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Fiscal Implications of Global Decarbonization

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ABSTRACT: Internationally coordinated climate mitigation policies can effectively put the world on a path toward achieving the agreed Paris temperature goals. Such coordination could be initiated by large players, such as China, the US, India, the African Union, and the European Union. We find that the implications for fiscal revenues over time will be shaped by a combination of rising carbon prices, the gradual erosion of existing fuel tax bases, and possible revenue sharing arrangements. Public spending rises during the transition to build green public infrastructure, promote innovation, and support clean technology deployment. Countries will also need financing for compensating vulnerable households and industries, and to transfer funds to poor countries. With well-designed climate-fiscal policy relying on carbon pricing, global decarbonization will have anything from moderately positive to moderately negative impacts on fiscal balances in high-income countries. For middle and low-income countries, net fiscal impacts are generally positive and can be significant. Revenue sharing at the global level would make an historical contribution to breaching the financial divide between rich and poor countries.

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WORKING PAPERS

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Contents

Glossary

BCA	Border Carbon Adjustment
CO_2	Carbon Dioxide
CPAT	Climate Policy Assessment Tool
EITE	Energy-Intensive, Trade Exposed
ETS	Emissions Trading System
EV	Electric Vehicle
GHG	Greenhouse Gases
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
IRA	Inflation Reduction Act
LCT	Low-Carbon Technology
NDC	Nationally Determined Contribution
TPS	Tradable Performance Standards
VKT	Vehicle Km Travelled

I. INTRODUCTION

The planet is warming. 2023 was the hottest year on record. According to the World Meteorological Organization, temperatures are likely to increase by more than 1.5°C above pre-industrial levels already within the coming five years.[2] Even with moderate increases in the stringency of global mitigation policy, temperatures are expected to increase relative to pre-industrial levels by more than 3°C by 2100.[3] This would have devastating effects on macroeconomic stability through lower productivity; disruption and destruction of activity and productive capital due to extreme weather events, natural disasters, and rising sea levels; diversion of resources toward adaptation and reconstruction; increased morbidity and mortality due to more prevalent infectious diseases and natural disasters; and greater risks of migration and human conflict. Moreover, there are risks of triggering tipping points in the climate system like melting of ice sheets, changing ocean circulatory systems, or the releasing of underground methane. Given the strong interconnectedness of the global economy, no country is likely to remain unscathed, even if the worst warming impacts are initially concentrated in hotter regions.

In 2015 in Paris, countries agreed to reduce greenhouse gases (GHG) emissions in order to "[hold] the increase in the global average temperature to well below 2°C above pre-industrial levels" and ideally to 1.5°C (Black et al. 2023c; Hassler et al. 2023; Gourinchas et al. 2023). To achieve this, they have defined Nationally Determined Contributions (NDCs) which commonly include emission reduction targets for carbon dioxide (CO_2) and other greenhouse gases in or around 2030 relative to some benchmark[4]. More recently, around 140 countries have also committed to targets for zero net emissions by around midcentury (i.e., a zero balance of gross carbon emissions and negative emissions from carbon sinks and through technology, e.g., direct air capture). Unfortunately, while some countries have achieved significant progress in reducing carbon emissions, there remain large ambition and implementation gaps for 2030 against the agreed temperature goals. First, while countries have adopted a variety of policies, such as carbon pricing and sectoral policies, the NDC targets for 2030 are themselves insufficient to limit temperatures to 1.5 to 2°C—this is the ambition gap. Second, actual and announced policies often fall well short of delivering on the emission reductions needed—this is the implementation gap. Section II of this paper provides further details on current mitigation targets, policies, and emission impacts of these policies.

Achieving the world's climate goals agreed in Paris necessitates forceful and urgent global action. High-income countries cannot do it alone because of the large share of emissions and projected growth in middle- and low-income countries. For instance, by 2030 the EU and the US together are expected to emit a little over 20 percent of global emissions, while China and India will be responsible for almost 40 percent. Unilateral action will help reduce global emissions and could even induce positive policy spillovers on other countries.[5] However, the sum of all unilateral actions will unlikely be sufficient without coordination. Indeed, each individual country will be concerned about the lack of ambition in other countries and be cautious about the possible adverse effects of its policies on the competitiveness of its energy-intensive, trade exposed (EITE) industries. Unilateral action may also entail greater emphasis on regulatory and subsidy approaches and limited

[2] https://public.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years

[3] Central estimate per the IPCC's scenario 'SSP2-4.5' though the range is large at 2.1-3.5°C (IPCC 2022).

[4] The focus here is on reducing carbon emissions, which is responsible for 75 percent of total GHGs. For a discussion of second most important GHG, methane emissions (17 percent), and policies to address them, see Parry et al. (2022b).

[5] Including diffusion of mitigation polices and technologies (Linsenmeier et al. 2022).

international support to finance clean energy transitions in developing countries. International coordination will therefore be critical.

Multiple global policy scenarios can be envisaged to meet the required emission reductions, with different fiscal, economic and distributional implications. Policies in this paper are chosen such that they close the global mitigation gap in 2030 consistent with a path of 2°C warming (Section III). These scenarios build on earlier IMF work. For instance, global climate mitigation options to achieve the temperature goals of the Paris agreement have been analyzed in a recurring series of notes by Black et al. (2021, 2022b, 2023c). Parry, Black and Roaf (2021) explore the implications of an internationally agreed carbon price floor, which forms the basis for the analysis in this paper. International coordination of carbon pricing policies has also been emphasized in editions of the IMF's Fiscal Monitor (IMF 2019; 2022), while its October 2023 edition (IMF 2023a) elaborates on the fiscal implications of a wider set of policies, including on the spending side. The latter also discusses the three-way trade-off under unilateral climate mitigation policies, namely between achieving national climate objectives, maintaining fiscal sustainability (if mitigation is predominantly achieved through spending policies, such as subsidies), and managing political constraints (if mitigation relies mainly on carbon pricing). This trilemma is also emphasized in De Mooij and Gaspar (2023), who argue that international coordination can relax it by reducing international spillovers from unilateral climate action. The underlying paper is closely related to De Mooij and Gaspar (2023), but deepens and expands it in several ways, including by analyzing sectoral policies and different international transfers.

The focus of this paper is on the fiscal impact of global climate mitigation policy. On the revenue side of the budget, we explore the implications of a mix of carbon pricing and non-pricing policies. Moreover, we consider the revenue effects from an erosion of existing fuel tax bases as economies decarbonize (Section IV). On the spending side, we discuss public investment in green infrastructure and subsidies for low-carbon technological innovation and deployment (Section V), as well as fiscal support for vulnerable households and affected firms (Section VI). Subsequently, we consider the implications of possible compensation payments to low and lower-middle-income countries (Section VII) and international revenue sharing arrangements (Section VIII). Section IX puts the pieces of fiscal equation together and discusses the expected net fiscal impact in various countries. Finally, Section X concludes.

II. Current and Planned Mitigation Policies

We first take stock of existing and planned mitigation policies at economywide and sectoral levels for G20 countries, as specified in their Nationally Determined Contributions (NDC) and other government documents. Policies are summarized in more detail in Black et al. (2023c) and Annex I discusses sectoral options and technologies in greater depth. Our estimates put the combined reduction in emissions as a result of these policies, relative to a counterfactual with no climate mitigation policy, at 11 percent by 2030 across the G20. Such a reduction falls well short of the 25–50 percent reduction by 2030 compared with 2019 levels needed to get on track with the Paris Agreement's temperature goals of, respectively, 2°C and 1.5°C warming.

Carbon pricing schemes (at various levels of government) are operating in most G20 countries.[6] In eight cases, these cover more than 50 percent of national GHGs (Canada, France, Japan, Korea, Mexico, South Africa, Germany, and the UK). For example, emissions trading systems (ETSs) at the European Union (EU) level and in the United Kingdom (UK) apply to emissions from power generation and industry. Japan and South Africa apply carbon taxes midstream on fuel supply, while Korea's ETS covers emissions for power, industry, waste, buildings, and the public sector. Canada requires provinces and territories to implement a minimum carbon price through a carbon tax or ETS.

For power generation, nearly all G20 countries have renewable energy targets and eight have targets for scaling back coal generation (including in five cases a complete ban on or before 2030). Common policies for the sector are feed-in tariffs, renewable portfolio standards, and investment or production tax credits.[7]

For transportation, aside from fuel taxes, CO_2 emission rate or fuel economy standards apply nationally in nine G20 countries and at the EU level. Fifteen countries have targets for phasing in electric vehicles (EVs) or phasing out internal combustion engine vehicles (ICEVs). Feebates involving fees for the purchase of emissions-intensive vehicles and subsidies for relatively clean vehicles, apply in some form in nine countries (Annex II). Emission rate standards, feebates, and EV sales requirements aid the transition to clean vehicle fleets (though they do not promote faster retirement of existing, high-emission vehicles nor reduce vehicle kilometers travelled).

For buildings, France, Germany, Italy, and Japan have targets for reducing energy use from the total building stock (by 25-44 percent between 2020 and 2030), while nine other G20 countries have targets for new buildings to produce approximately zero emissions by 2030 or later. Countries typically use multiple instruments such as design codes to reduce energy consumption, incentives for insulation and other retrofitting, certification programs for meeting green criteria, clean fuel requirements (e.g., phasing out fossil fuel heating in new buildings), and efficiency standards for appliances. Combinations of these policies reduce emissions, but less effectively to the extent they apply only to new as opposed to all capital, especially given the gradual turnover of building stock.

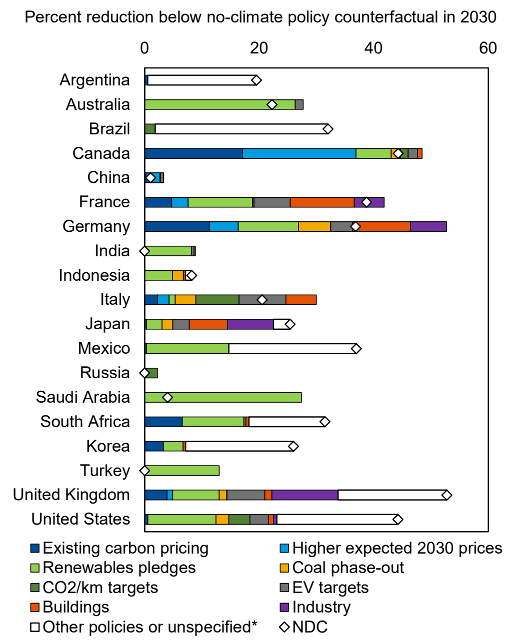
[6] Among the G20, carbon pricing is already in place in most countries, under consideration in Turkiye and Brazil and absent in India and Saudi Arabia. Globally, there are 73 national, subnational, and regional carbon pricing schemes in place, covering almost one quarter of global emissions. At the same time, the average price across these schemes is modest at around $20 per ton of CO_2.

