Getting on Track to Net Zero: Accelerating a Global Just Transition in This Decade

Abstract

To contain global warming to between 2°C and 1.5°C, global greenhouse gas emissions must be cut 25 to 50 percent below 2019 levels by 2030. Even if fully achieved, current country pledges would cut global emissions by just 11 percent. This Note presents illustrative options for closing this ambition gap equitably and discusses their economic impacts across countries. Options exist to accelerate a global just transition in this decade, involving greater emission reductions by high-income countries and climate finance, but further delays in climate action would put 1.5°C beyond reach. Global abatement costs remain low under 2°C-consistent scenarios, with burdens rising with income levels. With efficient policies of carbon pricing with productive revenue use, welfare costs become negative when including domestic environmental co-benefits, before even counting climate benefits. GDP effects from global decarbonization remain uncertain, but modeling suggests they exceed abatement costs especially for carbon-intensive and fossil-fuel-exporting countries. Ratcheting up climate finance can help make global decarbonization efforts more progressive.

Policy highlights

- Pure abatement costs are about $0.5 trillion or 0.4 percent of GDP worldwide in 2030. Costs are higher for HICs (about 0.7 percent of GDP) and lower for LICs (0.3 percent of GDP).
- However, implementing carbon taxes or emissions trading systems and using revenues for productive public investment (while compensating vulnerable households for elevated fuel prices) could cut these costs for MICs and LICs by two-thirds or more.
- Global impacts on GDP vary between a reduction relative to baseline in 2030 of 0.6 and 1.5 percent depending on effort distribution and revenue recycling. The midpoint is 1.0 percent globally, equivalent to around 0.1 percentage point reduction in annual global GDP growth. Given projected average global growth of 3 percent a year to 2030, this implies costs that are very small compared to the broader welfare benefits. However, GDP costs are somewhat larger for fossil fuel exporters (2–2.5 percent) and carbon-intensive MICs (0.6–1.5 percent). GDP impacts may be lower when carbon pricing revenues fund investment or measures are taken to limit output losses.
- Moderate increases in climate finance flows from HICs to lower-income countries can ensure that the global distribution of mitigation burdens is progressive and supports the development needs of low-income countries.

INTRODUCTION

Under the Paris agreement, each country determines its own voluntary emissions reductions. But the success of the Paris agreement will hinge on global emissions reductions being sufficient. So far commitments are jointly falling short and need to be scaled up. What would be a reasonable approach to gauge the needed ambition enhancement by countries to cover the ambition gap between the proposed NDCs and 2-C consistent emission pathways? Requiring that each country reduces emissions by the same proportion from current levels by 2030 would be unfair, because emerging and developing economies are expected to develop fast over the next decades and hence their emissions would grow fast in the absence of further climate policies. The distribution of emissions reductions must consider and allow for the development needs of emerging and developing economies.

To do that, we suggest focusing on reductions in the carbon (or GHG) intensity of output and to use as a simple benchmark similar pace of reduction in the carbon intensity of output (i.e., carbon emissions per unit of GDP). This is not a perfect criterion. Indeed, emerging and developing economies have a larger share of industry in economic activity, in part because these activities were outsourced from advanced economies to these countries and in other part because they are still on the path to development and industrialization. This tends to increase the carbon intensity of their GDP, since industry is intensive in energy use. But the requirement would not be to equalize these carbon intensities, rather than reduce them at a similar pace. We also discuss ways to further increase international burden sharing through climate finance and technology transfers to emerging and developing economies.

EFFORT SHARING IN CLIMATE CHANGE MITIGATION

Global cooperation is the most cost-effective solution to the challenge of achieving coordination on climate policy. Whether climate policy increases or decreases GDP compared to the baseline depends on the policy design, the ambition level of the policy and also on how comprehensively indirect effects of climate policy are considered. The concern for economic losses, however, has caused a coordination challenge, where most countries did not want to act unless other countries acted as well. Simultaneous mitigation efforts of all countries would remove concerns by individual countries to suffer a competitive disadvantage. This raises the question of how mitigation efforts should be distributed across countries. For the distribution of mitigation efforts, a variety of “burden sharing” approaches have been suggested.

The IPCC classifies effort sharing approaches into three archetypes which are based on a concept of fairness: equality, responsibility and capability (IPCC 2014, Section 6.3.6.6)[1]. These three approaches are thought to span a space of approaches which are a combination of the three basic approaches. The three archetype approaches work as follows:

[1] The WGIII contribution (Mitigation of climate change) for the sixth assessment report is expected to be published in March 2022. The 2014 IPCC report is thus still the most recent IPCC report.

- In the responsibility approach, emission goals are allocated based on historical emissions.
- In the capability approach, emission goals are allocated based on the ability to pay for mitigation. This includes the basic needs approach, which allows the least capable countries to make less ambitious reduction efforts to secure their basic needs.
- In the equality approach, emission goals are allocated on a per capita basis.

An additional approach is cost effectiveness, which means that those emissions with the least abatement cost are eliminated first. It could be implemented with a simple global carbon price.

In addition to the three archetypes, three combinations of them are discussed in chapter 6 of the IPCC (2014). The combinations are frequently used in studies comparing effort sharing approaches. We will thus introduce them here:

- “Equal cumulative per capita emissions” is a combination of equality and responsibility. It allocates emission goals so that per capita emissions converge.
- The combination of responsibility and capability is another important combination.
- In “staged approaches”, countries take differentiated commitments (possibly based on all three archetypes) in various stages. This approach includes grandfathering, where countries follow equal percentage reduction goals.

“Cost effectiveness” and “grandfathering” are burden sharing approaches but are not based on fairness principles. They are included in the literature mostly as reference cases. The classification in chapter 6 of the (IPCC 2014) with the archetypes and their three main combinations is based on (Höhne, den Elzen, and Escalante 2014) and has proven to be highly influential (Robiou du Pont et al. 2017; Pan et al. 2017; Fyson et al. 2020; van den Berg et al. 2020). (Kartha et al. 2018) and (Dooley et al. 2021), by contrast, argue that this group of approaches “cannot be considered an authoritative and ethically robust taxonomy of equity approaches in any sense”.

(van den Berg et al. 2020) provide a consistent framework for implementing the burden sharing approaches. The authors implement six approaches: 1) Per capita convergence (PCC), which represents the equality approach, 2) equal cumulative per capita emissions (ECPC), the combination of equality and responsibility, 3) ability to pay (AP), which is the capability approach, 4) greenhouse development rights (GDR), the combination of responsibility and capability, 5) grandfathering (GF), which represents the staged approach and 6) the cost-optimal (CO) approach as a reference. Following the implementation of these approaches means that we use an established methodology.

(Dooley et al. 2021) present a more comprehensive set of burden sharing approaches than chapter 6 of (IPCC 2014), which includes progressivity and subsistence emissions. The authors present 13 burden sharing approaches, which include those of (IPCC 2014), chapter 6, and (Höhne, den Elzen, and Escalante 2014). This more comprehensive list is discussed in chapters 3 and 4 of (IPCC 2014). One of the two most important additional ones is progressivity, which says that wealthier countries should make a larger effort. The other is subsistence, which considers a subsistence level of emissions, defined as emissions by people who cannot afford anything else than fossil fuels. Now that non-carbon energy has become as affordable and accessible as fossil fuels the concept has become less clear (Shue 2019). Both of these additional measures seem closely related to the capacity approach, however.

The Paris Agreement is based on “nationally determined” contributions and hence not based on any of the burden sharing approaches. Before the Paris Agreement, negotiations on global climate change mitigation took the approach of determining a budget of remaining emissions and distributing it across countries, preferably based on a concept of fairness. An example for this is the distinction between Annex I (industrialized countries) and non-Annex I countries. This top-down approach failed definitely at the 2009 Copenhagen Summit. The success of the Paris Agreement was due to a switch to a bottom-up process. The bottom-up approach did not guarantee that an ambitious carbon budget would be respected, but it was hoped that the process of “ratcheting up” ambition subsequently would eventually keep global emissions within the budget.

