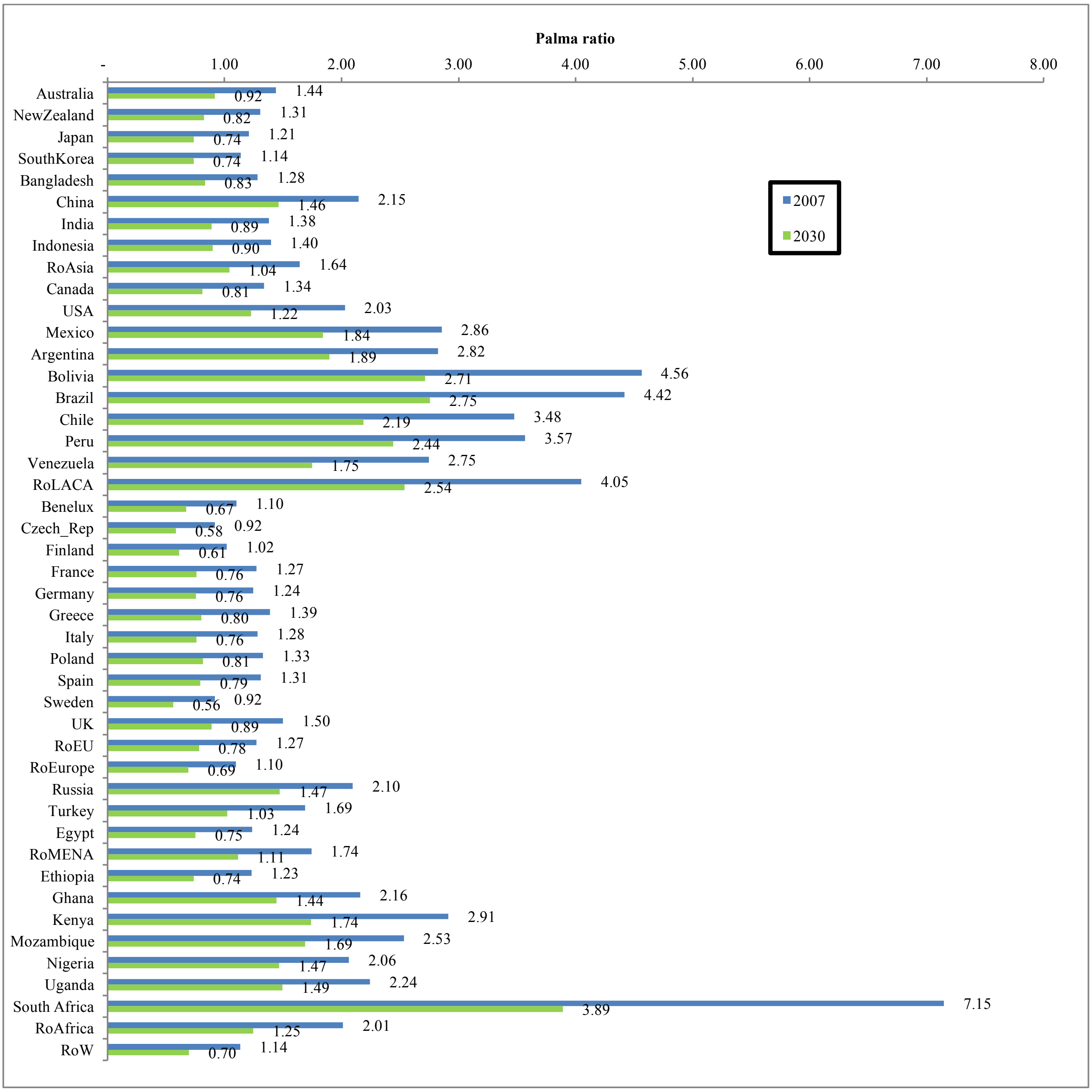

Figure 4 Palma ratio in the SSP2 baseline scenario, 2007 vs. 2030

In the SSP scenario, the Palma ratio drops on average of 37% in 2030 compared to 2007 levels due to the increase of income share owned by the poorest 40% of the population and a slight decrease of income share of the richest 10% of the population.
These projections on Palma ration are then used to compute the evolution of poverty rate in a second off-sample estimation. Figure 5 accounts for a strong reduction of poverty prevalence in Asia and Sub-Saharan Africa due to the rising income per capita and the decreasing within country inequality that characterize the SSP2 scenario. In 2030 the number of people below the 1.25$ poverty line are halved compared to the 2007 levels (i.e. 644 million of poor less than in 2007).