[7] The analysis assumes sectoral targets are met—it would be difficult, analytically, to disentangle the impacts of individual, overlapping measures.

Industrial sectors are generally subject to lighter sectoral emissions targets/policies than other energy-intensive sectors. Only five G20 countries have binding emissions targets for industry. Regulations like tradable performance standards (TPSs)[8] and fiscal incentives like clean technology subsidies are less common for this sector. An exception is Canada where TPSs apply to industrial emissions in many provinces and territories, while China intends to expand its TPS for power generation to industry.

The combined effect from the above policies and targets up to 2022 varies substantially across countries (Figure 1). CO_2 reductions relative to a 2030 baseline range between 20 and 50 percent in 11 countries and are less than 20 percent in eight cases. Additionally, countries vary significantly in their choice of instrument and relative contribution of sectoral targets. Renewables targets make a significant contribution to reductions in 15 cases and explicit carbon pricing contributes substantively to eight cases. As the attribution of emissions reductions to individual policies and targets is ambiguous where they overlap (e.g., for carbon pricing of power emissions and renewable generation targets), the total CO_2 reductions should be considered more accurate than the relative contribution of specific policies and targets.

Figure 1. Emissions Impacts of Current Policies and Sectoral Targets



Source: Black and others 2022a.

Note: *"Other policies or unspecified" includes policies not quantified in this exercise or not yet specified by the authorities. Does not include policies enacted since the working paper such as the United States' Inflation Reduction Act or the European Union's Green Deal.

Countries vary in the extent to which specified policies achieve economy-wide mitigation pledges in NDCs. Targets are not binding, or barely binding, in four cases—including two of the three largest global emitters (China and India). Some countries achieve greater reductions than their pledges in NDCs with sectoral policies (Australia, Canada, China, France, Germany, Italy, Saudi Arabia)—economywide targets could be enhanced in these cases by bringing them in line with existing sectoral targets, though this relies on sectoral targets being met. In seven cases the economywide emissions reductions from policies and targets identified in this analysis fall well short of the NDCs.

Some large economies have recently adopted expenditures-based measures. These include public funding for investments in clean energy and green subsidies (or tax expenditures) to provide incentives for private investment and adoption of low-carbon technologies (LCTs). For example, the Inflation Reduction Act of 2022 represents the largest federal climate policy to date in the United States (US), estimated to cost nearly $400

[8] Under TPSs, firms are required to meet a standard for average CO_2 emissions, for example, per kilowatt-hour across power generation plants or per ton of steel. Those that fall short of the standard can purchase credits from firms that exceed the standard. These standards require fluid markets for trading credits and are less practical for some sectors, such as forestry and residential buildings.

billion over 10 years (Box 1).[9] It envisages subsidies and tax incentives for investments in clean electricity and transmission, clean transportation, and energy-efficiency upgrades in homes (see Bown and Clausing 2023). The EU has supplemented its carbon-pricing approach by proposing a Green Deal Industrial Plan comprising tax breaks and relaxation of state aid (subsidy) rules in the coming years to boost renewable investment of the private sector. China has scaled up green public investment and subsidized the deployment of solar energy over the last decade under its Made in China 2025 initiative. Other countries, such as Canada, Japan, and Korea have adopted or are considering similar policies.

Box 1: The Inflation Reduction Act in the US

The 2022 Inflation Reduction Act (IRA) forms the centerpiece of the US climate mitigation strategy. The law directs federal funding over a 10-year period (estimated at $394 billion, or 0.17 percent of GDP) to clean energy (especially for clean electricity and transmission, followed by clean transportation), mostly through tax credits.

- 55 percent of the funding is for corporations, including: $30 per MWH for new zero-carbon generation (progressively reducing to $15 per MWH in 2035); $15 per MWH for new nuclear; $1.75 per gallon for sustainable aviation fuel; and $3 per kg for clean hydrogen.
- A projected $43 billion is allocated in consumer incentives including tax credits of up to: $7,500 and $4,000 for new and used EVs; $2,000 for heat pumps; and 30 percent of the costs of energy efficiency upgrades in homes.

Many tax incentives contain domestic-production or procurement requirements—for example, 80 percent of the critical minerals for EV batteries must have been recycled in the US (or a country with a free trade agreement with the US) for the vehicle to qualify for the full credit and the battery must have been manufactured in the US.

The EU has argued that the IRA's tax credit for EVs and manufacturing subsidies for battery and wind turbine producers violate World Trade Organization (WTO) rules. In response, the EU has proposed the Green Deal Investment Plan, containing €250 billion in new tax breaks to further boost private sector renewable investment along with loosening of the bloc's state aid rules.

[9] In a recent IMF staff analysis, Voigts and Paret (forthcoming) arrive at a larger fiscal cost until 2030.

III. A Global Agreement on Mitigation Policy

The previous section makes clear that more ambition and policy actions are needed globally to mitigate climate change. A global side agreement on coordinated climate mitigation policy to complement the Paris Agreement could make a major contribution. Several principles could guide such an agreement. First, it should include the largest emitting countries and blocs in the world. Agreement among the G20, for example, would cover over 80 percent of global GHG emissions. But a smaller group comprising China, the EU, India, the US would still cover more than 60 percent of global emissions. When complemented with the African Union (which recently joined the G20 as a member), it would also cover a great deal of the world's diversity and establish a clear link with the global development agenda.[10]

Second, a side agreement should contain concrete policy actions (like minimum pricing requirements as discussed in Parry et al. 2021) to deliver the needed global emissions reductions. Since carbon pricing might not be politically feasible in all countries, the agreement should allow for flexibility in instrument choice to accommodate alternative (but emissions equivalent) approaches (Black et al. 2022a). Third, the side agreement should address international equity issues. Those are reflected in the Paris Agreement through the principle of 'common but differentiated responsibilities and respective capabilities', and under a side agreement could entail different requirements for emission reductions or minimum carbon prices. For developing countries such an agreement would also have to be compatible with energy access and in line with the Sustainable Development Goals. Moreover, side payments in the form of financial and technological transfers and/or revenue sharing of a globally agreed minimum carbon price could form part of an international agreement.

Based on these principles, we consider concrete scenarios that close the global mitigation gap to be consistent with 2°C warming (see Black et al. 2023c). It assumes that high- and upper-middle income countries[11] agree to reduce their emissions in 2030 by 49 percent and 26 percent, respectively, below 2019 levels. Low-income and lower-middle income countries would still be able to grow their emissions by 6 percent relative to 2019, but this is less than implied by current mitigation pledges and the baseline. The scenario brings about near convergence in per capita CO_2 emissions among high and higher-middle-income countries while per capita emissions remain well below that in lower-middle and low-income countries. While the scenario assumes global implementation, the paper focuses on results for members of the G20, including the African Union. Within the G20, India, Indonesia, and the African Union are captured under the group of lower-middle and low-income countries (the group with the smallest required emission reduction). We also present separate results for 3 large members of the African Union: Egypt, Kenya, and Nigeria.

The IMF-World Bank Climate Policy Assessment Tool (CPAT) is used to simulate the policy scenario (Black et al., 2023a, for full documentation of the model).[12] CPAT is a streamlined (or 'reduced form') model that captures the main aspects of climate policies in significant detail. It is flexible in providing projections for all

[10] Global collective decision making might involve a mix of representatives from nation-states and supra-national organizations, such as the African Union, the EU, ASEAN, or the Organization of American States (e.g., Murithi 2023). The G-20 constitutes a precedent as the EU is a member (alongside several EU member states).

[11] For the purposes of this paper, we define country groups in accordance with the World Bank Classification which includes four income groups, the thresholds for the lowest group (LIC) being $1,135 per capita GNI in 2022 and for the second lowest (Lower-middle income countries, LMIC) being $4,465. It is different from the IMF's World Economic Outlook classification (which distinguishes between advanced economies and emerging and developing economies).

[12] See also CPAT documentation here: CPAT Documentation (cpmodel.github.io).

countries of future fuel use and GHG emissions by major energy sectors (power, transportation, industry, buildings, and agriculture). It can simulate the impact of a diverse range of pricing and non-pricing mitigation policies on emissions and on fiscal, distributional, and economic variables. Baseline emissions projections depend on GDP growth, income elasticities for energy products, autonomous improvements in energy efficiency, and reductions in the cost of renewables. In the baseline scenario, fuel taxes/subsidies and carbon prices are held fixed at current levels in real terms. The responsiveness of emissions to pricing and other policies depends on induced changes in energy prices and fuel price responsiveness in different sectors. Parameters are set at the mid-range of the estimates from the empirical literature on income and fuel price elasticities and emissions-price responsiveness from more detailed, country-specific energy models. The focus is on the impact in 2030.

Emission reductions could efficiently be achieved through carbon pricing, i.e., carbon taxes or emission trading schemes, ETSs (see next section).[13] However, alternative emissions-equivalent price or non-pricing measures could also be used, such as feebates, standards, regulations, or subsidies, possibly applied to specific sectors like industry, power, buildings, transport, forestry, and extractives (Annex I and II). The assumption here is that policies are efficient in the sense of minimizing the cost of emission reduction. This would hold under a single carbon price but not necessarily under non-pricing approaches. The next section discusses assumptions about an agreed carbon price floor.

Using CPAT, we first estimate the impact of these efficient policies on marginal abatement costs in 2030—reflecting the shadow carbon price of induced policies at the efficiency frontier (left panel of Figure 2). Shadow prices are calculated as the CO_2 price that induces the target emissions reductions. They are truncated at $150 per ton because uncertainty about marginal abatement costs rapidly increases beyond this point. For instance, it will depend on non-linear adoption of uncertain ‘breakthrough’ technologies, like carbon capture and storage for large stationary emitters, direct air capture, and green hydrogen. The shadow carbon prices are estimated at around $145, $90, and $35 per ton in high, higher-middle, and low and lower-middle-income countries, respectively. The global weighted average would be around $90 per ton. Truncation at $150 per ton implies some underestimation of total abatement costs in countries where the actual marginal abatement costs will exceed $150 per ton. This applies to several high-income countries in Figure 2.[14]

The right panel in Figure 2 shows the total abatement costs, or welfare costs, of these policies. These are approximately the annualized costs of using cleaner but costlier technologies (in the model, based on the areas under the marginal abatement cost schedules).[15] Total abatement costs are estimated at around 0.5 percent of GDP at the global level. Costs are somewhat higher in high-income countries, where cheaper mitigation options have been largely exhausted. The total costs are well below 0.5 percent of GDP in low- and lower-middle income countries, reflecting the availability of cheaper mitigation options and less stringent emissions reductions. The lowest costs are observed in India, Indonesia, Egypt, Nigeria, and Kenya. Costs might become higher, of course, if less efficient mitigation policies would be used that do not strike a cost-effective balance

[13] Parry et al. (2022a) compare carbon taxes and emissions trading schemes.