As an alternative to effort sharing approaches based on fairness principles, (Aldy, Pizer, and Akimoto 2017) propose six measures of mitigation efforts, which could be used together as a portfolio of indicators. The authors mention the use of emission intensity as a way of making mitigation effort comparable. The metric has been supported in particular by China and India. The advantage of the measure is that it accounts for economic growth. A disadvantage is that emission intensity can be affected by factors that do not reflect mitigation efforts, in particular changes in the growth rate of the economy. Other effort measures are emission reductions compared to a business-as-usual scenario, (implicit) carbon prices, energy prices and mitigation costs. The authors argue that a portfolio of measures for mitigation efforts should be used, as all of them have disadvantages and advantages, without a clear best option.

MODEL DESCRIPTION

IMF-ENV

The IMF-ENV model[2] is a recursive dynamic neoclassical, global, general equilibrium model, built primarily on a database of national economies and a set of bilateral trade flows. The model describes how economic activities and agents are interlinked across several economic sectors and other countries or regions. The central input of the model is the data of the Global Trade Analysis Project version 10 database (Aguiar and others 2019). The database includes country-specific input-output tables for 141 countries and 65 commodities and real macro flows. It also represents world trade flows comprehensively for a given starting year. The currently used version 10 is based on data from 2014. The model is based on the activities of the key actors: representative firms by sector of activities, a regional representative household, a government, and markets. Firms purchase inputs and primary

[2] Applications of the IMF-ENV model can be seen in Chateau, Jaumotte, and Schwerhoff (2022) and Chateau and others (2022). A full model description is under development. Meanwhile, readers interested in the model can consult the documentation of the twin models the current model is built on the ENVISAGE model (van der Mensbrugghe 2019) and the OECD ENV-Linkages Model (Dellink, and Lanzi 2014).

factors to produce goods and services, optimizing their profits. Households receive the factor income and in turn buy the goods and services produced by firms; household demands result from standard welfare optimization under households' budget constraints. Markets determine equilibrium prices for factors, goods, and services. Frictions on factor or product markets are limited, except as described elsewhere in the following.

The model is recursive dynamic: it is solved as a sequence of comparative static equilibria. The fixed factors of production are exogenous for each time step and linked between time periods with accumulation expressions, like the dynamic of a Solow growth model. Output production is implemented as a series of nested constant-elasticity-of-substitution functions to capture the different substitutability across all inputs. International trade is modeled using the so-called Armington specification, which posits that demands for goods are differentiated by region of origin. This specification uses a full set of bilateral flows and prices by traded commodity. In contrast to intermediate inputs, primary factors of production are not mobile across countries. Model closures assume real government expenditure and nominal current account to be constant to baseline values. Assumptions made on trade closure rules can impact results for export shares of countries in global trade and trade balances for both surplus and deficit countries (Bekkers and others 2020). In the baseline, the values of regional current-account-to-GDP ratios and total foreign-savings-of-government-to-GDP ratios are calibrated to projections from ENV-Linkages and thus, for consistency, the same closure rules are retained in IMF-ENV.

While the capital market is characterized by real rigidities, the labor market is not. One major characteristic of the model is that it features vintage capital stocks in such a way that a firm's production structure and a firm's behavior are different in the short and long term. In each year, new investment is flexible and can be allocated across activities until the return to the "new" capital is equalized across sectors; the "old" (existing) capital stock, on the contrary, is mostly fixed and cannot be reallocated across sectors without costs. Consequently, short-term elasticities of substitution across inputs in production processes (or substitution possibilities) are much lower than in the long term and make adjustments of capital more realistic. In contrast, labor (and land) market frictions are limited: in each year, labor (land) can shift across sectors with no adjustment cost until wages (land prices) equalize, and the labor (land) supply responds with some elasticity to changes in the net-of-taxes wage rate (land price).

The model also links economic activity to environmental outcomes. Emissions of greenhouses gases and other air pollutants are linked to economic activities either with fixed coefficients, such as those for emissions from fuel combustion, or with emission intensities that decrease (nonlinearly) with carbon prices—marginal abatement cost curves. This latter case applies to emissions associated with non-energy-input uses (for example, nitrous oxide emissions resulting from fertilizer uses) or with output processes (like methane emissions from waste management or carbon dioxide emissions from cement manufacturing). In the very long term, the model may overestimate the cost of decarbonization, since it does not take into account radical technology innovations that could materialize at this longer horizon (hydrogen, second generation of nuclear and biofuel technologies, carbon capture and storage technology). While some of these new technologies are at an experimental stage, it is difficult to include them in the model at the moment because of a lack of information about the future costs of these technologies if they were deployed at industrial scale.

The model can be used for scenario analysis and quantitative policy assessments. For scenario analysis, the model projects up to 2050 an internally consistent set of trends for all economic, sectoral, trade-related, and environmental variables. In this context, the model can be used to analyze economic impacts of various drivers of structural changes like technological progress, increases in living standards, and changes in preferences and in production modes. A second use for the model is quantitative economic and environmental policy assessment for the coming decades, including scenarios of a transition to a low-carbon economy. In this case, the model assesses the costs and benefits of different sets of policy instruments for reaching given targets like greenhouse gas emission reductions. With the recursive dynamic framework of IMF-ENV, in a policy simulation for example of carbon pricing, the model considers not only the direct effects of changes in relative prices of the carbon-intensive fuels but also the second-round effects of the policy on investment and labor over years. Moreover, the model projects the structural changes resulting from the policy over time by differentiating the elasticity of substitution between labor and capital-energy over the short term and the long term (less elastic in short term but more elastic in long term).

There are various upside and downside risks around estimated GDP effects. For example, on the upside, new rapid technological innovations or more learning by doing could reduce the costs. On the downside, stranded assets and a difficult reallocation of labor across sectors could increase the costs. Additional risks might affect abatement costs to stay within the temperature goals of the Paris Agreement positively or negatively, including economic and population growth and strategies used by fossil fuel producers.

Annex 2. Business as Usual Emissions Projections

Projected carbon dioxide (CO_2) emissions growth varies significantly within country groupings (Annex Figure 2.1). GDP growth remains the major contributor of growing CO_2 emissions at the global level and for MICs, LICs, and oil exporters in the baseline. In many MICs and LICs, high economic growth remains the driver of rising emissions as it offsets the emission reductions from reduction in energy intensity. Differently, many HICs (for example, Canada, EU-27, and United Kingdom) are expected to grow moderately, and this, coupled with energy efficiency gains, allows these countries to keep CO_2 emissions growth low and, in some cases, even falling emissions (for example, both baselines project falling CO_2 emissions in Japan compared to current levels). In the IMF-ENV baseline the carbon intensity of the energy structure is projected to increase globally and in each income group.

ENHANCED AMBITION SCENARIOS

There are various possibilities for integrating equity into the allocation of mitigation burdens across countries.[3] Annex 3 discusses several regimes that have been considered by policymakers and

[3] Technically, the most efficient solution to global mitigation is to implement a globally uniform carbon price and address equity through international transfers entirely. However, the political feasibility of such transfers is severely limited. In practice, a differentiation of global mitigation efforts by income levels,

analysts and uses them to infer a “high equity” scenario for emissions reduction allocations under alternative temperature targets. Two further possibilities are considered. One defines efforts in terms of reducing the emission intensity of GDP, which gives more leeway to fast-growing countries. Targeting emission intensity reflects an approach used by some large emitters in their NDCs, but also allows quickly growing countries to turn around their economies more gradually than absolute emission reductions would.[4] The other is the international carbon price floor proposed by the IMF (Parry and others 2021; Chateau, Jaumotte, and Schwerhoff 2022) to facilitate an equitable scaling up of global mitigation action through coordination over minimum price floors differentiated according to countries' income level. For a given emissions reduction allocation across countries, a further possibility for promoting equity is transfers from HICs to LICs.

