

**EXECUTIVE
BOARD
MEETING**

SM/19/39
Correction 1

March 19, 2019

To: Members of the Executive Board

From: The Secretary

Subject: **Fiscal Policies for Implementing Paris Climate Strategies—From Principle to Practice**

Board Action: The attached corrections to SM/19/39 (2/19/19) have been provided by the staff:

Evident Ambiguity Pages 33 (para. 43), 37 (para. 52, line 5 and para. 55 line 1), 58 (fourth paragraph, subsequent footnotes renumbered)

Factual Errors Not Affecting the Presentation of Staff's Analysis or Views Pages 5, 15, 32

Typographical Errors Pages 9, 11, 12, 13, 16, 19, 20, 22, 23, 30, 33 (footnotes 62 and 63), 37 (para. 55, line 3 and footnotes 75, 76, and 77), 41, 43, 50, 51, 52, 58 (footnotes 9 and 10), 59, 95, 96, 97, 98, 99, 100, 103, 104, 105

Questions: Mr. Parry, FAD (ext. 39724)
Mr. Mylonas, FAD (ext. 34167)

	<p>countries whose energy prices are increased by climate policy. Alternatively, it could result from increased demand for fossil fuels in other countries as world fuel prices fall in response to reduced fuel demand in countries taking mitigation actions.</p>
ETS	<p>Emissions Trading System or Scheme. A market-based policy to reduce emissions (sometimes referred to as cap-and-trade). Covered sources are required to hold allowances for each tonne of their emissions or (in an upstream program) embodied emissions content in fuels. The total quantity of allowances is fixed, and market trading of allowances establishes a market price for emissions. Auctioning the allowances provides a valuable source of government revenue.</p>
Externality	<p>A cost imposed by the actions of individuals or firms on other individuals or firms (possibly in the future, as in the case of climate change) that the former does not consider.</p>
F-gases	<p>Fluorinated Gases. Gases caused by human activity that remain in the atmosphere, thus leading to global warming. The most important F-gas is HFCs.</p>
Feebate	<p>This policy would impose a sliding scale of fees on firms with emission rates (e.g., CO₂ per kilowatt-hour) above a ‘pivot point’ level and corresponding subsidies for firms with emission rates below the pivot point. Alternatively, the feebate might be applied to energy consumption rates (e.g., gasoline per kilometer driven) rather than emission rates. Feebates are the fiscal analog of an emissions (or <u>energy efficiency</u>) standard, but they can better accommodate uncertainty (e.g., over future technology costs and fuel prices).</p>
GHG	<p>Greenhouse Gas. A gas in the atmosphere that is transparent to incoming solar radiation but traps and absorbs heat radiated from the earth. CO₂ is easily the most predominant GHG.</p>
GWP	<p>Global Warming Potential. A measure of how much heat a tonne of a non-CO₂ GHG traps in the atmosphere over a given period (usually a century) relative to the amount of heat trapped per tonne of CO₂.</p>
HFCs	<p>Hydrofluorocarbons. An F-gas, with especially high GWPs, used for example, in refrigeration and air conditioning.</p>
INDC	<p>Intended Nationally Determined Contribution. Commitments to climate mitigation (via a reduction in GHG emissions) and adaptation submitted by 190 countries for the Paris Agreement.</p>

such as runaway warming (e.g., from sub-surface methane releases), collapsing ice sheets, and flipping ocean circulatory systems.³ 17 of the 18 warmest years on record have occurred since 2000.⁴

3. BAU fossil fuel CO₂ emissions—growing much faster than most other emission sources—are projected to roughly double by 2100. Atmospheric CO₂ concentrations under the BAU are projected to reach about three times their pre-industrial levels by the end of the century.⁵ Annual GHG emissions are currently about 50 billion (metric) tonnes of CO₂ equivalent, with 63 percent from fossil fuel CO₂ emissions (Figure 1b). National governments may lack incentives to mitigate GHGs however—the free rider problem—as the potential global climate benefits mostly accrue to other countries and (due to the long atmospheric residence times of GHGs⁶ and gradual adjustment of the climate system) to future generations.

4. Climate change is potentially macro-critical at the global, and in many cases national, level, and mitigation policies have large fiscal implications. Central case scenarios suggest warming of 4°C would permanently lower global GDP by around 3.5 percent below GDP levels with no climate change.⁷ The overriding concern however is tail risks that are difficult to incorporate in these estimates and that could imply considerably larger global damages.⁸ Indeed the World Economic Forum⁹ now ranks climate change as the greatest threat to the planet. Some countries are more at risk than others: simulations suggest BAU temperature rises (let alone other climatic effects) would lower GDP for a typical low-income country by 9 percent in 2100.¹⁰ Many small island states are no higher than a few meters above sea level and face an existential threat from projected sea level rises of 0.3–2.5 meters by 2100.¹¹ As climate change builds up over time, not only low-income countries but also advanced economies may experience substantially worse macroeconomic effects.¹² On the mitigation side, carbon pricing could have potentially large impacts on fiscal balances for most countries (see below).