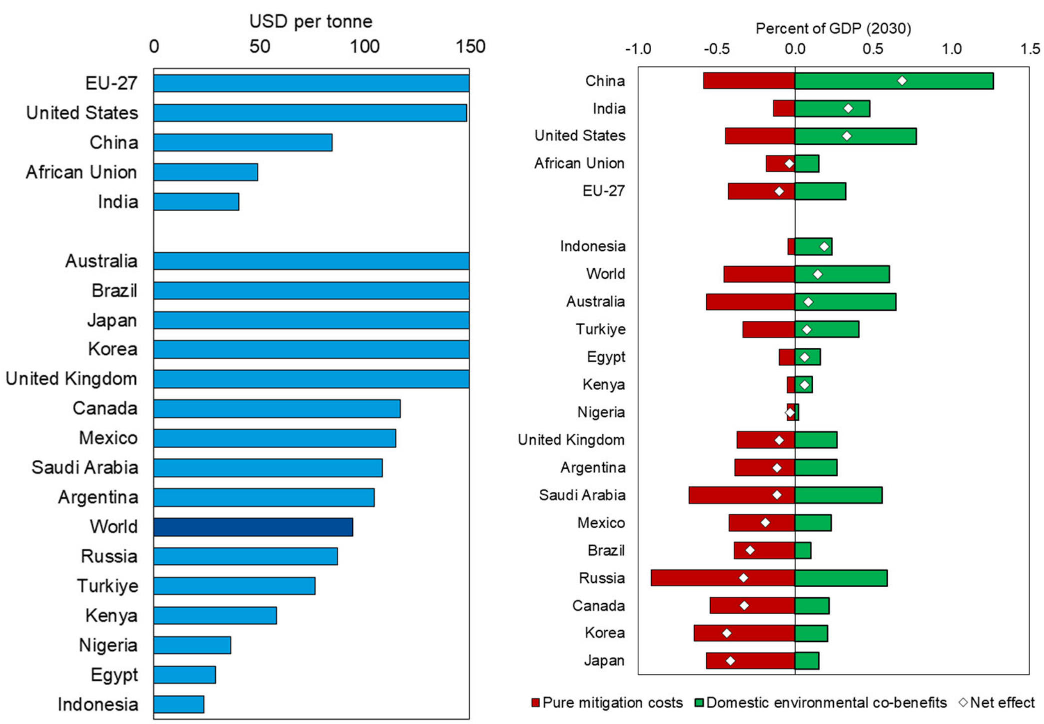
[14] For example, raising the threshold to $200 or $250 per ton and linearly extrapolating the marginal abatement cost curve would increase the total costs for EU-27 by, respectively, 12 and 17 percent.

[15] Welfare costs are a standard metric in cost/benefit assessments of environmental and other policies. They reflect losses in consumer and producer surplus in fossil fuel markets net of government revenue gains and accounting for pre-existing fuel taxes or subsidies. The cost estimates however do not account for mitigation in forestry and agriculture nor revenue losses to energy exporters. They can mask significant distributional impacts, including the shift of resources from emissions intensive to cleaner production. GDP effects differ from welfare costs by including changes in net exports and investment.

across mitigation responses. Moreover, for high-income countries they may also be higher to the extent that marginal abatement costs exceed the $150 per ton ceiling.

Figure 2. Incremental and Total Mitigation Costs from Equitable Ambition Scenario for 2°C

- **A. Shadow CO_2 Prices (or Incremental Mitigation Costs)**
- **B. Mitigation Costs and Domestic Environmental Co-Benefits**



Source: Black, Parry, and Zhunussova (2023c).

Notes: Prices and annual costs are measured relative to a baseline with no new, or tightening of existing, mitigation policies. Shadow CO2 prices are truncated at $150 per ton. Actual marginal abatement costs will likely be higher for many high-income countries, although uncertainty in this range of the cost curve is large.

The right panel of Figure 2 also shows the effects on so-called domestic environmental co-benefits. In particular, the burning of fossil fuels not only leads to climate change, but also creates local air pollution. This causes premature deaths, more instances of disease and undesirable health impacts (e.g., strokes and lost pregnancies) and reduces labor productivity. Fossil fuel use in transportation, moreover, contributes to congestion, accidents, and other transportation externalities. Climate mitigation policies can reduce these externalities, yielding localized welfare gains. CPAT quantifies their value, based on extensive data of such impacts and information about localized effects. The right panel in Figure 2 shows that domestic environmental co-benefits will offset a substantial portion of the higher mitigation costs of climate policy in several countries. For some countries, such as China, India, and Indonesia, they even exceed the abatement costs. Hence, these countries are better off from a decarbonization policy, even before accounting for climate benefits. For the average country in the African Union abatement costs are slightly higher than the local environmental co-benefits.[16]

IV. Public Revenue

Carbon pricing is the centerpiece of an efficient mitigation policy—which also encompasses regulatory and spending measures. A carbon price internalizes the external cost of carbon emissions, promoting the full range of behavioral responses for reducing emissions intensity, including through investment in clean technology, fuel substitution, and energy saving. Aside from boosting the adoption of existing LCTs, carbon pricing also encourages the development of new technologies through innovation. A uniform price on carbon equalizes the marginal abatement cost of each alternative behavioral responses, ensuring that the policy is efficient by minimizing total abatement costs. This is not necessarily the case with regulations, subsidies, or sectoral policies. Carbon pricing can be implemented through a tax on the carbon content of fossil fuels, or through an emissions trading system (ETS) where permits can be auctioned. It can raise significant amounts of public revenue, which we refer to as the 'fiscal dividend'.[17] Revenue from carbon pricing has attracted ample attention, especially since it could be used productively to contain the overall costs of decarbonization for the economy. For instance, carbon tax revenues could provide a new source of funding for high-return public investments or for cutting other distortionary taxes that harm incentives to work and invest.[18]

We explore the fiscal dividend in the 2°C decarbonization scenario outlined in the previous section using CPAT. Effects are presented relative to a baseline that includes only current policies. We consider two pricing scenarios. The first scenario is implemented by using only carbon pricing ("Full carbon price") to achieve the agreed emission reduction. Thus, carbon prices are equivalent to the shadow prices presented in Figure 2. The second scenario uses two policy instruments. First, we set carbon prices at a globally agreed minimum level ("Capped carbon price") of $75, $50, and $25 per ton of CO2 for, respectively, high-, middle-, and lower-middle and low-income countries in 2030.[19] While significantly reducing emissions, these carbon prices are insufficient to meet the required targets aligned with a 2°C temperature increase. We assume that pricing is supplemented by additional (revenue neutral) policies that mitigate the remainder of the emissions, such as feebates, standards, and regulations.

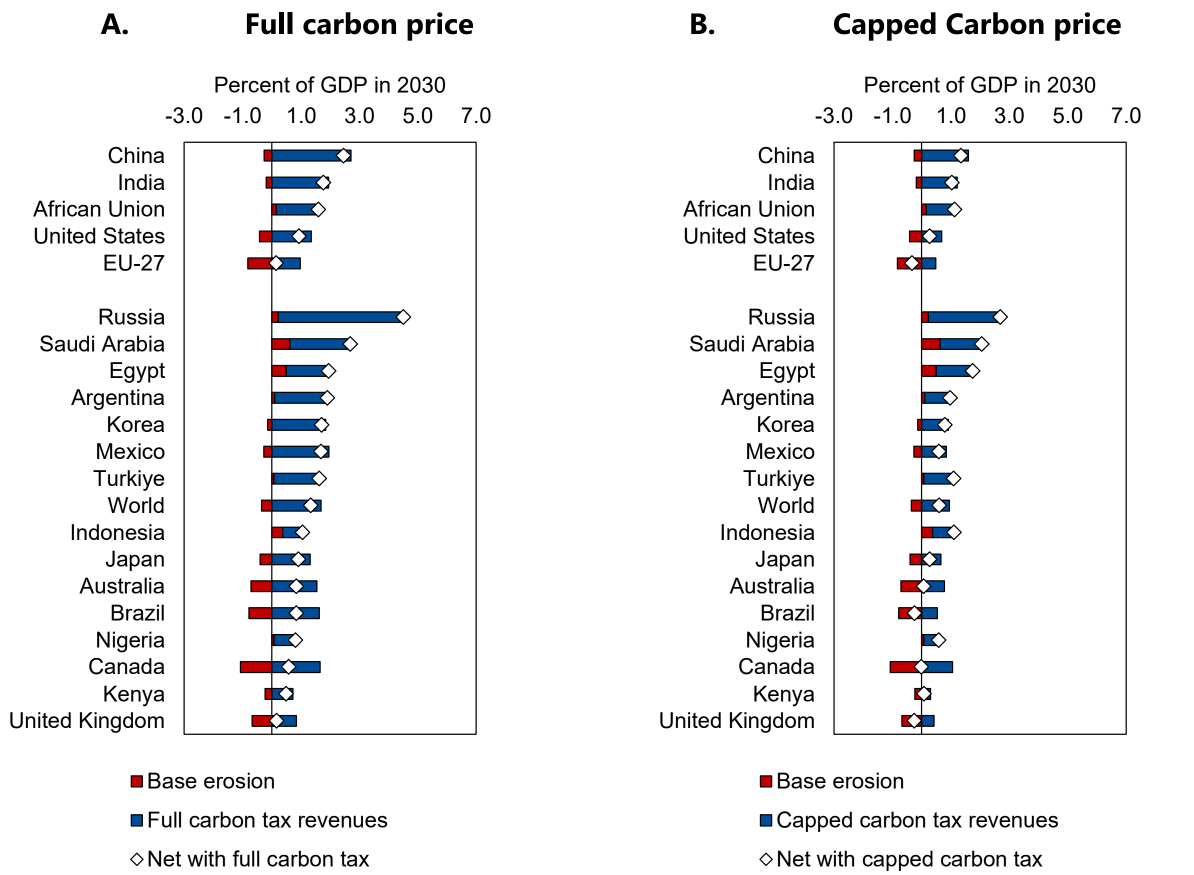
[16] Co-benefits vary substantially across countries with, for example, variations in local air emission rates, population exposure to local pollution, and people's willingness to pay to lower health risks. In Saudi Arabia a disproportionately large share of the CO_2 emissions reductions comes from reduced use of road fuels where congestion and accidents per unit of fuel use are large.