This Note considers five enhanced ambition scenarios that achieve Paris temperature goals while respecting international equity. Three scenarios focus on a 2°C temperature target to consistently compare outcomes under alternative equity regimes for a given temperature goal. The remaining two scenarios scale emissions allocations to be consistent with more ambitious global goals of 1.8°C and 1.5°C. In all scenarios, reductions are considered relative to 2030 BAU emissions or to emissions intensity (rather than historical emissions) as this better accommodates fast-growing MICs and LICs (indeed some regimes allow some LICs to increase their absolute emissions to 2030). In each scenario, individual countries all follow the rule for their group.

The scenarios are as follows:

- Emission intensity reduction (“Intensity”) 2°C: All HIC, MIC, and LIC countries cut their CO_2 emissions/GDP intensity by 36, 32, and 21 percent, respectively, relative to 2030 BAU.[5]
- International carbon price floor (“ICPF”) 2°C: All HIC, MIC, and LIC countries implement a minimum carbon price of $75, $50, and $25 per tonne in 2030, respectively. This implies HICs, MICs, and LICs cut CO_2 emissions by 38, 29, and 24 percent below 2030 BAU, respectively.
- High equity (“Equity”) 2°C: HICs, MICs, and LICs reduce their CO_2 emissions below BAU levels by 46, 27, and 17 percent, respectively.
- High equity 1.8°C: To meet the more ambitious temperature target, emissions reductions for each country group from the 2°C high equity case are raised by around 9 percentage points.
- High equity 1.5°C: emissions reductions for each country group from the 1.8°C high equity case is raised by around 10 percentage points.

In all scenarios it is assumed that countries achieve the more stringent of their groups' emissions reduction target or their existing NDC target. Additional scenarios consider transfer payments among countries and are discussed later.

either through different quantitative targets (for example, on emission reductions or emission intensity reductions) or differentiated carbon prices, helps to reduce the needed international transfers.

[4] Targeting emission intensity does however introduce large uncertainties in terms of absolute emission reductions if realized GDP growth deviates significantly from projected levels, suggesting the need for regular updating of intensity targets.

[5] For comparison, in the baseline between 2021 and 2030 the CO_2 emissions intensity of GDP declines 8, 41, and 49 percent in HICs, MICs, and LICs, respectively.

The three 2°C scenarios would achieve 1.5 to 2°C with varying emissions reductions across country groups. The 2°C scenarios (Intensity, ICPF, and Equity) would cut global CO_2 emissions by 31 percent compared with BAU, equivalent to a 27 percent cut on 2019 levels. The Intensity and ICPF scenarios are similar in their allocations across country groups, though they would vary within groups as countries have differing responsiveness to carbon pricing under the ICPF. The Equity scenario would allocate even more of the emissions cuts to developed compared with developing countries.

All scenarios imply some convergence in emissions per capita. 2030 per capita emissions are broadly similar in HICs and MICs across the scenarios—indeed this is the case even when countries only meet their NDC commitments—while the difference between HIC/MIC and LIC per capita emissions is progressively reduced with the more stringent temperature scenarios. Emissions per capita of LICs also decline (relative to 2030 baseline levels) but only moderately.

RESULTS –

1) MITIGATION BURDENS: GDP

GDP impacts differ from welfare costs in several regards. Welfare costs focus on changes in the level of consumption, while GDP also includes changes in the levels of investment and net exports but excludes domestic environmental co-benefits. On net exports, these can change due to (1) downward pressure on demand for fossil fuels due to global decarbonization, which adversely affects energy exporters; and (2) impacts of carbon mitigation policies on the competitiveness of energy-intensive, trade-exposed industries, though countries usually implement measures (like free allowance allocations) to limit competitiveness impacts. To an approximation, changes in net exports wash out at the global level, but these changes can be significant at the domestic level.[6]

Evidence on both the magnitude and the sign of the GDP impacts of carbon pricing and mitigation policy are unsettled. Besides the form of revenue recycling, GDP effects are sensitive to assumptions about how mitigation policy affects the allocation of investment across sectors and time, demand and supply elasticities in world energy markets, the future availability of low-carbon technologies, and the rate at which learning-by-doing lowers their costs, all of which are difficult to pin down. Estimates also vary depending on whether policies are assumed to be budget neutral or involve a fiscal expansion financed by debt. For example, studies by the IEA and OECD suggest that with clean energy

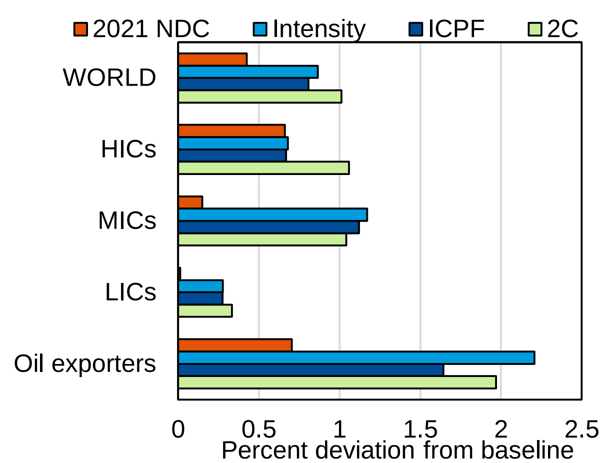
[6] Impacts of mitigation policies on inflation are beyond the scope here; however, inflationary impacts should be negligible if policies are implemented immediately, progressively, and credibly (IMF 2022d).

investment, decarbonization policies can significantly boost global GDP over the medium to longer term; the most recent IPCC report finds that mitigation pathways aligned with the 2ºC temperature goal would moderately reduce GDP, while an earlier IMF study suggests mixed results for 2030 (see International Energy Agency 2021; IMF 2020; IPCC 2022; OECD 2017). At the national level, a review of computable general equilibrium models found that just over half of studies showed increases in GDP from carbon pricing (Freire-González 2018; see also Bernard and Kichian 2018; Bretscher and Grieg 2020; review in Heine and Black 2019). Ex post empirical studies decomposing the effects of climate policies on GDP find either zero or small positive impacts of reforms implemented in Europe and North America (see Metcalf and Stock 2020; Azevedo and others 2022; Metcalf 2019).

With these uncertainties in mind, this section uses the IMF-ENV model to estimate GDP impacts for key countries and country groupings. A key attraction of IMF-ENV is that it accounts for changes in investment, international fuel prices, and trade patterns for energy-intensive, trade-exposed industries induced by global mitigation policies. The model distinguishes 19 individual countries and groups other countries into six regional aggregates. The model also captures the costs of reducing all GHG emissions, including non-CO_2 emissions which account for 30 percent of GHG emissions globally. See Annex 1 for further details. In reporting GDP effects, the country groupings for HICs, MICs, and LICs roughly correspond to those used earlier, but in addition impacts on oil-producing countries are separated out. The simulations are run for budget-neutral policies. Carbon pricing revenues are assumed to reduce labor taxes though other possibilities are considered later (see Figure 18).