5. The 2015 Paris Agreement established a process that could lead to meaningful mitigation action,¹³ consistent with other Sustainable Sustainable Development Goals (SDGs).

³ NAS (2018). For BAU temperature projections see, for example, Kriegler and others (2015), Figure 1, Nordhaus (2018).

⁴ NASA (2018).

⁵ Projections are from Nordhaus (2018).

⁶ CO₂ emissions have an expected atmospheric residence time of about 100 years.

⁷ See Nordhaus (2018), pp. 345, though impact assessments remain contentious (e.g., Pindyck 2017).

⁸ Weitzman (2011).

⁹ WEF (2019).

¹⁰ IMF (2017).

¹¹ NOAA (2018).

¹² Burke and others (2015), IMF (2017), Ch. 3.

¹³ See UNFCCC (2016), UNFCCC (2018a), and Stern (2018).

considerable cross-country dispersion in emissions prices implicit in NDCs (see below). Current NDCs are consistent with a global emissions trajectory stabilizing projected warming at about 3°C.¹⁶ China, India, and the United States account for 33, 9, and 12 percent respectively of projected BAU (fossil fuel) CO₂ emissions in 2030 (Table 1). Mitigation pledges in China and India will, however, require smaller proportionate emissions reductions than for many other large economies (see below)—partly reflecting their smaller contribution to historical atmospheric CO₂ accumulations—and the United States has announced its withdrawal from the Paris Agreement in 2020.

7. Quantitative, country-level analysis of policy options can help move carbon pricing and other mitigation policies forward.

Besides a global climate concern going beyond ~~its~~their own interests, countries may have incentives to act unilaterally if this: generates substantial domestic environmental co-benefits (e.g., fewer air pollution deaths); mobilizes domestic revenues; puts peer pressure on others; and leverages external finance. Mitigation policies are proliferating. For example, many countries now have energy efficiency and renewables policies¹⁷ and over 50 national or sub-national governments have implemented pricing through carbon taxes or emissions trading systems (ETs)¹⁸ (Table 2), though the global average CO₂ price is currently only US\$2 per tonne.¹⁹ To design, and scale up, national mitigation strategies, it is helpful for governments to have transparent, quantitative frameworks for projecting the emissions requirements for their NDC commitments, and for assessing the environmental, fiscal, and economic impacts of carbon pricing and alternative policy options. Consistent, cross-country procedures for evaluating mitigation pledges and their implicit

Table 2. Selected Carbon Pricing Schemes Around the World, 2018

Country/Region	Year Introduced	Price 2018, US\$/Tonne CO ₂	Coverage, %GHGs
Carbon taxes			
Chile	2017	5	39
Colombia	2017	6	40
Denmark	1992	29	40
Finland	1990	77	38
France	2014	55	37
Iceland	2010	36	50
Ireland	2010	25	48
Japan	2012	3	68
Mexico	2014	1-3	47
Norway	1991	56	63
Portugal	2015	8	29
S. Africa	2019	10	10
Sweden	1991	139	40
Switzerland	2008	101	35
ETs			
California	2012	15	85
China	expected 2020	na	na
EU	2005	16	45
Kazakhstan	2013	2	50
Korea	2015	21	68
N. Zealand	2008	15	52
RGGI	2009	4	21
Carbon price floors			
Canada	2016	8	70
UK	2013	25	24

Source: WBG (2018), and authors calculations.

Note: Coverage rates for fossil fuel CO₂ emissions are significantly higher than for total GHGs.

¹⁶ UNEP (2018).

¹⁷ IEA (2018a).

¹⁸ Under these systems, covered sources are required to hold allowances for each tonne of emissions; the government caps the quantity of allowances and market trading establishes the emissions price.

¹⁹ Calculated from WBG (2018).

prices can also inform international dialogue over revisions to NDCs.