[17] Governments can also employ alternative pricing schemes that forego some or all revenue, such as an ETS with free allocation of allowances or feebates. The focus of this section is on the fiscal dividend from carbon pricing schemes.

[18] Governments should first consider phasing out fossil fuel subsidies if they still have them. Black et al. (2023b) find that explicit subsidies (undercharging of the supply costs of fossil fuels) globally cost $1.3 trillion in 2022, up from $0.5 trillion in 2020. Their phase out would imply a significant cost saving for governments across the globe, while eliminating the perverse incentive to consume more fossil fuels. Black et al. (2023b) also quantify implicit subsidies, measured as the undercharging of external costs of fossil fuel use (climate externalities and other, domestic environmental externalities) plus foregone consumption taxes. If the total subsidies would be removed, primary balances for governments would improve by $4.4 trillion globally.

[19] This follows the proposal for a global minimum carbon price floor in Parry, Black and Roaf (2021). The "capped" carbon pricing achieves 67 percent of the reduction needed to stay within 2°C (and more if high-income countries also meet their NDC commitments).

Figure 3. Fiscal Impacts of Policies in 2030 to Close Ambition Gaps and Stay on Track with Net Zero Targets



Source: IMF staff calculations using CPAT.

Note: "Full carbon price" assumes that the carbon price is equivalent to the shadow price presented in Figure 3. This scenario is equivalent to Black, Parry, and Zhunussova (2023c). "Capped carbon price" assumes a carbon price of $25 for low and lower-middle income countries, $50 for upper-middle income countries and $75 for high-income countries (cf. Parry, Black and Roaf 2021); remaining emission reduction to achieve the target is assumed to be achieved by non-pricing instruments.

Figure 3 shows estimates of the fiscal dividend in 2030 for both pricing scenarios relative to the baseline. The estimates capture the revenue effects of not only the carbon tax itself, but also the base erosion of existing fuel taxes on road and other fossil fuels (or subsidy in some cases). Decarbonizing road transport by shifting to electric vehicles will progressively erode the existing tax bases of motor fuel excises.[20]

The blue bars in left panel of Figure 3 shows that gross revenues from full carbon taxes in 2030 range between 0.5-3 percent of GDP for most countries. For several high-income countries, such as countries in Europe and the US where prices are close to $150 per ton, revenue typically ranges between 1 and 1½ percent of GDP. Prices in middle and low-income countries are often lower, ranging from less than $50 per ton in Nigeria, Egypt,

[20] Similar analysis was conducted in OBR (2021) for the UK and in Direction Générale du Trésor (2023) for France.

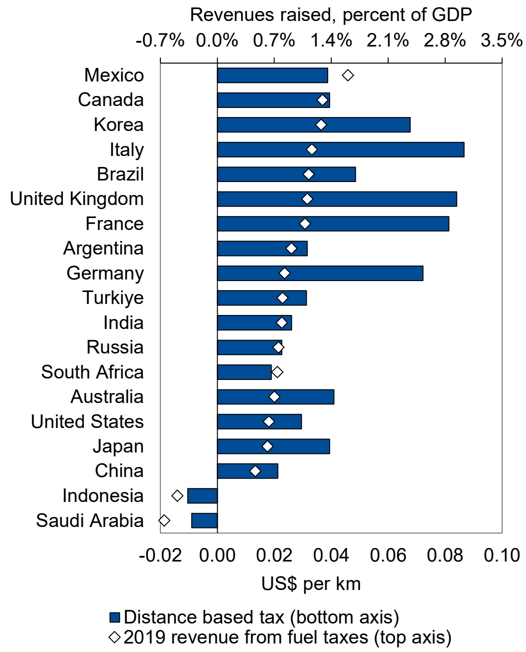
and Indonesia up to $150 per ton in Brazil and Korea. Revenue varies from less than 1 percent of GDP in Kenya, Nigeria, and Indonesia to 2 percent or more in China, India, Saudi Arabia, and Mexico.
The blue bars in right panel in Figure 3 shows gross carbon revenue under the capped carbon price, which is lower than the full carbon price. Hence, gross revenue from this carbon tax is also lower, especially since the emission reduction is the same due to the assumed non-pricing policies. Gross carbon revenue in Europe is generally around ½ percent of GDP, while in the US and Japan it is slightly higher at ¾ percent of GDP due to relatively higher emission intensity of GDP. In most middle and low-income countries, revenue is somewhat higher, at around 1 percent of GDP. This may seem surprising as the carbon price in middle- and low-income countries is lower than in high-income countries. The reason for this difference in revenue effects is that the emissions intensity of GDP in high-income countries tends to be relatively lower, in part as a result of current policies. Revenue potential under the capped carbon price is found to be the largest in China and Russia, where it exceeds 1.5 percent of GDP. In countries of the African Union, revenue is around 1 percent of GDP on average.

The red bars in both panels of Figure 3 show revenue loss from base erosion of existing fuel taxes. In most countries, revenue from existing fuel taxes will decline in 2030. Currently, road fuel taxes typically raise between 0.5 and 1.5 percent of GDP across G20 countries. In countries with more aggressive targets for replacing ICEVs with EVs, these fuel tax bases will erode significantly by 2030. In Figure 3, we see that the erosion causes a decline in fuel tax revenue between 0.2 and 1.1 percent of GDP. However, in seven cases (Indonesia, Egypt, Russia, Saudi Arabia, African Union, Argentina, Nigeria), fuels are currently subsidized. For these countries, the switch to EVs will imply an additional fiscal gain (though it is desirable to eliminate these explicit fuel subsidies irrespective of electrification).

Overall, when mitigation policy puts revenue-raising carbon pricing at the center, net revenues can be expected to increase for most countries out to 2030. Hence, in the near-term at least, climate mitigation can yield a fiscal dividend. However, under an alternative approach where emission targets would be met entirely with non-pricing instruments, there would be no fiscal dividend from climate policy. If non-pricing instruments are applied and harmonized across the power, industry, transport and building sectors, they would promote many of the same behavioral responses as carbon pricing. But the revenue gains shown in the blue bars in Figure 3 would disappear. At the same time, the revenue loss from base erosion of existing fuel taxes (the red bars) would be approximately the same. Hence, this decarbonization scenario would imply a significant revenue loss for almost all countries.

To offset this revenue loss, countries may seek alternative revenue sources from transportation. One such option is to transition to a tax system based on charging all motorists per vehicle km travelled (VKT). This could provide an alternative robust revenue base during the transition away from ICEVs to EVs, as it is unaffected by average emission rates of the vehicle fleet. Ultimately, charges on VKT could be fine-tuned to efficiently manage road traffic congestion (for given road capacity) through differentiating them by location and time of day. The development of electric metering technologies has, at least to some degree, addressed implementation difficulties and potential abuse of information collected on individuals' driving habits. For example, using global-positioning systems, motorists' VKT can be monitored, and bills periodically mailed to households based on their driving at relatively low administrative cost. The transition to VKT charging might be initially promoted through subsidizing/taxing new vehicles with/without monitoring capacity with capacity ultimately becoming mandatory. Across countries, VKT charges (applied nationwide at a uniform rate to light- and heavy-duty vehicles) of around 4-8 cents per km could raise the same revenue (as a percent of GDP) as currently raised by road fuel taxes (Figure 4).

Figure 4. Maintaining Transportation Tax Revenue



Source. IMF staff using CPAT.
Note. revenue excludes VAT collected on fuels.

V. Public Spending

Some forms of government spending will be necessary as part of an efficient decarbonization scenario. This includes spending on green public infrastructure, public support for innovation, and possibly support for deployment of existing LCTs where market imperfections are substantive.

Estimates of the total investment necessary to achieve climate mitigation objectives (such as renewable energy, electrification, energy saving, and carbon capture) vary significantly but often run into trillions of US dollars. For instance, the World Energy Outlook (2022) of the International Energy Agency (IEA) reports that global energy investment, currently estimated at $2 trillion, would more than double in a net zero scenario – an increase by more than 2 percent of global GDP.[21] These investment figures are much larger than abatement costs—they do not net out the reduced need for fossil based investments like coal plants (most of the clean technology investment is redirected rather than additional) as well as lifecycle energy savings from improved energy efficiency.

[21] Estimates of global investment needs vary significantly across studies, see e.g. IMF (2021). Country-specific estimates vary even more and depend on specific circumstances such as carbon intensity.

Who will pay for this investment? We expect the private sector to fund most of the investment expenses for decarbonization. For example, incentivized by pricing and regulatory policies, private firms will invest in renewable power generation and electrified industrial processes, while households will pay for purchases of EVs, heat pumps, and energy-efficient lighting/appliances. However, investments in infrastructure networks may benefit multiple users and would be undersupplied when left to the market. Examples are pipelines for hydrogen and carbon capture and storage, high voltage transmission lines to link up different sites for renewable plants, and EV charging stations. With a share of public investment in total investment of approximately 15 percent in high-income countries, this would imply a fiscal cost of around 0.2 percent of GDP in the coming decades, based on the IEA (2022) estimates. In middle- and low-income countries, however, the current share of public investment is higher at around 60 percent, as the power sector and certain industries in these countries is often dominated by greater state-ownership and electricity prices are regulated. Hence, a larger share of investments in renewable plants may be reflected in government accounts. Yet, the public share in the future is highly uncertain and depends on the pace of privatization and developments in the cost of LCTs.[22] As a larger share of investment gets borne privately and countries liberalize energy markets over time, the public costs would fall. Moreover, even if a significant share of the power sector remains in public hands, it would still be more efficient to reflect investment costs in higher prices for users (e.g., higher electricity tariffs) rather than subsidize the investments from public budgets. This would help promote the efficient allocation of capital and other resources across sectors rather than favoring the power sector over other sectors.

Estimates for public investments in a decarbonization scenario feature a hump-shaped pattern over time (IMF 2021): the increase is concentrated over the next 20 years and will likely decline thereafter. In many sectors, LCT means building infrastructure that has a higher initial cost and lower operating cost due to a reduction in fuel consumption. For example, renewable energy has a high upfront investment cost in the form of solar panels and windmills, but low operating costs as no fossil fuels are needed.

Private sector efforts to innovate and deploy LCTs may be inefficiently low because individual firms do not capture possible benefits to other firms, such as knowledge spillovers from developing or pioneering LCTs. For instance, other firms can imitate or use embodied knowledge to further their own technology or benefit from 'learning-by-doing'. Scale economies may also deter manufacturing of immature technologies. Hence, public support for innovation in LCTs is warranted.