Global GDP costs are around 0.8 of BAU GDP by 2030 for the 2°C scenarios, with proportionate GDP losses moderately larger for MICs and more so for oil producers (Figure 15). Although GDP losses are larger than welfare costs (see the following), in the context of economic growth the global losses are manageable—even a 1 percent GDP loss in 2030 is equivalent to a reduction in annual global GDP growth (projected to average about 3 percent a year to 2030) of only around 0.1 percentage point. These estimates are in line with those recently released in IMF (2022d). For MICs, GDP losses vary from 1 percent in the high equity 2°C scenario to 1.2 percent in the Intensity scenario. GDP losses are much smaller for LICs at around 0.3 percent, but much higher for oil producers at 1.6–2.2 percent. Of the three scenarios considered, the high equity 2°C scenario is the most progressive—because it shifts some of the mitigation burden from MICs to HICs compared with the other scenarios. From a global perspective, the ICPF scenario is the

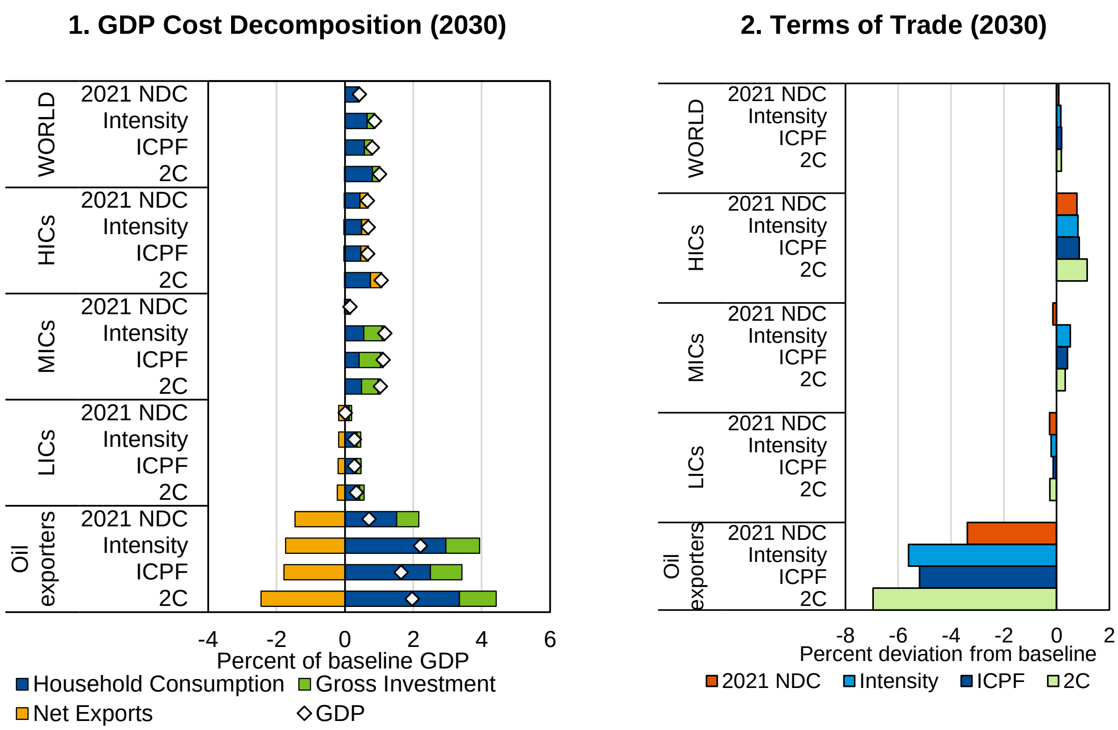
Figure 15. GDP Costs under Alternative Ambition Scenarios by Country Grouping in 2030



Notes: 2C = High equity 2°C consistent scenario; HIC = high-income countries; ICPF = international carbon price floor; Intensity = emission intensity reduction; LIC = low-income countries: MIC = middle-income countries. NDC most efficient, as measured by a lower GDP cost, because the common carbon price by income group targets the emission reductions to where they are cheaper.

GDP costs are larger than pure abatement costs because of reductions in investment (especially in MICs and oil producers) and trade effects (especially in oil producers; Figure 16). Investment falls to the extent production levels fall in the power and industry sectors (reductions in the emissions intensity of production generally reflect a redirection of investment to cleaner capital). In MICs, coal is often used intensively in power generation and industry, and therefore carbon pricing has a proportionately bigger impact on production costs. This production/investment effect could to some extent be offset by using carbon pricing revenues for output-based rebates for power/industrial firms, or using other instruments like tradable performance standards or feebates in place of carbon pricing.[7] For the oil

Figure 16. GDP Cost Decomposition under Alternative Ambition Scenarios by Country Grouping in 2030



Note: Terms of trade is a GDP weighted average for the countries in the region. 2C = High equity 2°C consistent scenario ; HIC = high-income countries; ICPF = international carbon price floor; Intensity = emission intensity reduction; LIC = low-income countries; MIC = middle-income countries; NDC = nationally determined contribution.

producers—besides high carbon intensity and high share of fossil electricity—there is also a deterioration of their terms of trade from lower international demand for oil, especially for high-cost

[7] These strategies cost-effectively reduce the emissions intensity of production, though pure abatement costs would be somewhat higher than for pricing, given they do not promote the same reduction in production.

producers, which translates into lower income, reducing private consumption and investment. Real net exports increase but this reflects that import volumes reduce more than exports, offsetting some of the decline in GDP.[8]

GDP impacts can differ substantially within country groupings (Figure 17). For example, within MICs GDP impacts for the high equity 2°C scenario are 1.5 percent in Mexico (an energy exporter), 1.1 percent in China, 0.5–0.7 percent in Argentina and Brazil (relatively decarbonized power sectors), 0.6 percent in South Africa (heavy coal dependence), and even a marginal gain of 0.03 percent in Turkey. For China—which has an outsize influence on the MIC group—half of the GDP loss reflects reduced investment. In practice, however, the GDP cost in China is likely lower than shown here, because overcapacity exists in some sectors of the Chinese economy and drawing down these overcapacities would be less harmful in terms of GDP than reflected by the models.

In short, GDP costs may be less progressive across countries than welfare costs (reflecting additional components in the former which disproportionately affect MICs and oil producers) though GDP impacts can be reduced through productive revenue use (Figure 18). Among the considered options, the global GDP costs are the least when revenues are used to fund productive public investments, while costs are largest when revenues are recycled as lump sum transfers to households.[9] Lump sum transfers to households or other affected groups may be helpful to manage the political economy of climate policy, but investments and a reduction in labor taxes are more efficient. Under the high equity 2°C scenario GDP losses fall to 0.6 and 0.02 percent for MICs and LICs, respectively, if revenues fund public investments (implying a net increase in investment overall). In contrast, if revenues fund lump sum transfers, GDP losses for MICs and LICs increase to 1.5 and 0.7 percent, respectively. Costs in the 2C-Mix[10] scenario fall between the range from full public investments and lump sum transfers for all income groups.

[8] Macroeconomic models project that the current account of oil producers as a percent of GDP would improve as investment would fall much more than saving (see IMF 2022a). In the IMF-ENV model, this results from an assumption ("closure rule") of unchanged nominal current account balance which translates into an increase of net exports-to-GDP given the decline in GDP relative to baseline (see Annex 1 for more details). As a group, oil producers could impose a coordinated carbon tax on oil exports to appropriate revenues and partially offset GDP losses (IMF 2019a, Annex 1.10).

[9] The size of generated carbon revenues varies by income groups due to differentiated emission reduction goals. Under the 2C scenario, carbon revenues generated in HIC, MIC, and LIC regions are equal to 3, 2, and 2 percent of GDP, respectively.

[10] In 2C-Mix, all countries allocate 30 percent of carbon tax revenues toward lump sum transfers to households. The remaining 70 percent is used to reduce distortionary wage taxes in HICs while MICs and LICs use it as public investments.