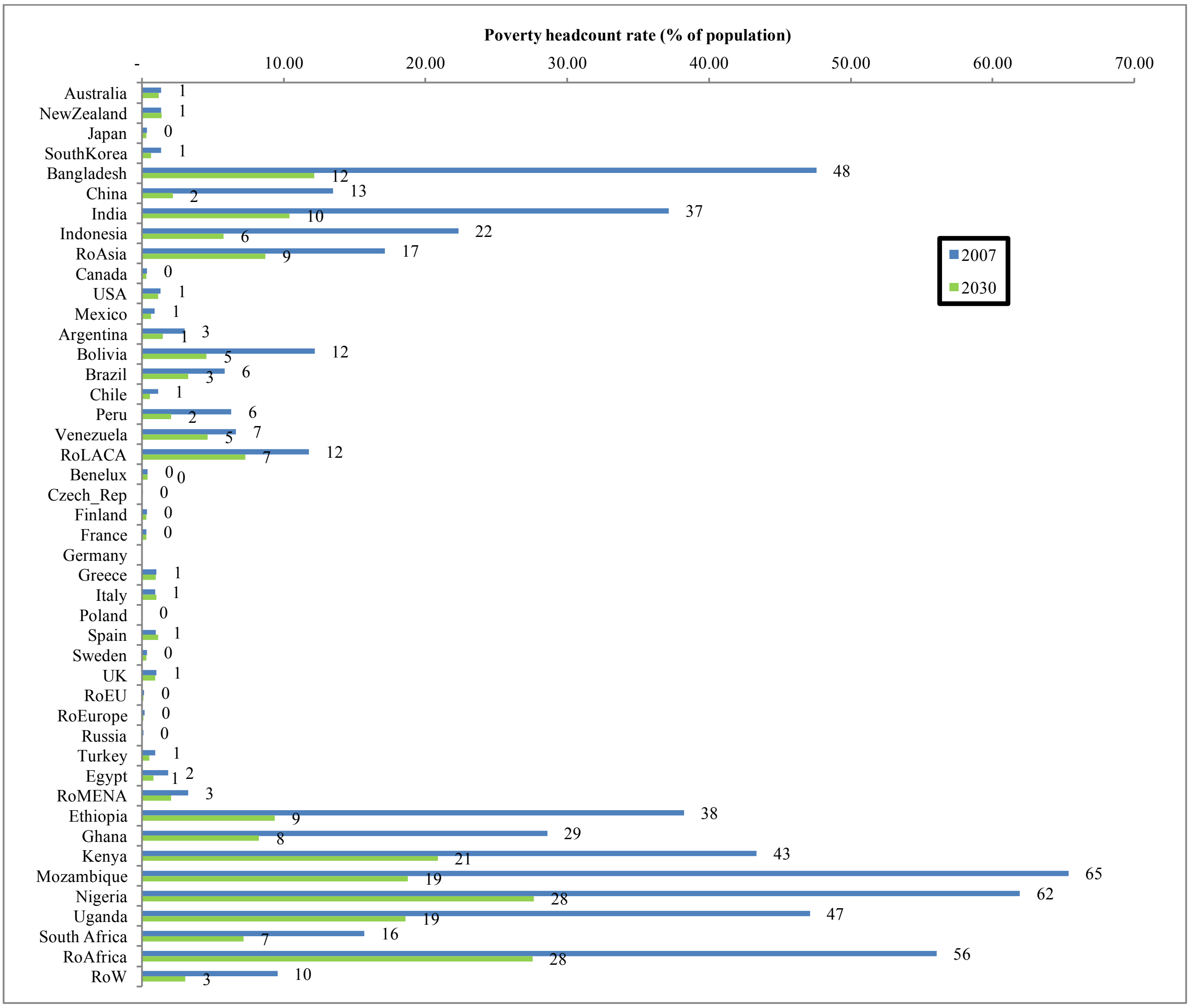

Figure 5 Poverty headcount rate in the SSP2 baseline scenario, 2007 vs. 2030

6. Policy setting

After the failure of the COP15 (Copenhagen, 2009), where countries were unable to define a new agreement to replace the Kyoto Protocol, a new negotiating stream was launched in Durban with the objective to develop a new legal instrument applicable to all Parties, to be adopted in Paris by 2015 and to come into force in 2020. On December 12, 2015, the 21st session of the UNFCCC Conference of the Parties (COP21), held in Paris, managed to close more than 4 years of negotiations by adopting the Paris Agreement. The Agreement aims at strengthening the global response to climate change through three major actions: i) keep the increase in the global average temperature to well below 2 °C above pre-industrial levels, with aspirational efforts to limit it to 1.5 °C; ii) increase the ability to adapt to the adverse impacts of climate change and foster climate resilience and iii) mobilize consistent finance flows to achieve these mitigation and adaptation objectives (UNFCCC 2015).

Central element of the Paris outcome are the “Nationally Determined Contributions” (NDCs), which represent bottom-up domestic plans to deal with climate change from 2020 on that all countries, both developed and developing ones, are requested to undertake and communicate. Ahead of the Paris Conference, more than 180 countries communicated climate actions they intend to undertake under the new agreement, known as *Intended* Nationally Determined

Contributions (INDCs).Although the INDCs certainly represent a breakthrough in terms of participation to such an international effort, one aspect that immediately stands out is their wide heterogeneity, both in terms of scope and coverage of mitigation efforts. If from one side developed countries generally express their contributions in the form of a quantified economy-wide mitigation effort compared to a reference year, developing countries, on the other, usually formulate their pledges in terms of emission intensity or link their emission reduction target to a Business-as-Usual (BaU) scenario. In addition, most of the developing countries define both an unconditional and a conditional target: in the first case the emission reduction is achieved with internal funds and capabilities; in the latter case, a more ambitious mitigation effort will be undertaken conditionally to the provision of external financial and technical support.