Government intervention to support innovation can come in different forms. First, governments in high-income countries should invest in basic research for unproven or costly technologies that may ultimately be essential for the low-carbon transition, such as direct air capture, green hydrogen, and electricity storage. Given the global public good nature of basic research, international coordination may help scale up such investments to account for positive cross-border knowledge spillovers. Fiscal outlays for basic research into clean energy technologies have been estimated at around $30 billion per year globally (IEA 2020). A gradual ramping up of such research funding might be needed, along with an expansion of the supply of scientists and engineers in this area (Newell 2015).

Second, governments, at least in high-income countries, play an important role in promoting private R&D considering the positive externalities this creates for others (IMF 2016). Governments commonly do this through intellectual property rights protection, research subsidies, R&D tax credits, and technology prizes. In

[22] The October 2023 Global Financial Stability Report of the IMF assumes that the private share in low- and middle-income countries will rise in the coming decades to between 85 and 90 percent (IMF 2023b).

principle, with a robust and efficient carbon price, policies for clean R&D should be similar to those for general R&D. However, more generous treatment for green technologies can be warranted if the appropriability problem is more severe than for other R&D. This may be plausible for technologies that are currently far from the market, such as green hydrogen-based energy and carbon capture, or those yet to be discovered through basic research. The fiscal outlays for R&D subsidies and R&D tax credits across all (energy and non-energy) sectors in high-income countries are modest, however, at around 0.2 percent of their GDP[23] (somewhat higher in Canada, France, UK, and the US, and somewhat lower in Germany and Scandinavia). And only a small fraction of these general R&D incentives is geared toward LCTs.

Finally, governments can assist technology deployment, such as through subsidies for EVs, heat pumps, energy storage, and renewables (although part of these might be captured by public entities, e.g., if power companies are public). In the power sector, wind and solar have already become cheaper than new, and in some cases, existing fossil fuel-based power. Nevertheless, public support for deployment may still be warranted due to market failures impeding dissemination (such as scale economies and the reliance on electricity distribution networks). Subsidies and tax incentives for green technologies are heavily concentrated in a few key countries, such as China, Italy, Japan, Korea, Germany and the US. While they are generally below 0.2 percent of GDP, these policies have recently gained interest (see Box 1). If carbon pricing is hard to implement (e.g., for political reasons), scaling up spending policies may provide an alternative incentive for adopting LCTs. Yet, subsidies and tax credits are contentious due to several inefficiencies they can create:

- The budgetary costs will either raise public debt or, if covered by raising other taxes, exacerbate pre-existing tax distortions in labor and capital markets. To minimize these inefficiencies, it would be best to apply subsidies and tax credits incrementally and avoid windfall gains for investments that would have been made also without the policy. Moreover, subsidies and tax incentives should be temporary and gradually removed as technologies mature and become competitive.
- While they encourage substitution toward clean energy, subsidies do not incentivize other behavioral responses promoted by carbon pricing like reductions in energy demand and shifting from coal to gas or from these fuels to nuclear. Leaving out these potentially important behavioral effects renders them less efficient.[24]
- They can distort international markets, especially if provisions discriminate against foreign manufacturers through domestic content requirements. However, even without such discrimination they can induce green companies to relocate to countries with larger tax incentives and subsidies, at the expense of countries without such benefits. A technological race has a winner-takes-all logic that can exacerbate geopolitical tensions and protectionist sentiments.
- Like traditional industrial policies, green subsidies and tax credits could suffer from government failures associated with rent-seeking and corruption, especially if they allow for discretionary policy choices. Thus, they could lead to wasted resources, competitiveness losses, or state capture if not well-implemented.

[23] See OECD R&D tax incentives database.

[24] For instance, Bistline, Mehrotra, and Wolfram (2023) find that the marginal abatement cost of the US Inflation Reduction Act ranges between $45-$61, while a $15 uniform carbon price could have achieved the same overall emission reduction.

VI. Fiscal Compensation

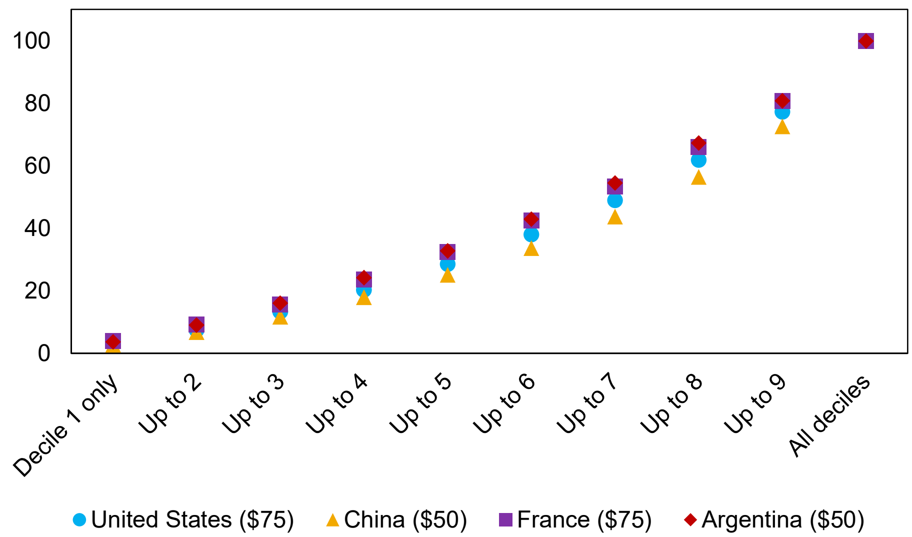
Compensation schemes are necessary to achieve an equitable and politically viable policy mix. This will be especially so in the case of carbon pricing schemes, which impose an additional burden on households and firms from tax or rents transfers prior to revenue recycling. This section discusses the fiscal impacts of compensation.

Carbon pricing will have negative implications for households' purchasing power by directly raising the cost of energy. For instance, a $75 per ton carbon tax would, on average across countries, increase the user price of coal by about 2.5 times, raise natural gas prices by about 60 percent, that of electricity by 25 percent, and gasoline by 19 percent.[25] Moreover, these higher energy prices would indirectly raise the prices of non-energy goods that use fossil fuels as an input in their production. In high-income countries, the effects on real household incomes tend to be slightly regressive or distribution neutral (IMF 2019). In middle- and low-income countries, however, they are usually found to be neutral or slightly progressive (due to lower rates of grid access and vehicle ownership among lower income households). In either case, household impacts can be offset by recycling the revenues through strengthening social protection and/or by lowering taxes elsewhere—provided these policy instruments can effectively be employed. If a portion of revenues are used for a combination of targeted compensation for bottom income deciles and increases in lower personal income tax thresholds, the overall reform can be made progressive (meaning the overall equity of the fiscal system increases) and pro-poor (meaning the poorest deciles benefit in net terms; Black et al. 2022). However, in practice targeting compensation to the poor can be difficult, with some left out ('undercoverage') and a portion of the non-targeted benefitting ('leakage'), which need to be considered when developing and costing compensation schemes.

We use CPAT to analyze how much of the carbon price revenue is required to offset the impact on households in different income deciles in four countries: Argentina, China (both for a $50 per ton carbon price), France and the US (both for a $75 per ton carbon price; Figure 5). The estimates on household real incomes include both policy-induced increases in energy prices and higher prices for other consumer goods (using country specific input-output tables and matching to consumer budget shares for different products from household surveys). Burdens are generally regressive (i.e., larger relative to consumption for lower income than higher income households) but only moderately so. Figure 5 suggests that targeted transfers to compensate the three bottom income deciles will require around 15 percent of the carbon price revenue in each of the four countries. Compensating the bottom half of households requires approximately 30 percent.

[25] Energy prices can fluctuate significantly and did notably so in recent years. The price increases reported here are based on projections for 2030, using extrapolations from data for the early 2020s.

Figure 5. Costs to Fully Compensate Household Deciles for the Impact of a Carbon Price
(% of revenue raised)



Source: CPAT

Note: The transfer is calculated to fully offset the higher tax burden on households up to the respective income decile and expressed as a share of overall revenue from the carbon price. Carbon price for France and the US is assumed to be $75 per ton and for Argentina and China $50 per ton.

Countries may also consider compensating households for other costs of decarbonization, i.e., from non-pricing instruments. For instance, to reduce emissions from buildings, several countries require the replacement of gas boilers and other fossil-fuel heating systems with cleaner but generally more expensive alternatives, such as heat pumps. Compensating households for these additional costs through subsidies would raise the fiscal costs of decarbonization. For instance, the Office of Budget Responsibility (OBR) in the UK (2021) and Mahfouz and Pisani-Ferry (2023)[26] for France assume that a significant share of these investments in the decarbonization of buildings will be borne by the government instead of households. In the OBR decarbonization scenario, for example, nearly 40 percent of total fiscal costs is due to these expenditures.[27] This is also the case in Pisani-Ferry and Mahfouz (2023), where about half of the increase in public debt is associated with public expenditures.[28]

Compensation might also be needed for certain firms. A global agreement on climate mitigation would help sustain a level playing field across countries and thus reduce the need for countries to take unilateral measures to maintain competitiveness of industries (e.g. through exemptions from carbon pricing). Moreover, a global

[26] The analysis by Mahfouz and Pisani-Ferry for France reflects solely the opinions of the authors and not necessarily that of the French government.

[27] A revenue neutral approach, perhaps with subsidies financed through higher taxes on residential gas, can be more efficient as it avoids fiscal costs on the government and favoring the housing sector over other sectors.

[28] Another significant portion of the rise in debt in their analysis is caused by the loss in tax revenue due to a slowdown in economic growth. A meta-analysis in the October 2023 Fiscal Monitor shows a wide variety of findings in the literature on the GDP effects of climate mitigation policies. While simulation-based studies often report (small) negative effects, recent empirical studies suggest mostly positive or insignificant effects.

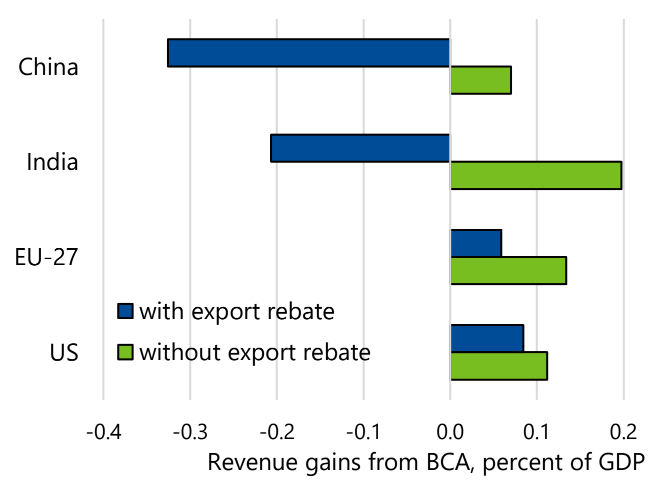
deal would mitigate concerns about carbon leakage (counteracting increases in emissions abroad due to international migration of production) since all firms in energy-intensive trade-exposed industries would be affected by similar mitigation measures. However, in the absence of a global side agreement, there will be calls for offsetting measures if a country unilaterally imposes a carbon price. Indeed, unlike subsidies or regulations, carbon pricing imposes a charge on remaining (non-abated) emissions, which could negatively impact production costs for energy-intensive trade-exposed industries. This could be addressed by combining carbon pricing with partial assistance to firms (providing free allowance allocations, broader tax reliefs, output-based subsidies), or by using other approaches (TPSs, feebates, subsidies). This, however, would forego the fiscal dividend and, if pursued though subsidies, even entail an additional fiscal cost.