Figure 17. GDP Costs under High Equity 2°C Scenario by Country, 2030

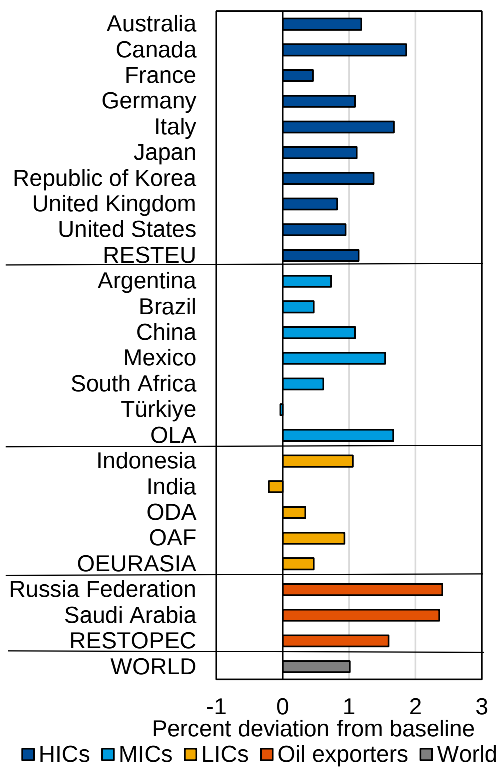
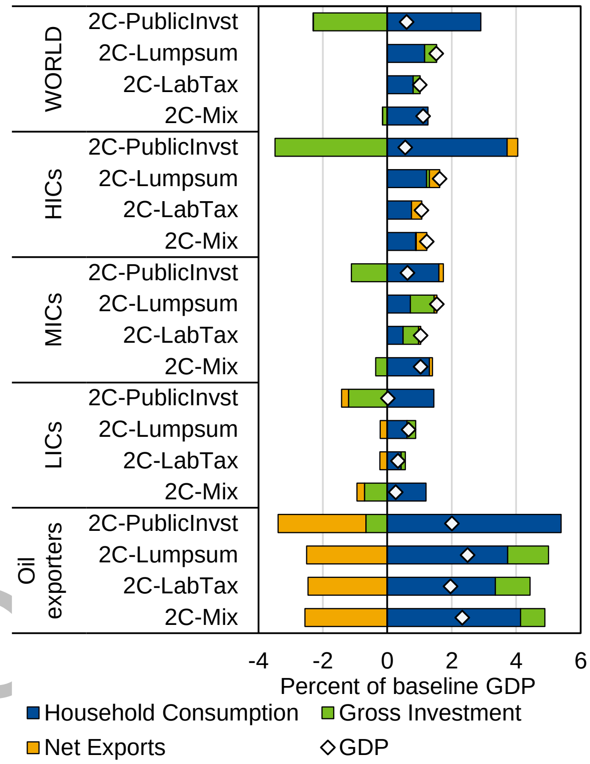


Figure 18. GDP Costs under High Equity 2°C Scenario and Alternative Recycling Schemes by Country 2030



Note: 2C = scenarios achieving 2°C; HIC = high-income countries; LIC = low-income countries; MIC = middle-income countries; OAF = Africa (except South Africa); ODA = other East Asia and New Zealand; OEURASIA = other Eastern Europe and Caspian countries; OLA = other Latin America; RESTEU = rest of European Union and Iceland; RESTOPEC = other oil-exporting countries.

Given that the intensity-based approach considers differences in economic growth, GDP losses are largely even across countries of all income groups. **Error! Reference source not found.** shows GDP losses of climate policy in the CGE model. It should be emphasized that these estimates do not account for substantial co-benefits from reduced local air pollution (Vandyck et al. 2018) and tax efficiency improvements (Bento, Jacobsen, and Liu 2018). As a consequence, the economic cost will be considerably overestimated.[11] The linear emission reductions cause disproportionate GDP losses to regions like Africa (OAF) or Indonesia. With the intensity approach, the losses are more evenly spread. The MICs have relatively high GDP losses, but they also stand to gain considerably from reductions in their currently high local air pollution levels. Countries that gain GDP in this scenario

[11] Future versions of the model will take these benefits into account to obtain more realistic GDP estimates.

are gaining market share in the scenario, so that international trade shifts in their favor. The large GDP losses in the OPEC countries results from decreased demand for oil from the rest of the world.

Carbon prices in the intensity-based approach are roughly proportional to income level, meaning that taxation is progressive. **Error! Reference source not found.** shows the carbon tax rates which would be necessary to achieve the intensity-based approach. For the moment, carbon taxation is the only climate policy implemented in the model. Sector-specific policies would be more effective in some cases, for example infrastructure investments in the transport sector or support for sustainable farming practices in agriculture. This would allow the level of taxation to be lower. Further, the carbon tax is applied only to CO2. Additional policies addressing other GHG would further allow for a lower carbon tax level. Regarding climate policies, the model should thus be considered illustrative.

CLIMATE FINANCE

Climate finance can promote equitable emission reduction regimes without increasing global abatement costs. Scaling up public and private sources of climate finance is critical to addressing climate change (IMF 2022c). At present, HICs pledged to mobilize $100 billion a year from 2020 onwards in climate finance for developing countries.[12] However, estimates of current annual flows fall about one-fifth short of this target. Additionally, a large portion of the finance is from multilateral development banks and private sources, much of it is lending rather than transfers, and the pledge covers financing for adaptation as well as mitigation. Hence current bilateral transfers from HIC government budgets for mitigation in developing countries amount to around $10 billion a year.[13] This subsection discusses how finance could be used to compensate lower-income countries under different scenarios and how such transfers would alter GDP impacts on different income groups.

Abatement costs may be a more appropriate metric for informing dialogue over climate finance than GDP effects. The former is directly related to the costs of shifting away from fossil-based technologies to low-carbon technologies and is estimated with a reasonable degree of confidence—in contrast, GDP effects are sensitive to, for example, domestic fiscal objectives for revenue use.

For illustration, fully compensating all LICs (with per capita income below $5,500) for their pure CO_2 abatement costs under the 2°C scenario would require annual transfers of about $30 billion, while compensating for their abatement costs in the 1.8°C scenario would cost about $50 billion. When total GHG abatement costs (all sources including land use, land-use change, and forestry) are accounted for, with mitigated non-CO_2 emissions being disproportionately higher in LICs, annual transfers of about $60 billion would be needed to fully compensate them under the 2°C high equity scenario. The total amount of transfers needed can be negotiated by countries based on several factors like differences in sources of emissions and GHG coverage. Therefore, the two transfer values of $30 billion and $60 billion are chosen to illustrate differences between the CO_2-only abatement costs and full GHG abatement costs for LICs.

[12] Climate finance is distinct from “loss and damage,” which refers to proposed compensation for countries’ climate damages.

[13] Calculated using Organisation for Economic Co-operation and Development (OECD 2022).

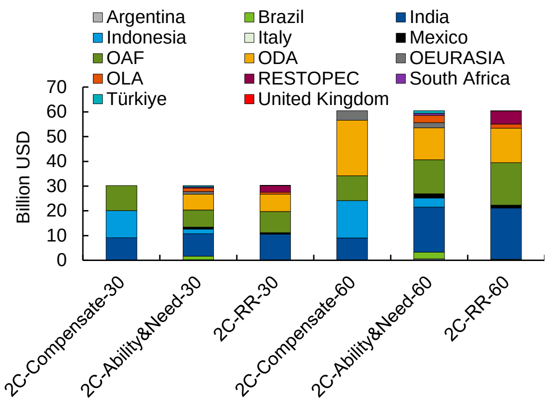
The GDP effects of budgetary contributions to recipient, and from donor, countries can differ from the pure amount of the transfer. GDP impacts will depend on the size of transfers relative to GDP and how they are used in recipient countries. For example, if transfers fund productive public investment, this will directly boost GDP, while if they increase households' disposable income this will increase demand for goods and services which in turn affects domestic production, imports, and exports. The main purpose of the transfers, however, is to ensure global equity irrespective of how they are used. In the illustrative simulations that follow, the international transfers are assumed to be distributed as lump sum payments to households.