Our modelling exercise aims at understanding the impact of the Paris Agreement in a global perspective and under a coordinate effort; therefore we assume that all the countries achieve their conditional targets by 2030.

Furthermore, due to modelling limitations, the GHG emission target coming from INDCs is applied only to CO2 emissions; therefore no mitigation policies are imposed on the other GHGs (CH4, N2O and CFC). The target emissions in 2030 are computed using data from CAIT (WRI 2016) for countries committing to a reduction target with respect to a specific year; whether the reduction target is relative to Business As Usual scenario, SSP2 baseline scenario is used as reference.

The Table below shows the emission reduction targets considered for each country. In some cases, countries are clustered in regional groups to which an aggregated target is attributed.

Table 4 Emission reduction target in 2030

Country	Emission target (%)	Target type	Country	Emission reduction target	Target type
Australia	-27	Emission reduction wrt 2005	**Venezuela**	-20	Emission reduction wrt 2030 BAU scenario
NewZealand	-30	Emission reduction wrt 2005	**RoLACA**	-25.2	Average mission reduction wrt 2030 BAU scenario
Japan	-26	Emission reduction wrt 2013	**EU28**	-40	Emission reduction wrt 1990
SouthKorea	-37	Emission reduction wrt 2030 BAU scenario	**RoEurope**	-11.9	Average mission reduction wrt 2030 BAU scenario
Bangladesh	-13.8	Emission reduction wrt 2030 BAU scenario	**Russia**	-27.5	Emission reduction wrt 1990
China	-62.5	Emission intensity reduction wrt 2005	**Turkey**	-21	Emission reduction wrt 2030 BAU scenario
India	-34	Emission intensity reduction wrt 2005	**RoMENA**	-8.3	Average mission reduction wrt 2030 BAU scenario
Indonesia	-41	Emission reduction wrt 2030 BAU scenario	**Ethiopia**	-64	Emission reduction wrt 2030 BAU scenario
RoAsia	-20.9	Average mission reduction wrt 2030 BAU scenario	**Ghana**	-45	Emission reduction wrt 2030 BAU scenario
Canada	-30	Emission reduction wrt 2005	**Kenya**	-30	Emission reduction wrt 2030 BAU scenario
USA	-27	Emission reduction wrt 2005	**Nigeria**	-45	Emission reduction wrt 2030 BAU scenario
Mexico	-36	Emission reduction wrt 2030 BAU scenario	**Uganda**	-22	Emission reduction wrt 2030 BAU scenario
Argentina	-30	Emission reduction wrt 2030 BAU scenario	**South Africa**	0	Emission level target in 2030 is in the range 398 and 614 Mt CO2–eq and coincide with the level observed in the SSP2 scenario
Brazil	-37	Emission reduction wrt 2005	**RoAfrica**	-31.2	Average mission reduction wrt 2030 BAU scenario
Chile	-40	Emission intensity reduction wrt 2007	**RoW**	-38.6	Average mission reduction wrt 2030 BAU scenario
Peru	-30	Emission reduction wrt 2030 BAU scenario			