Box 2: Border Carbon Adjustments

When countries unilaterally adopt carbon pricing, they can also use border carbon adjustments (BCAs) for energy-intensive trade-exposed industries to mitigate competitiveness effects. BCAs are charges on embodied carbon in imports, potentially complemented by rebates for embodied carbon in domestic exports, in order to offset the impact of domestic carbon pricing. They have the potential to level the playing field in domestic markets (for imports) and foreign markets (when rebates are provided on exports). Moreover, they mitigate carbon leakage effects and may provide incentives for other countries to impose similar carbon prices to preempt the impact of the BCA. Intuitively, taxing carbon emissions on a destination basis—as opposed to an origin basis—does not induce production distortions. However, BCAs need to be designed and administered carefully to be effective.[29]

The potential revenues from BCAs on imports are estimated at around 0.1-0.2 percent of GDP for a $50 per ton charge—for China, India, the EU, and the US (Figure 6). With export rebates, net revenues are found to be negative for China and India. From a broader perspective, however, taxing carbon on a destination basis leaves more scope for countries to exercise their domestic ambitions without hurting competitiveness. For instance, BCAs may enable higher domestic carbon prices and thus higher revenue. The revenue losses from export rebates might be small compared to the overall revenue gain from comprehensive pricing of domestic carbon emissions.

Figure 6. Revenues Effects from a $50 per ton BCA



Note: based on 2015 embodied carbon data
Source: Keen, Parry, and Roaf (2021).

[29] For example, their coverage should be limited to vulnerable firms and any export rates should be based on industry emission rates to preserve firm-level mitigation incentives. See Parry, Dohlman, et al, (2021).

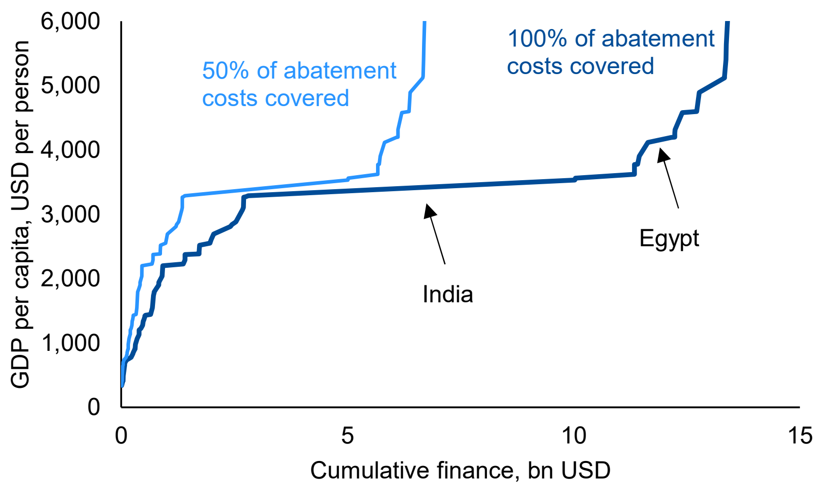
VII. International Transfers

Financial transfers from high-income to low and lower-middle-income countries will be part of an international side agreement on decarbonization. In 2009, high-income countries pledged to mobilize US$100 billion a year from 2020 for mitigation and adaptation in developing economies, both from private and public sources. Estimates suggests that flows have only recently reached this level (OECD 2023). Still, developing economies face much higher investment needs for adaptation to climate change, i.e., investments to make countries resilient against the impact of climate change. Moreover, the transition to a low-carbon economy might be costly for developing countries with rapidly growing energy demand and fiscal and financial constraints limiting options for funding green public investments or domestic compensation measures.

There are multiple approaches to determine the size of international transfers. A pragmatic one is to consider what international financial transfers would be necessary to compensate poor countries for the abatement costs under an international agreement on carbon pricing (before considering climate benefits and domestic environmental co-benefits). Such transfers would thus compensate them for the direct cost increase from the side agreement and may induce them to accept it. Transfers could be in the form of budget support or be related to technology transfers, for instance through de-risking mechanisms like loan guarantees, public equity co-investments, and political risk insurance for private investments in LCTs (Pigato et al 2020), as well as supporting policies to absorb knowledge transfers trough trade and investment.

We use CPAT to calculate the transfers required to offset the economic cost of climate mitigation policy, approximated here by the average abatement costs in low- and lower-middle income countries, i.e., the additional costs of using cleaner but more expensive technologies, as shown in the right panel of Figure 2. As discussed above, these costs are around 0.1-0.2 percent of GDP in low-income and lower-middle income countries. Figure 7 illustrates how this translates into billions of US$ for the cumulative finance required to compensate countries for their economic costs if increasing levels of GDP per capita would be covered under the compensation scheme. For instance, if compensation would be provided for 100 percent of the abatement costs in countries with GDP per capita of less than $5,500, the total global costs for the donor countries would be $15 billion (with nearly half going to India).

Figure 7. Transfers to Compensate Low-and Lower-Middle-Income Countries for CO2 Abatement Costs, 2030



Source: Black and others (2023c).
Note: Shows cumulative amount of climate finance necessary to compensate countries with per capita income up to $5,500 for their mitigation costs in 2030 under the scenario discussed above.

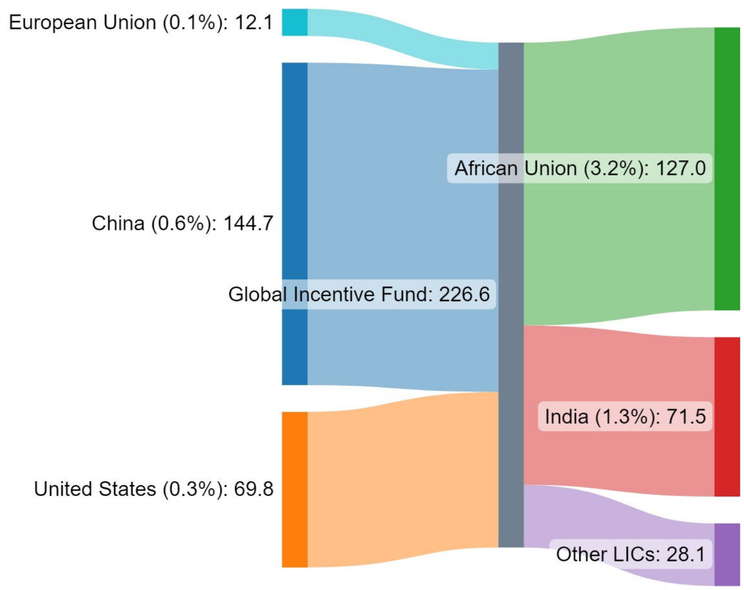
VIII. International Revenue Sharing

There are various other approaches to financial transfers under a global side agreement and sharing the burden of decarbonization between countries. For instance, a normative approach proposed by Rajan (2021) starts from the assignment of equal property rights of global citizens to access the global common. If climate externalities are efficiently internalized by making polluters pay for the social cost of carbon through a globally agreed carbon price, the global revenue from such a charge could then be distributed across the global population on a per-capita basis to reflect the equal distribution of property rights. This section combines this idea with the global minimum price floor proposed in Parry, Black and Roaf (2021). In particular, we consider a minimum global price floor of $25 per ton of carbon, the revenue of which is allocated to countries on a per-capita basis (while carbon prices set by countries above this level will continue to flow to their national budgets).

A key question is of course how this principle could be implemented in the absence of a global authority to administer and enforce it. The answer is that it may rely on a combination of a globally agreed carbon price and fiscal transfers between countries. If carbon prices are initially collected by individual countries based on their own emissions at source, poor countries should likely be compensated by rich countries through these financial transfers. Indeed, fiscal transfers would depend on the difference between a country's own emissions per capita (on an origin basis) and the world average: countries with emissions per capita below the global average (usually poor countries) would be net receivers, while countries with higher emissions per capita (usually rich countries) will be net payors. This would link the climate agenda directly to the broader development agenda and the sustainable development goals. Revenue sharing is perhaps most salient for carbon pricing in international shipping and aviation, where international organizations exist to possibly enforce revenue sharing.

This is particularly so, as it is not straightforward to allocate taxing rights from international transportation to either origin, destination, residence, or transit countries.[30]

Figure 8. Fiscal Transfers if Revenue of a $25 per ton Global Carbon Tax is Shared on a per-capita basis (2030)



Source: IMF Staff using CPAT.

Figure 8 uses CPAT to simulate the magnitude of these transfers under a $25 per ton carbon tax in 2030 for five countries or country groups (EU, African Union, China, US, India). We see that approximately $230 billion would be transferred to low- and lower-middle income countries, as they feature carbon emissions per capita below the world average—an amount that exceeds today's official development aid. Out of the total, $127 billion would go to the African Union (3.2 percent of their GDP) and $71 billion to India (1.3 percent of GDP). Net payors would be countries with carbon-per-capita above the global average, which includes China (0.6 percent GDP), the US (0.3 percent GDP) and the EU (0.1 percent GDP).

This scenario is merely illustrative. Many other possibilities exist. For example, the scheme could also operate on a destination basis (in line with an overall system of carbon taxation complemented with carbon-border adjustments).