Annual transfers in 2030 from HICs to MICs/LICs of $30 and $60 billion, respectively, are considered, using the high equity 2ºC scenario, under three allocation rules:

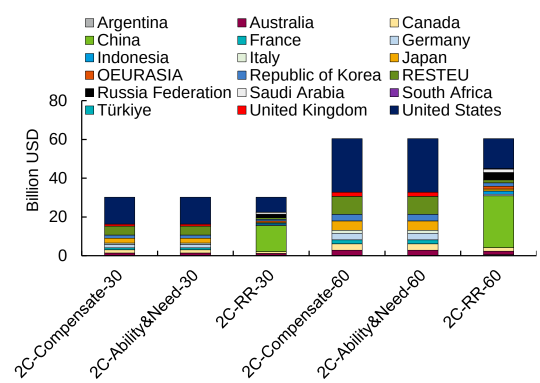
- *2C-Ability&Need:* HICs (excluding oil producers) contribute in proportion to their share in total HIC BAU emissions while MICs and LICs receive transfers in proportion to their population shares. Among MICs, recipients include only countries that either expressed a need for financial support in any round of NDCs (for example, Argentina, Brazil, and Mexico) or have already received financial support for climate action from HICs (for example, South Africa and Turkey).
- *2C-Compensate:* HIC contributions and the selection of potential recipients are the same as previously stated. However, for recipients, starting from the poorest country, transfers are made in the amount equivalent to the full abatement cost of the country and until cumulatively $60 billion (or $30 billion) are disbursed. All LICs are compensated with the $60 billion mark while $30 billion is sufficient to fully compensate Africa (except South Africa) and India, and partially compensate Indonesia for about three quarter of total GHG abatement costs.

Figure 20. Total Transfers

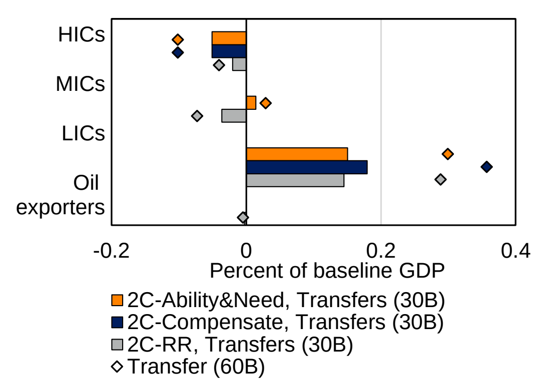
1. Transfers Received (2030)



2. Contributions (2030)



3. Transfers in 2030



Note: HICs = high-income countries; LICs = low-income countries; MICs = middle-income countries; OAF = Africa (except South Africa); ODA = other East Asia and New Zealand;

- *2C-RR*: This option is based on the Raghuram Rajan's proposal, which applies to all countries.[14] In this case, countries either contribute or receive funding in proportion to the difference between their per capita emissions and the global average per capita emissions scaled by an emissions price and regional population. The globally implied carbon price here is set at \$4 per ton of CO_2, which implies total transfers of \$60 billion.

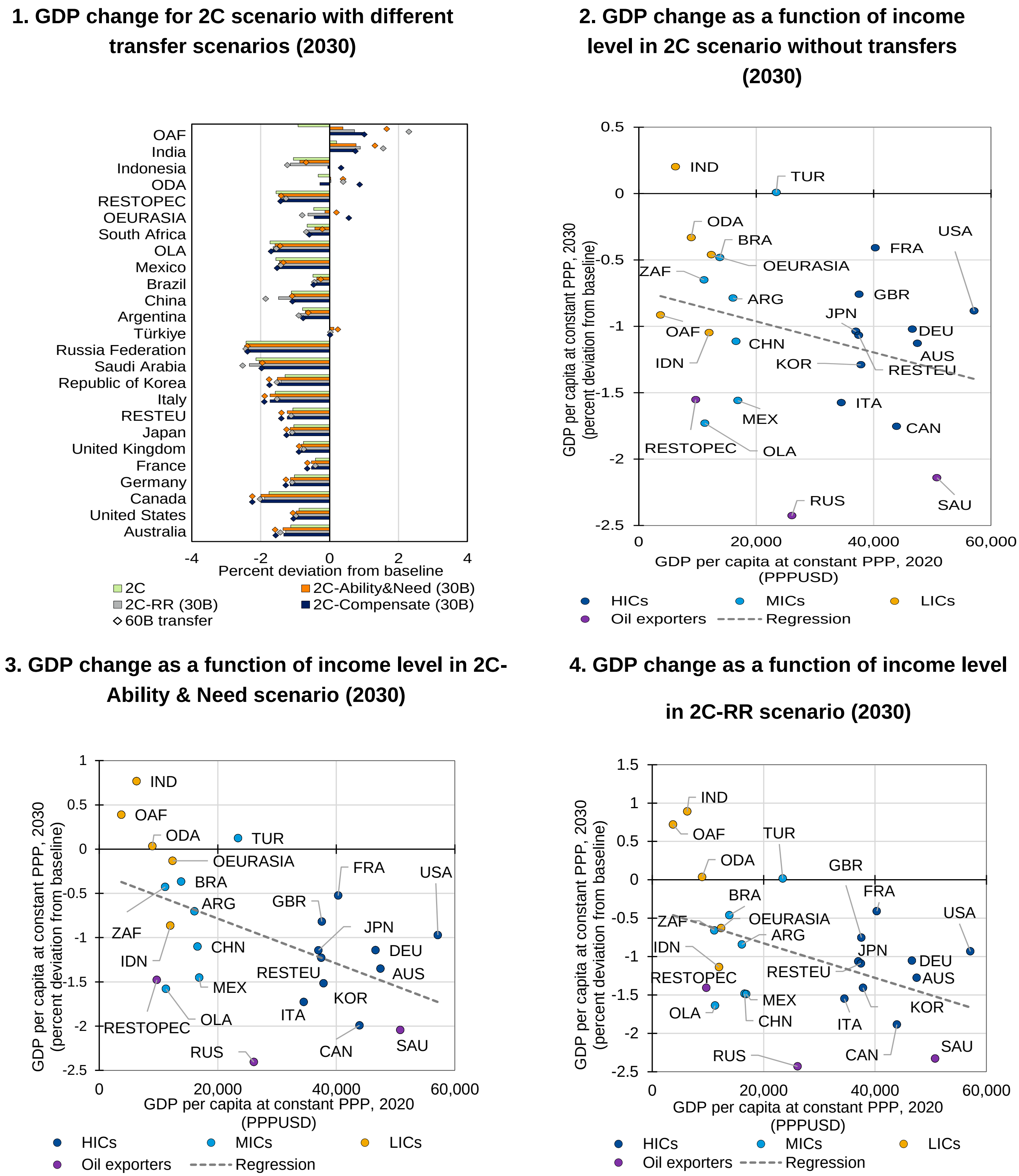
Transfers of \$30 and \$60 billion from HICs could be funded from only 1.5 and 3 percent, respectively, of potential carbon pricing revenues for this country group (Figure 20). At the country level, the United States is one of the top three contributors, its share of contributions varying from 26 to 46 percent. In the 2C-RR case, China is the largest contributor (45 percent of the total) reflecting its high carbon intensity and the large size of its economy. The transfers received by LICs range from 0.30 to 0.36 percent of GDP for \$60 billion. With the \$60 billion goal, India (15 to 35 percent) and Africa (excluding South Africa) (23 to 34 percent) are the top two recipient countries. Indonesia switches from a recipient to contributor under the 2C-RR scenario as its per capita emissions exceed the global average.

The transfers help make mitigation burdens, measured in GDP cost terms, more progressive (Figure 21). Even in the high equity 2°C scenario, economic cost is not yet very "progressive" in the sense that HICs have low GDP costs relative to MICs and LICs. The reason is that HICs depend less on GHG emissions economically than MICs and LICs due to past efforts to reduce emissions. Relative to the high equity 2°C scenario, which has relatively "flat" GDP costs, when HICs initiate transfers toward LICs and MICs by using a share of their carbon revenues, the GDP cost distribution becomes more progressive. The contribution of HICs increases and allows LICs (and some MICs) to reduce GDP cost and even in some cases increase GDP. There are global cost savings of 0.03 to 0.06 percent of GDP relative to the high equity 2°C scenario when international transfers from HICs to MICs and LICs are considered in scenario 2C-Compensate and 2C-Ability&Need. When transfers are made according to the Rajan proposal, the progressivity of costs also holds, with a marginal increase of 0.02 to 0.04 percent in the global costs relative to the high equity 2°C scenario.