The proposed mitigation scenario considers a coordinated effort to curb emissions from 2013 assuming the INDC as binding targets for all countries. The European Union (EU28) implements an Emission Trading System (ETS) as already foreseen by the EU ETS domestic legislation, while all other countries achieve their targets unilaterally with a domestic carbon tax. China, India and Chile have INDCs expressed as emission intensity targets; this peculiarity is preserved in modelling policy scenario. Therefore China, India and Chile achieve unilaterally their INDCs.
The mitigation scenario is characterised by two different recycling schemes of the revenues collected from the carbon market or the carbon taxes:

- revenues are redistributed internally in a lump sum (MPOLICY scenario);
- revenues are used in part internally in EU28 and other developed countries and in part flow to a Development Fund benefiting Least Developed Countries (LDCs) through a lump sum transfer (MPOLICY+LCDFUND scenario): EU28 uses at least 50% of the revenues recycled to support clean energy in EU, 5% goes to the Development Fund and the rest is redistributed internally. The other committing countries allocate 1% of the carbon tax revenues to the Development Fund.
- Revenues are collected as above but in LDC countries the transfer from the Development Fund is used to subsidise specific sectors: Clean Electricity, Health, Education, R&D and Public Services sectors (MPOLICY+LCDFUND_SUB scenario).

7. Macroeconomic results

Implementing the conditional INDCs determines a 26% reduction of CO_2 emissions at global level in 2030 with respect to the SSP2 baseline scenario (17% reduction of GHG emissions). The cost of mitigation targets computed with respect to countries' GDP in the baseline scenarios ranges between -5% and +4% in 2030. Ethiopia lies outside this range with a GDP loss of 12% due to the stringency of conditional INDC target of this country. The bars in Figure 66 highlight the results of mitigation policy scenarios under different recycling schemes of the carbon tax revenues.