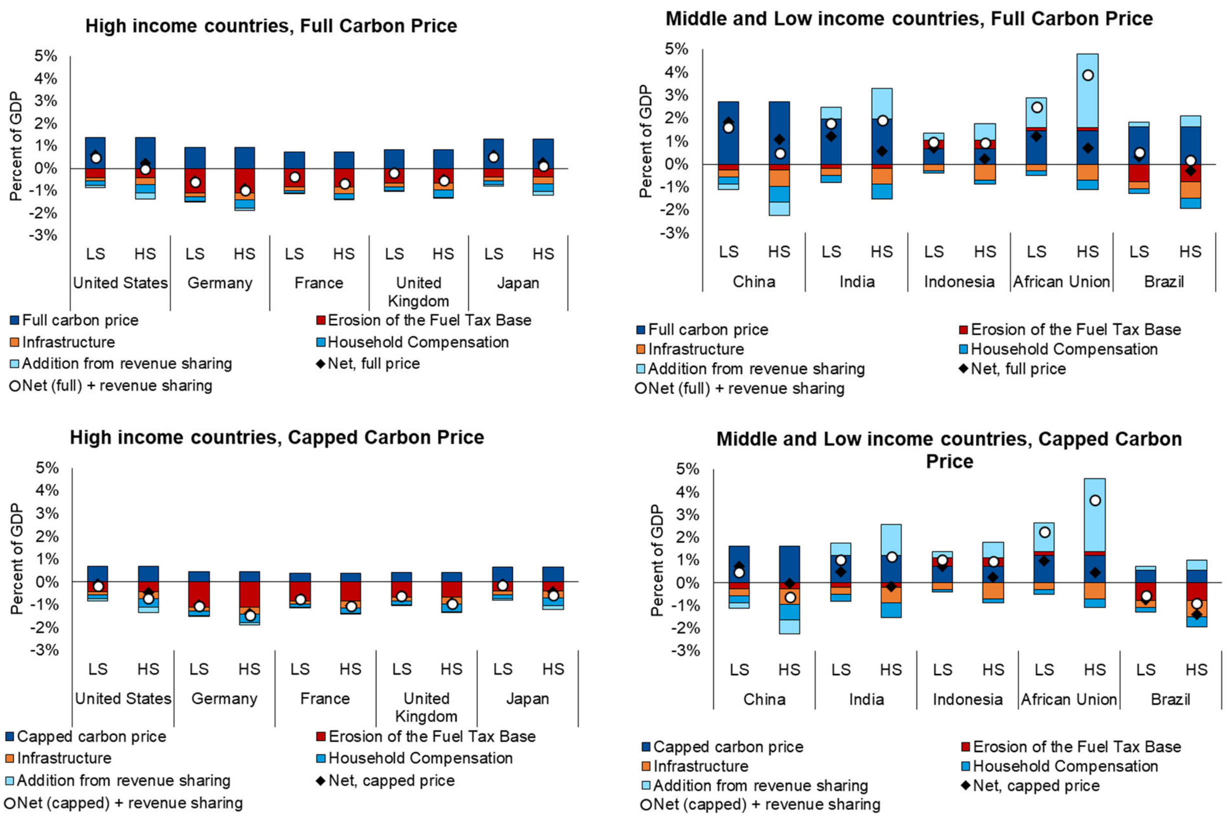
IX. Putting Pieces Together

The net fiscal impact of global climate action for individual countries will depend on how policies affect the different pieces of the fiscal equation. Fiscal revenues increase if mitigation is done through carbon pricing. However, revenue from pre-existing taxes on motor fuels are currently significant in many high-income countries and will decline. On the spending side, decarbonization calls for higher outlays on public

[30] For a $75 per ton carbon price, global revenue from international transportation could be around $100 billion in 2030 (Black, Parry, and Zhunussova 2023c).

infrastructure, public research, stimulus for private R&D, and possible deployment subsidies. Transfers will be necessary to compensate domestic households and firms. Financial transfers from high to low and lower-middle-income countries (based here on the revenue sharing approach discussed in Section VIII) will further impact the fiscal equation of individual countries.

Figure 9. Impact of Decarbonization Scenario on the Fiscal Balance in Selected Countries in 2030



Note: LS = Low Spending Scenario; HS = High Spending Scenario. Carbon tax revenue and erosion of the fuel tax base are based on Figure 3 under both full and capped carbon pricing. Low spending scenario (LS) assumes additional spending on infrastructure and subsidies by 0.15% GDP in advanced economies and 0.3% in emerging and developing economies; transfers compensate the bottom 3 deciles (0.15% of carbon revenue), and revenue sharing of $10 carbon price. High spending scenario (HS) assumes additional spending on infrastructure and subsidies by 0.3% in advanced economies and 0.7% in emerging market and developing economies; transfers compensate bottom 5 deciles (0.3% of carbon revenue), and revenue sharing of $25 carbon price.

Figure 9 illustrates the net effects on the government budget for a selection of G20 countries in 2030. Given the uncertainty and arbitrary nature of some assumptions about public spending, we consider two public spending scenarios: a high-spending scenario and a low-spending scenario (see details in Figure 9).[31] Moreover, we show both the scenario with full carbon pricing to achieve global climate targets and the scenario with a capped carbon price, which is supplemented by non-pricing policies.

[31] Public spending needs in each group are assumed to be the same as a percentage of GDP across countries. In practice, however, they will differ and depend on e.g. carbon intensity of GDP. The numbers presented here are therefore illustrative and should be interpreted with caution.

In European countries, Figure 9 shows that net revenue (from carbon pricing and fuel tax) changes by between –0.2 and +0.1 percent of GDP in 2030 in the full pricing scenario. Even where the net revenue effect is positive, this is insufficient to cover higher expenditures on green public infrastructure, subsidies, and transfers – irrespective of the low or high spending scenario. A cap on the carbon price further deteriorates the fiscal equation for these countries. Hence, European countries may see their deficit rise or they need to raise other taxes, such as road-user charges, to offset negative effects on the primary fiscal balance.

In the US and Japan, net revenue gains are closer to 1 percent of GDP in the full pricing scenario. This is higher than in Europe due to higher carbon-intensity of GDP and smaller revenue loss from existing fuel excises. In the low-spending scenario, this revenue gain renders the impact on the fiscal balance positive. Hence, these countries could reduce pre-existing taxes as part of a revenue-neutral reform, or they could reduce their public debt burden. In the high-spending scenario, however, the impact on the fiscal balance is close to neutral. If the carbon price is capped, the fiscal balance is close to neutral under the low-spending scenario but deteriorates under the high-spending scenario.

Revenue gains are generally positive in middle and low-income countries and largest in China and India, where carbon revenue under full carbon pricing without base erosion is more than 2 percent of GDP. In the African Union and Brazil, carbon revenue rises by around 1.5 percent of GDP under full pricing, while it is close to 0.7 percent of GDP in Indonesia. The revenue side is further augmented in the African Union, India, and Indonesia by revenue sharing of a global carbon price equal to $10 or $25 per ton in the two spending scenarios. This revenue sharing also improves the fiscal balance in Brazil. However, it reduces the fiscal balance for China, which will be a net contributor to the global fund due to its relatively high carbon intensity.

In India, Indonesia and the African Union, net revenue gains in the full carbon price scenario exceed the additional expenditures – both under low- and high-spending and even in the absence of revenue sharing. Hence, these countries could use the additional fiscal space to support the wider development agenda, e.g., for adaptation investment or other sustainable development goals. In China, the fiscal balance improves in the absence of revenue sharing and in the low-spending scenario. This improvement largely disappears, however, if the carbon price is capped at $50 and spending is high. While the same applies to India, revenue sharing would turn the net fiscal impact positive also under high spending and capped pricing. Finally, for Brazil the effects on the fiscal balance are small and can be somewhat negative if the carbon price is capped, revenue sharing is absent and with high spending. Revenue sharing, however, will turn it into a marginally positive fiscal impact if carbon pricing is not capped.

X. Conclusion

Achieving the world's climate goals agreed in Paris necessitates urgent policy action. High-income countries cannot mitigate global climate change alone given the large share of current and future emissions in middle- and low-income countries. Given the difficulty for countries to adequately scale up mitigation policies unilaterally, a global side agreement to complement the Paris Agreement can help while it would maintain a level playing field and address concerns about competitiveness, relocation of industries and carbon leakage. Such an agreement should include at least the largest countries and blocks in the world and reflect its diversity (China, EU, India, US, and African Union); contain concrete policy actions (like minimum pricing requirements or equivalent approaches); and address international equity issues (by linking climate mitigation to the wider development agenda).

Carefully designed and concrete policy packages to guide such an international side agreement are explored in this paper, with a focus on the implications for fiscal balances. Carbon pricing forms the centerpiece of the policy package. It is complemented by other regulatory and spending policies as well as compensation schemes to enhance political acceptability. We also explore transfers from high-income to low- and lower-middle-income countries as part of the agreement.

The quantitative impact on fiscal revenues for countries depends on the balance between rising carbon revenue and a gradual erosion of existing carbon and fuel tax bases. Public spending rises during the transition to build green public infrastructure, promote innovation, support clean technology deployment, and compensate households and firms. Assumptions about the size of these spending needs are speculative and estimates vary with country characteristics (especially the emissions intensity of the energy sector) and policy choices (whether investments are funded through user fees or taxes for the sector or by the general budget).

On balance, the paper finds that the global decarbonization scenario will likely have moderately negative implications for fiscal balances in advanced European countries. Effects are more likely to be positive for the US and Japan if public spending is contained. For middle and low-income countries, net fiscal impacts are generally positive and sometimes significantly so—mostly due to relatively buoyant revenue effects from carbon pricing that exceed spending increases. For low-income countries, these effects are reinforced if a portion of the global revenue from carbon pricing is shared across countries on a per-capita basis. Thus, a global agreement on mitigation policy has the potential to support the global development agenda.

Annex I. Sectoral Mitigation Options and Technologies

This annex discusses mitigation options and technologies in the power sector, transportation, industry and agriculture.

Decarbonization of **the electricity sector**—which generates 32 percent of carbon emissions globally—is a low-hanging fruit because alternative technologies have become competitive with fossil fuel technologies. The cost of adding new wind and solar energy capacity is below the upper end of the cost range for new fossil fuel capacity in all G20 countries, offering attractive investment opportunities. The cost comparison is done for the levelized cost of energy which is a measure of the average net present cost of electricity generation for a generating plant over its lifetime. In fact, in most G-20 countries, the cost is at the lower end of the fossil fuel cost range. For instance, the cost for onshore wind is below the cost range for new fossil fuel capacity in Brazil, China, India, and the United States, and solar is below the range in India. Given the steady downward trend in the price of these technologies, more countries can be expected to see the cost of new renewable energy capacity falling below any possible new fossil fuel power capacity additions in the near future.

In **ground transportation** decarbonization is possible through public transportation and electrification. In 2018, almost 17 percent of global greenhouse gas emissions were emitted by the transportation sector. In road transportation, electrification is developing dynamically, while the use of hydrogen in road transportation would exceed the production capacity, given that the green hydrogen production capacity is needed for aviation and shipping until 2050. An important policy measure for vehicles are feebates (see Annex II). Another option is to impose a ban on vehicles with internal combustion engines as preannounced by seven G20 countries—typically for 2030-40— and under consideration in China. Boosting public transportation capacity is an important option since it is more energy efficient and less space consuming. Supporting this mainly requires public investments.