A robust and predictable carbon price would help catalyze and efficiently allocate private climate finance flows. Private financing has a key role to play in advancing the transition (IMF 2022c). A key concern of private investors is policy uncertainty. By committing to carbon pricing, countries can increase investor confidence and enable private climate finance. While private finance cannot substitute for direct support from public sources, it is a key complement.

[14] https://www.project-syndicate.org/commentary/global-carbon-incentive-for-reducing-emissions-by-raghuram-rajan-2021-05.

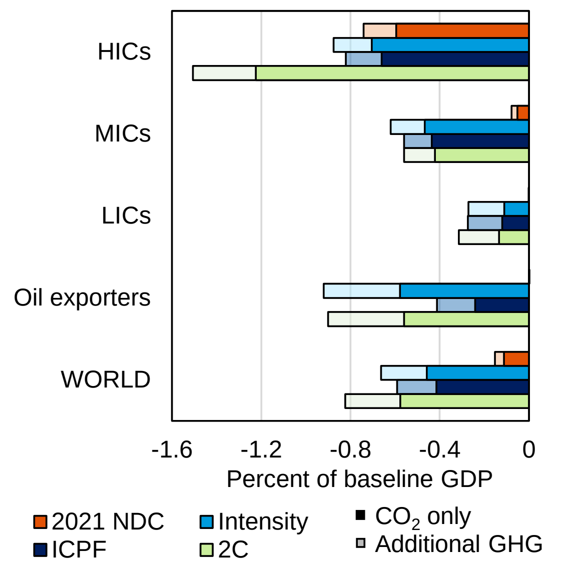
Figure 2. Progressivity in costs with international transfers



Note: 2C = High equity 2°C consistent scenario; HICs = high-income countries; LICs = low-income countries; MICs = middle-income countries; OAF = Africa (except South Africa); ODA = other East Asia and New Zealand; OEURASIA = other Eastern Europe and Caspian countries; OLA = other Latin America; PPP = purchasing power parity; RESTEU = rest of European Union and Iceland; RESTOPEC = other oil-exporting countries.

The share of CO_2 and non-CO_2 abatement costs varies across regions. IMF-ENV applies carbon pricing to all GHGs and hence we can compare abatement costs for CO_2 and non-CO_2 emissions (Annex Figure 2.2). In the 2°C-aligned scenarios, 70 percent of the global abatement costs arise from CO_2 mitigation. By income groups, this share increases to around 80 percent in HICs while in MICs it lies between 75 to 78 percent. However, non-CO_2 GHGs are mitigated in much larger share than CO_2 in LICs and hence, CO_2 mitigation only accounts for about 41 to 44 percent of the total abatement costs. This high share of GHGs other than CO_2 in LICs is due to the relatively high share of emissions from agriculture in these countries. Most other GHGs come from agriculture, where particularly methane is emitted in considerable amounts, especially from livestock production. Expectedly, the total GHG abatement costs are higher than CO_2-only abatement costs and for the international carbon price floor scenario for world, HICs, MICs, and LICs they are 0.59, 0.82, 0.56, and 0.27 percent of GDP, respectively.

Annex Figure 2.2. Abatement Costs for GHG and CO_2

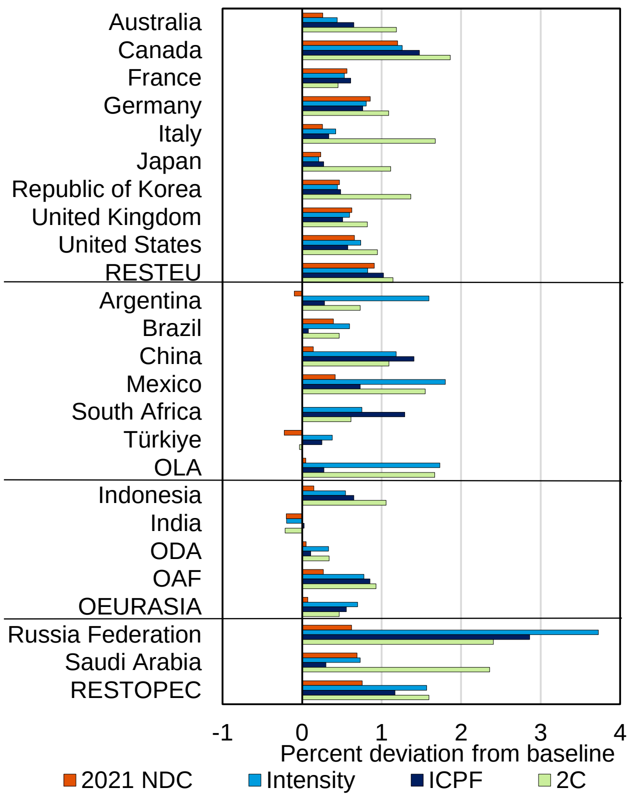


Note: Includes emissions from land use and land use change. 2C = High equity 2°C consistent scenario; CO_2 = carbon dioxide; GHG = greenhouse gas; HICs = high-income countries; ICPF = international carbon price floor; LICs = low-income countries; MICs = middle-income countries; NDC = nationally determined contributions.

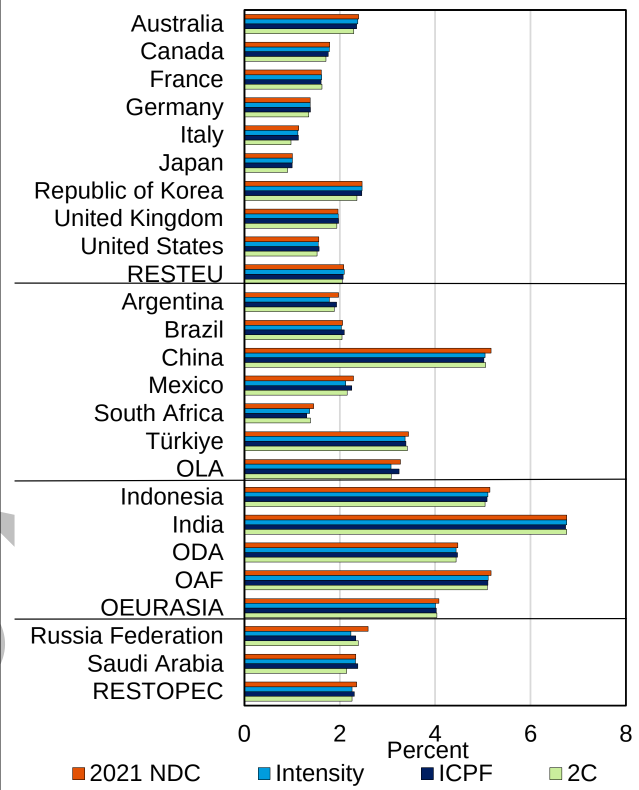
Annex 5. Country-Level Results and Additional Charts: IMF-ENV

GDP costs vary both across and within income groups (Annex Figure 5.1). For high-income countries, GDP costs are typically larger in the high equity 2°C scenario, which requires a larger percent reduction of their emissions than under the international carbon price floor and the Intensity scenario. The cost distribution is quite heterogenous across middle-income and low-income countries. Among middle-income countries, the Intensity and high equity 2°C scenarios imply smaller costs than the international carbon price floor for China and South Africa. In contrast, the Intensity scenario is particularly costly for Latin American countries given that their power sectors are already much more decarbonized, and therefore the stronger reduction in their emission intensity required in the intensity scenario is achieved at a higher cost. Among low-income countries, India even experiences GDP gains under both the Intensity and the high equity 2°C scenario. While these differences appear to be large, a conversion to growth rates, as in Annex Figure 5.2, shows that the differences across scenarios are indeed small and manageable. Though oil producers face a similar shock from falling global oil demand, the experienced costs vary depending on country characteristics (for example, income levels and production prices of oil). Generally, in all the 2°C-compatible scenarios, the largest costs are in Russia (2.4 to 3.7 percent of GDP) with the exception of high equity 2°C scenario where Saudi Arabia has costs comparable to those in Russia owing to the stricter target it faces as a high-income country.