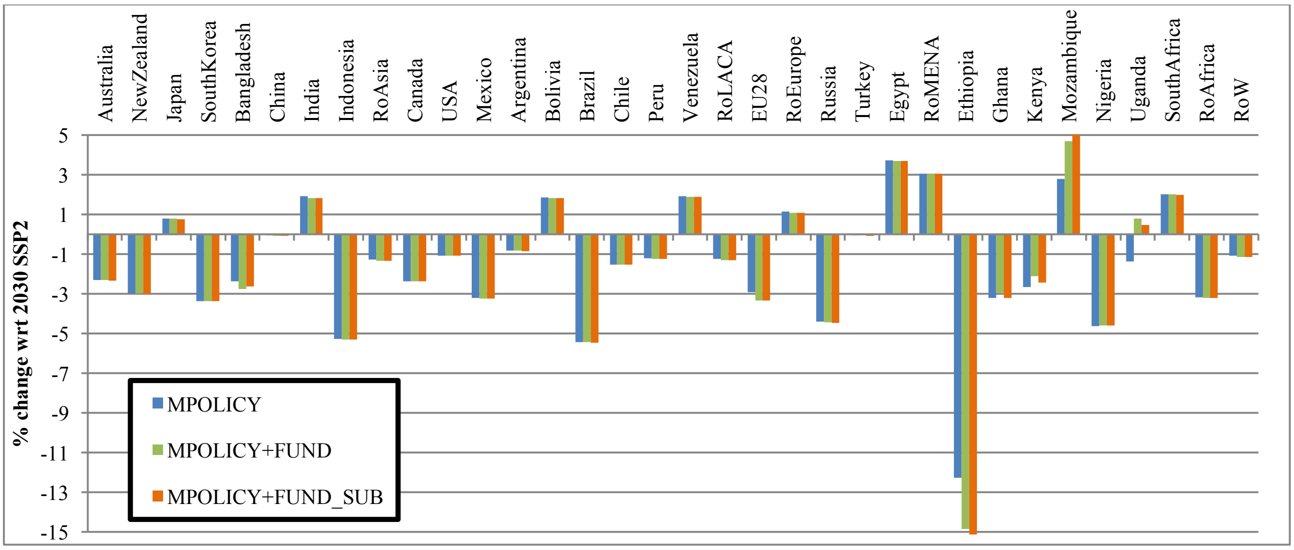

Figure 6 Mitigation policy cost in terms of GDP with respect to SSP2 baseline scenario

In the MPOLICY scenario, several countries gain in terms of GDP compared to the baseline scenario: Bolivia, Mozambique and Egypt experience a clear leakage effect due to their lack of mitigation commitments; India and South Africa have a non-stringent target; therefore we assume their emissions follow the SSP2 baseline trend also in the mitigation scenario. As well, Japan, Venezuela, Rest of Europe and Rest of MENA have loose INDCs targets which imply lower carbon tax and higher competitive advantages in comparison with other countries.

Figure 6 shows also the results of MPOLICY_LCDFUND scenario (green bars), which is characterised by a different recycling rule of carbon revenues: all counties committing to a emission reduction devote a part of the revenues to a development fund to support LDC (in our exercise Bangladesh, Indonesia, Rest of Asia, Ethiopia, Ghana, Kenia, Mozambique, Nigeria, Uganda and Rest of Africa). This development fund amounts to 68 billion $2007 in 2030 and 43% of it is funded by EU28. The allocation of fund across LDC is inversely proportional to the countries' GDP per capita (Figure 7).

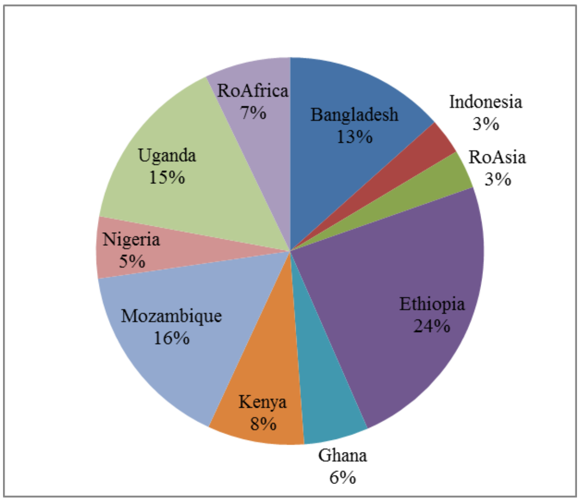

Figure 7 Developing fund recipients

In the MPOLICY_LCDFUND scenario, the LDC countries receive the fund in a lump sum; therefore the characteristic structure of the economy determines the effect of this transfer. As it is possible to notice in Figure 6, Ghana, Kenia, Mozambique, Nigeria and Uganda are better off in the MPOLICY_LCDFUND scenario compared to the simple mitigation scenario. The fund highly benefits Mozambique, which receives a push in addition to carbon leakage, and especially Uganda, which passes from a loss of GDP of 1.4% in the MPOLICY to a gain of 0.8% with respect to the 2030 baseline scenario. Additional losses are instead acknowledgeable in Bangladesh and Ethiopia due to structural rigidities in the energy and transport sectors that make the emission reduction even more binding in the scenario with the lump sum redistribution of development fund.