Green hydrogen and ammonia are viable options to decarbonize **aviation and maritime transport**. In aviation and maritime transport, electrification is not possible with current technology. Instead, the industry could switch to synthetic fuels, like green hydrogen and ammonia. Biofuels are not available at sufficient scale, synthetic carbon-based fuels are more expensive and liquefied natural gas has disadvantages such as methane leakage. Producing the green hydrogen or ammonia required for aviation in 2050 would require solar panels of 140.000 km2—about half of the area of Italy. The raw materials for this much renewable energy are available, but a quick increase in demand requires a careful planning of supply. Among the countries well suited for the production of zero carbon fuels are most of the current fuel exporters (because of favorable renewable energy conditions, available desert space in many cases, as well as existing infrastructure for exporting fuels), but also some others.

Many types of LCTs in **manufacturing and construction** are still comparatively expensive. In addition to consuming electricity (for which the emissions are attributed to electricity/heat), some manufacturing processes use fossil fuels directly, contributing close to 13 percent of global emissions. Technologies to decarbonize these processes exist, but they are expensive and boosting take up would require government support. An example is steel. Steel is today mostly produced with coke-based blast furnaces, which can be coupled with carbon capture systems or replaced with a new and clean technology called "direct hydrogen reduction". These types of technologies could be supported by governments in a similar way as some had supported renewable energy in its early stages of development. Emissions from industrial processes cannot be avoided altogether but can be reduced and compensated through negative emissions. This type of emissions results from chemical processes (most importantly the production of cement) and account for about 6 percent of global emissions (in addition to those associated by the electricity consumption and direct consumption of fossil fuels by the sector). Emissions from industrial processes can be lowered by increasing material efficiency, but within limits. The residual thus needs to be compensated through negative emission technologies to withdraw the emissions at source or from the atmosphere. As carbon storage options are limited, using it for these kinds of emissions, which cannot be avoided by other means, seems the most suitable. Re-using or recycling carbon are further options.

The largest part of emissions in **agriculture** originates from livestock production. Agriculture contributes 12 percent to global emissions. Livestock production releases large amounts of methane, a potent greenhouse gas. Enteric fermentation (40 percent), manure left on pasture (16 percent), manure management (7 percent) and manure applied to soils (3 percent) are estimated to have accounted for two-thirds of global agricultural emissions from 2001 to 2011. It is possible to determine the content of greenhouse gases in the products based on livestock. Meat and dairy products could thus be taxed in proportion to the climate damage they cause. This would be an indirect extension of carbon pricing to agriculture. Incentivizing low-carbon farming practices could mitigate the remaining emissions. The government can reduce emissions by incentivizing better farming practices, for example through new feed additives, better slurry management, and biorefining. Reducing fertilizer use can also contribute to reducing emissions, because the chemical input of nitrogen as fertilizer is an important source of greenhouse gas emissions. Reducing food loss is another obvious way to reduce emissions. Supporting organic farming would sequester more carbon and thus withdraw it from the atmosphere. Even reducing whaling has a positive effect as whales play a role in capturing carbon from the atmosphere.

ANNEX II. Feebates and its Applications

Feebates generally involve a sliding scale of fees on products or activities with emission rates above a pivot point and a sliding scale of rebates for products or activities with emission rates below the pivot point (IMF 2019). These mechanisms:

- Promote the full range of behavioral responses for reducing the emissions intensity of a sector. However, unlike carbon pricing they do not promote a demand response, (e.g., they encourage more fuel-efficient vehicles but do not encourage people to drive less).
- Are automatically cost effective because the reward (through lower fees or higher rebates) for reducing emissions by an extra ton is the same across all behavioral responses within and across firms and households (in contrast, fluid credit trading markets may be required for emission rate standards to be cost effective).
- Need not (unlike clean technology subsidies) impose a fiscal cost on the government, as the pivot point can be set at industry or market average emission rates and updated over time to maintain revenue neutrality—alternatively, the pivot point can be scaled to raise revenue.
- May also have greater political acceptability than carbon pricing as they do not impose a new first-order tax burden on the average household or firm, though at the same time the government is deprived of new revenues.

- Are compatible with existing regulations—in fact, feebates provide ongoing incentives for firms or households to exceed any regulatory standard.

In **transportation**, new vehicles would be subject to a fee equal to a CO_2 price times the difference between their CO_2 emission rate per kilometer (km) and a pivot point emission rate, scaled by lifetime vehicle km driven. Feebates could also apply on an annual basis to existing vehicles which would promote faster retirement of older, more polluting vehicles though administratively this is more complex (as it would cover all vehicle-owning households rather than a limited number of vehicle sellers). Some countries have incorporated elements of feebates into their registration tax systems for vehicle sales, though often tax schedules are staggered, and rates increase by more than in proportional to CO_2 emissions. These systems can still provide very powerful incentives for low-emission vehicles. For example, in European countries the implicit CO_2 price is often around $600 per ton or more. Capacity requirements may be minimal as they may just require a recalibration of existing vehicle taxes and emission rates for different vehicle models and vintages are generally available. Subsidies for EVs would decline over time as the average fleet emission rate declines, which is appropriate as the cost differential between EVs and their gasoline/diesel counterparts falls over time (e.g., with improvements in EV battery technology).

Feebates could reinforce incentives for cleaner production processes in **carbon-intensive industries** like aluminum, steel, cement, chemicals. Firms within an industry would be subject to a fee given by the product of a CO_2 price, the difference between a firms CO_2 per unit of output and a pivot point emission rate for the industry, and the firm's output. The feebate, which would apply to emissions from fuel combustion and process emissions (e.g., release of CO_2 during the transformation of clinker into cement) avoids a first-order burden on the average producer as they pay no charge on their remaining emissions which helps to alleviate competitiveness concerns. A separate scheme would be needed for each distinct industry but the emissions prices across different schemes could be harmonized to promote cost effectiveness. Capacity requirements are simpler than for ETSs—the government needs to monitor firm emission rates but not trading markets.

In the **power sector**, generators would be subject to a fee equal to the product of a CO_2 price, the difference between the CO_2 per kilowatt hour (kWh) averaged across their plants and a pivot point CO_2 per kWh, and their electricity generation. A feebate would potentially promote shifting from coal to gas generation and from these fuels to nuclear, renewables, and fossil generation with carbon capture and storage—in contrast, renewable policies promote only shifting to renewables and without differentiating according to the carbon intensity of the fuel that is backed out. Again, capacity requirements for a feebate include monitoring of CO_2 emission rates for power generators and applying the system of fees/rebates.

In countries (e.g., in the EU) with energy performance ratings for **buildings**, feebates might be integrated into annual property tax systems (e.g., to promote insulation upgrades) with fees/subsidies applying where buildings have relatively low/high energy performance ratings. Feebate schemes could be used to promote adoption of energy efficient appliances by levying fees on product sales in proportion to the difference between energy consumption rates and a market-wide energy consumption rate. Schemes could also apply taxes to gas- and oil-based heating systems and a subsidy for electric heat pumps.

A national **forestry** feebate program could cost-effectively promote a wide range of responses for increasing carbon storage including afforestation, reduced deforestation, and enhanced management practices (e.g., planting larger trees, lengthening rotations, fertilizing, tree thinning). Under this approach, landowners at the agricultural/forestry border that reduce carbon storage on their land relative to storage in a baseline year might be subject to fees while landowners that increase carbon storage over time receive subsidies. This system would require that property rights at the border are reasonably well defined and capacity for regular measurement (by satellites, aerial photography, and on-the-ground tree sampling) of carbon inventories as being developed, for example, under the Reducing Emissions from Deforestation and Forest Degradation (REDD+) program. Feebates should involve rental payments (on an annualized basis, this would be a CO_2 price times the interest rate) rather than large one-off payments for tree planting, given carbon storage may not be permanent (e.g., due to subsequent harvesting or loss through fires, pests, windstorms). Fees and rebates might build off registries of landowners used for business tax collection or farm support programs. And they might be introduced sequentially, starting with the subsidy part of the scheme (for which there should be more political acceptability).

Methane is an especially potent greenhouse gas and the bulk of the low-cost opportunities for mitigating it are in **the extractives sector**.[32] Methane emissions could be subject to taxes integrated into existing fiscal regimes for extractives but given the trade exposure of the sector (for oil and gas) there would likely be pressure for a revenue-neutral tax partially replacing other broader taxes in the regime. A feebate approach would have similar incentive effects and would be a little simpler administratively—firms would be subject to a fee equal to the product of a CO_2 price, the difference between their methane emissions per unit of output (expressed in CO_2 equivalent) and a pivot point emission rate, and their output. A complication here is that firm-level emissions are not directly monitored at present. Firms might therefore be required to develop their own capacity for metering emissions (as in Norway) or they might be subject to proxy emissions fees based on observed technological characteristics and default emissions factors linked to these characteristics—but allowing firms to petition for lower taxes/higher rebates by demonstrating, through their own metering or technology changes, their emission rates are lower than the default.

The International Maritime Organization (IMO) has pledged to reduce CO_2 emissions from **international maritime transport** (currently 2 percent of global CO_2 emissions) by 50 percent below 2008 levels by 2050. Achieving this target will require development and deployment of zero emission vessels (ZEVs) such as hydrogen ships. With an aggressive R&D program to advance ZEV technologies in the meantime, a carbon levy with price in the ballpark of $75 per ton in 2030 would be sufficient to promote deployment of ZEVs as the shipping fleet gradually turns over. This tax however would raise considerably more revenue (tens of billions of dollars a year) than needed for the R&D (Parry and others 2022c) and its high tax burden would likely face stiff opposition from member states at the IMO.

Again, an alternative is to use a feebate variant imposing a much smaller burden on the industry. In this case, ship operators would be taxed on the difference between their CO_2 emissions per ton-mile of freight and a pivot point CO_2 emission rate per ton-mile, multiplied by their total ton-miles (all this information can be inferred from data that large ship operators now report to the IMO). Separate feebate schemes would be needed for container and bulk shipping given their different emissions intensities. For a given feebate price, the pivot point can be chosen to meet a revenue target, though separate feebates (ideally with harmonized prices) may be needed for bulk and container shipping which have substantially different emission intensities. Fees/rebates could be applied by a new fund under IMO supervision based on fuel use and ton-km data that is routinely reported to the IMO—port access could be denied to operators unable to verify payments.

[32] For example, capturing methane at the mine mouth or wellhead and using it for on-site or regional power generation, compressing or liquifying the gas for sale, flaring methane (which releases CO_2 emissions which are a less potent GHG than methane), and improving maintenance of infrastructure for gas processing and distribution. See UNEP (2021).

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