8. Pricing and finance at the international level can also help. An international carbon price floor arrangement—requiring participants to impose a minimum price on carbon—could reinforce domestic mitigation efforts, accommodate diversity in prices and pricing instruments, and provide some reassurance against competitiveness impacts; and the technicalities seem manageable (see below). There also appear feasible pathways for meeting the advanced economies’ pledge to mobilize US\$100 billion a year (from both public and private sources in unspecified proportion) from 2020 onwards for climate projects in developing countries. However, the measurement of finance flows will likely remain contentious,²⁰ and total investment needs are at least an order of magnitude larger than pledged finance.²¹

9. Political economy aspects can, however, be challenging. To enhance the acceptability of fuel price reform, Fund advice has emphasized the importance of a broad strategy that includes specifics on how revenues are to be used, assistance to vulnerable households and firms, gradual price reform, stakeholder consultation, and public communication.²² But pricing may also need to be part of a broader fiscal and regulatory reform agenda that is perceived as fair overall and it can be difficult to anticipate public opposition. For example, resistance to carbon pricing can be compounded if it is introduced simultaneously with broader tax reductions perceived as benefitting the wealthy. If political obstacles are insurmountable or might require using up all the fiscal dividend in universal compensation schemes, fiscal instruments which are less efficient but avoid increases in energy prices (e.g., that tax/subsidize activities or products with above/below average emissions intensity), or regulations (e.g., emission standards for vehicles, appliances, and power generation), may provide a reasonable ‘second-best’ approach.

10. 140 NDCs include physical adaptation investment plans²³ though a more overarching resilience-building strategy is needed. These strategies should promote risk diversification across *ex ante* buffers (e.g., contingency funds, reduced debt) and *ex post* instruments (e.g., catastrophe bonds, regional insurance). They should ensure sustainable macro-fiscal frameworks accounting for climate/disaster risks, domestic financing of climate investments and fiscal buffers, as well as positive GDP effects from greater physical/fiscal resilience. Climate investments should also be integrated into national processes to ensure they are prioritized and the funds are efficiently spent. A complementary paper²⁴ addresses these issues in depth—here the focus is on the fiscal policies,

²⁰ UNFCCC (2018c), Figure 1, put flows for 2016 at US\$74.5 billion, with 45, 26, 21, and 8 percent from bilateral sources, multilateral development banks, privately-leveraged sources and miscellaneous sources (e.g., climate funds) respectively, though Government of India (2015⁵⁶) suggests that only a small amount of recorded finance could be rigorously defended.

²¹ For example, a review of NDCs and other policies in 21 developing economies (representing half of global GHGs) found an initial investment need of US\$23 trillion from 2016 to 2030 for mitigation alone (IFC, 2016).

²² Clements and others (2013).

²³ GIZ (2016).

²⁴ IMF (2019^a).

institutions and systems required to enable climate-vulnerable states to boost their resilience to the impacts of climate change.

MITIGATION

This section reviews instrument choice and design principles for domestic mitigation; presents country-specific results on the impacts of carbon pricing and trade-offs with other instruments; and discusses international pricing regimes. The focus is mostly on fossil fuel CO₂ emissions (given their large and growing share of global GHG emissions, the practicality of pricing them, and the availability of cross-country data for quantifying policy impacts). The potential for fiscal instruments to mitigate forestry, non-CO₂ GHGs, and other emissions is also highlighted.

A. General Principles for National-Level Mitigation²⁵

11. Mitigation strategies will reflect countries' differing initial positions, political constraints, and circumstances, but carbon pricing has considerable attractions.

Comprehensive carbon pricing can provide: (i) across-the-board incentives for energy conservation and shifting to cleaner fuels; (ii) substantial government revenue (which could be especially valuable where informality constrains revenue mobilization from standard fiscal instruments); and (iii) substantial domestic environmental gains (e.g., fewer local air pollution deaths). Carbon pricing has become the focal point for international dialogue on mitigation.²⁶ At the same time, the political difficulty of carbon pricing, due to its first-order impact on energy prices, underscores the need for accompanying measures to address sensitivities and understanding of the trade-offs with other (possibly more acceptable) instruments.

12. Ideally, carbon pricing should be comprehensive, well designed (with prices rising predictably over time and effectively targeted for mitigation), with the revenues used wisely.

In fact, efficient revenue use can be critical for maintaining the economic case for pricing over other (e.g., regulatory) approaches and raises questions (from an efficiency perspective) about diverting large amounts of carbon pricing revenues from the general budget for lump-sum dividends, earmarked spending, or free ETS allowance allocations (see Box 1).

²⁵ This section builds on earlier discussion in Farid and others (2016), Section III.