Annex Figure 5.1. GDP Cost by Country and Scenario



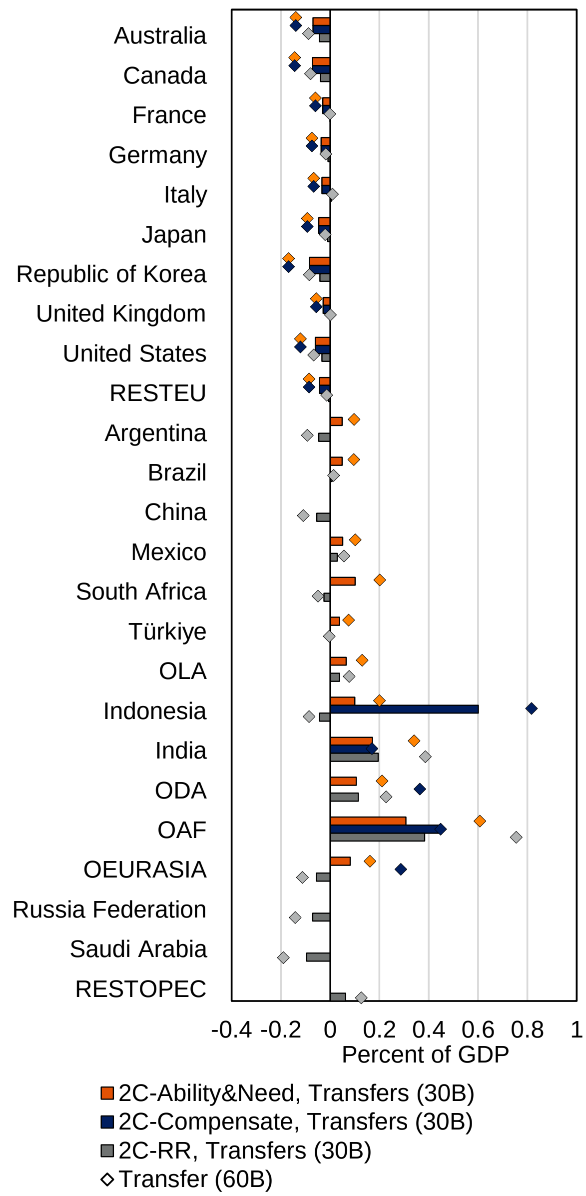
Annex Figure 5.2. Annualized Real GDP Growth, 2021–30



Note: 2C = High equity 2°C consistent scenario ; ICPF = international carbon price floor; NDC = national determined contributions; OAF = Africa (except South Africa); ODA = other East Asia and New Zealand; OEURASIA = other Eastern Europe and Caspian countries; OLA = other Latin America; RESTEU = rest of European Union and Iceland; RESTOPEC = other oil-exporting countries.

High-income countries generate carbon revenues that amount to 3 percent of their GDP in 2030 and a contribution of about 0.1 percent of GDP is sufficient to reach $60 billion. In comparison, under the high equity 2C scenario low-income countries generate carbon revenues equivalent to 2 percent of their GDP and receive transfers ranging between 0.16 to 0.82 percent of their GDP to reach the $60 billion goal. Annex Figure 5.3 shows how climate finance contributes to country budgets. In all advanced economies, the contributions to climate finance would be a small share of carbon pricing revenues. When countries' transfers are measured as shares of GDP for the $60 billion goal, under the 2C-Ability&Need and 2C-Compensate scenarios Korea is the largest contributor with 0.17 percent followed by 0.14 percent contributions by Australia and Canada. Africa (except South Africa) region stands out as receiving the highest amounts of climate finance compared to GDP. Transfer payments and receipts between the 2C-Compensate and the 2C-Ability&Need scenarios are quite similar for almost all countries. In the 2C-RR scenarios, China, Saudi Arabia, Russia, and other oil-exporting countries participate in the international transfers. These countries act as contributors towards the transfers albeit in very different shares with the exception of rest oil-exporting countries which act as recipients. For example, China's contribution covers 45 percent of the $60 billion goal, but in terms of share of GDP it only amounts to 0.11 percent of China's GDP. Differently, Russia's contribution would also amount to 0.14 percent of GDP though in total it would make up only 6 percent of the $60 billion goal.

Annex Figure 5.3. Transfers in 2030 (Percent of GDP)



Note: Calculations relative to GDP from respective scenarios. 2C = High equity 2°C consistent scenario ; OAF = Africa (except South Africa); ODA = other East Asia and New Zealand; OEURASIA = other Eastern Europe and Caspian countries; OLA = other Latin America; RESTEU = rest of European Union and Iceland; RESTOPEC = other oil-exporting countries.

Conclusion and discussion

Countries need to raise their collective climate mitigation ambition to be consistent with limiting global warming to 1.5°C to 2°C. This Note seeks to inform international dialogue by presenting various equitable, temperature-aligned scenarios, with mitigation burdens generally increasing across income groups. The scenarios encompass reductions in emissions intensity, carbon price floors differentiated by development level, and progressive distributions of emission reductions. They allow for some variety in the exact distribution of emission reductions across HICs, MICs, and LICs, and all imply emissions per capita would further converge.

Options exist for narrowing the global climate ambition gap equitably, but if countries delay further the Paris Agreement's temperature goals may soon be beyond reach. Cuts based in carbon intensity and through an international carbon price floor have similar allocations across income groups, but varying allocations for individual countries given differences in responsiveness to carbon pricing. The high equity scenario would allocate even more of the emissions cuts to developed compared with developing countries. Lastly, the 1.8°C and 1.5°C scenarios require substantial increases in ambition which, if action is delayed further, may soon become technically infeasible.

At the global level, abatement costs are equitably distributed and when including co-benefits costs become negative. This implies that there are net benefits from climate mitigation policies, especially in developing countries. Pure abatement costs are around 0.5 percent of GDP in 2030 for the high equity 2°C scenario and are larger in developed than developing countries. Assuming least-cost abatement strategies – through carbon pricing and using revenues allocated for productive purposes – substantially reduces abatement costs. Additionally, there are large domestic environmental co-benefits from mitigation policies, notably improvements in human health from better air quality, especially in developing countries. When including these local environmental benefits, the net welfare costs of mitigation policies become negative at a global level and for MICs and LICs. This is even before considering (the far larger) global benefits of reducing future damages from further global warming.

GDP impacts are somewhat larger than pure abatement costs due to changes in investment (large for MICs and oil exporters) and trade effects (large for oil exporters). The midpoint of global GDP losses in 2030 is about 1.0 percent for 2°C-consistent scenarios (with a range between 0.6 and 1.5 percent depending on effort distribution and recycling of revenues). However, this is entirely manageable considering it implies a reduction of annual global growth of just 0.1 percentage point. Moreover, there are strategies for limiting investment losses (using carbon pricing revenues for public investment or non-pricing instruments instead of carbon pricing). There are several upside and downside risks around these estimates. On the upside, rapid innovation or learning-by-doing in low-carbon technologies could reduce costs. On the downside, stranded assets and a difficult reallocation of labor across sectors could increase the costs.

Raising climate finance could further ensure that accelerating a global low-carbon transition is equitable. Though GDP effect estimates exclude the (globally progressive) domestic environmental co-benefits mentioned above and pure abatement costs are progressive, GDP impacts are less so: HICs bear relatively lower GDP costs than MICs and oil exporters, for example. However, an increase in annual bilateral transfers from developed to developing countries from currently $10 billion to $30 or $60 billion would make GDP impacts more progressive, while requiring only a small share of potential carbon pricing revenues from HICs.