8. Poverty and inequality in mitigations scenarios

Looking at the effect of mitigation policies on SDG1 and SDG10, i.e. poverty prevalence and inequality, highlights a trade-off between the climate mitigation targets and the development ones in LDCs. The different recycling schemes are for most of countries not enough effective to compensate the impact of climate policy.

Figure 88 depicts how inequality (Palma ratio) in 2030 is affected by climate policy; in general countries with strongly binding emission reductions and consistent cost of the policy experience lower inequality (higher income share for the poorest 40% of the population and lower for the richest 10%). The countries gaining from the climate policy due to a loose INDC or the lack of it show higher inequality than in the baseline scenario. In LDC countries, the mitigation policy impact is magnified by the inflow of foreign transfers in a lump sum that boost the economic growth of these countries (MPOLICY_LCDFUND scenario). This effect is mitigated when transfers are steered to specific sectors (MPOLICY_LCDFUND_SUB scenario).

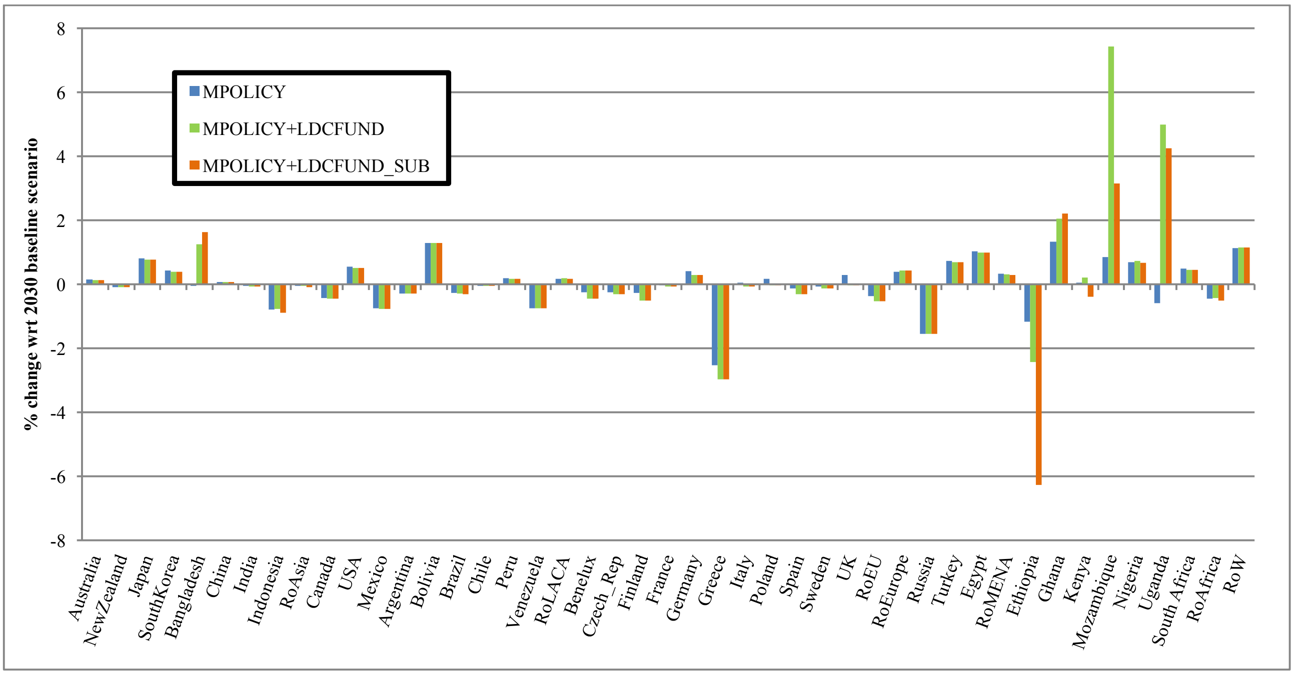

Figure 8 Palma ratio in mitigation scenarios, %change wrt 2030 SSP scenario

The mitigation has some implications also in terms of poverty prevalence altering inequality measure and average income per capita. Climate policy implying a loss of GDP for countries determines a small rise of poverty prevalence (+2% at world level). This is crucial in LDCs where population below poverty line is highest. This result is reinforced also by the rise of Palma ratio. Only Mozambique benefiting from carbon leakage effect fastens the poverty reduction compared to the reference scenario. In the MPOLICY_LCDFUND scenario, the rise of Palma ratio worsens the situation and the Development Fund size is not sufficient to compensate it. Again targeting the transfers to specific sectors (MPOLICY_LCDFUND_SUB scenario) leads to a slight reduction of poverty prevalence which remains in most of cases (excluding Mozambique) higher than in the reference scenario.

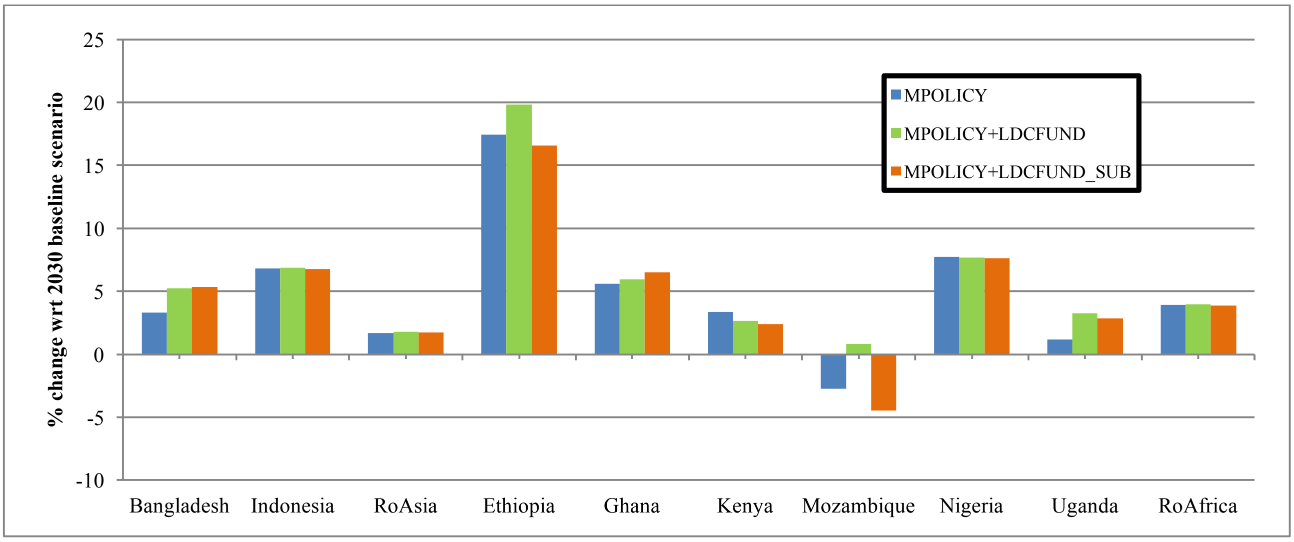

Figure 9 Climate policies effects on poverty in LDCs

This result has to be cautiously judged; although it is reasonable to think that climate policy, per se, and its cost will imply a slight increase of poverty prevalence, in this paper we disregard the impacts of climate change and the benefit of mitigation, i.e. lower magnitude of impacts. According to the recent literature climate change impacts will have strong distributional and poverty implications (Dennig et al. 2015); therefore the overall outcome of mitigation when an impact scenario is accounted is dubious and will be covered in our future research.

9. Conclusion

Linking empirically some social SDG indicators, such as "Poverty headcount ratio at $1.25 a day" and Palma ratio, to a CGE model allows assessing future trend of these indicators under different scenarios and policy interventions. In our "Middle of the road" reference scenario, the process of poverty prevalence reduction, boosted by Millennium Development Goals, continues up to 2030 and it is linked to a decrease of within-country inequality. Considering the INDCs as binding targets, COP21 agreement slows down the poverty reduction (-2% in 2030) compared to the reference scenario (not taking into account the likely mitigations benefits due to lower climate change impacts). Recycling carbon revenues with the creation of a Development Fund benefiting LDCs with a lump sum transfer or sector-specific subsidies is not sufficient to bring back poverty prevalence to the reference scenario level due to the inadequacy of the Fund.

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