²⁶ See, for example, ~~activities of the~~ Carbon Pricing Leadership Coalition (www.carbonpricingleadership.org2019).

exported fuels.²⁷ Carbon taxes with clearly specified rate schedules can establish predictable prices, with revenues accruing to finance ministries. As of 2018, 16 national governments had introduced carbon taxes (Table 2), though typically with only partial coverage (e.g., Colombia and Mexico exclude some, or all, natural gas). Moreover, current CO₂ prices, mostly about US\$5–35 per tonne, are often below levels needed for mitigation pledges (see below). Globally, an estimated 44 percent of carbon tax revenues have been used for lowering other taxes, 28 percent for general funds, and 15 percent for environmental spending.²⁸

14. ETSs could also meet the criteria but have fallen short in practice as well. Several ETSs are now in place (Table 2), most notably the EU ETS in which 31 countries participate. Additionally, a national-level ETS is slated for introduction in China in 2020. Such schemes may be chosen over carbon taxes on practical or legal grounds.²⁹ ETSs have been applied downstream to power generators and large industry, which, however, typically misses around 50 percent of emissions (from vehicles, buildings, and small enterprises). Moreover, the administrative costs of monitoring emissions and allowance markets may be prohibitive for a small jurisdiction or a capacity-constrained developing country (while much of the legal and administrative infrastructure for taxes would typically exist).³⁰ Prices in ETSs are uncertain and sometimes depressed by overlapping instruments³¹—recent prices have been around US\$5–25 per tonne of CO₂ (Table 2). Furthermore, prospects for large budget revenues can be diminished by: (i) the much narrower base for emissions pricing; (ii) the possibility of free allowance allocations; and (iii) earmarking of revenues from allowance auctions—in striking contrast with taxes, globally an estimated 70 percent of ETS revenues have been used for environmental spending, 21 percent for general funds, and 9 percent for lowering other taxes.³² These shortcomings could be overcome, however: ETSs could be extended midstream to cover fuels for small-scale users (though this would duplicate fuel tax administration); minimum auction prices or other mechanisms can (and often do) promote price stability;³³ and allowances could be fully auctioned with revenues remitted to finance ministries.

²⁷ Rebates are ultimately needed for downstream fuel users (e.g., fossil fuel plants) to promote adoption of [carbon capture and storage \(CCS\)](#) technologies (which might become viable with carbon prices around US\$70 per tonne—see Rubin and others 2015). Calder (2015) and Metcalf and Weisbach (2009) provide comprehensive discussions of administrative issues for carbon taxes (in a US context).

²⁸ Carl and Fedor (2016), Table 2.

²⁹ For example, ETSs can meet annual emissions targets with more certainty; they may be a more natural extension of pre-existing air pollution regulations applied at the point of combustion; and they may be a more suitable instrument if mitigation policy is under the purview of environment ministries. Unanimity requirements may have precluded a carbon tax in the EU.

³⁰ Markets may also be too thin to support trading (South African National Treasury 2013).

³¹ For example, energy efficiency and renewable policies lower emissions prices without affecting emissions when emissions are capped by an ETS.

³² Carl and Fedor (2016), Table 1.

³³ Flachsland and others (2018).

15. Carbon price trajectories can be aligned with mitigation objectives in NDCs. This requires projecting fuel use and emissions by sector with and without carbon pricing (see below) ~~and as well as~~ periodically updating prices if emissions targets are systematically unmet. Other approaches in the literature (not tied to country commitments) look at globally efficient prices. One strand focuses on cost-effective carbon price trajectories consistent with temperature stabilization goals, while another focuses on ‘Pigouvian’ taxes to reflect environmental damages. The former approach implies that emissions prices of around US\$50–100 per tonne by 2030 would (along with other policies) be consistent with the 2°C goal, while a recent assessment of the latter suggests prices of US\$55 per tonne by 2030 (all prices in US\$2015).³⁴

16. Carbon taxes are not new and existing taxes often amount to substantial carbon prices. Averaged globally, road fuel taxes are currently around US\$1 per liter, or US\$380 per tonne of CO₂ emissions from these fuels, while average royalty rates for oil and gas extraction are around 12 and 6 percent respectively, implying taxes equivalent to US\$33 and US\$10 per tonne of CO₂ respectively.³⁵ Carbon charges need to be imposed on top of these taxes because existing taxes are embedded in BAU fuel use projections and may be addressing non-carbon externalities and fiscal needs.

17. For acceptability or other reasons, alternative, second-best mitigation instruments may be used, but the same basic design principles should apply. Pricing might be combined with other (less efficient but perhaps more acceptable) instruments that do not raise energy prices. Ideally, other instruments would mimic, insofar as possible, the behavioral responses of carbon pricing, with certainty over emissions prices and combined prices from the policy package aligned with mitigation objectives. Although other approaches have tended to focus on regulations (e.g., vehicle emission rate standards), their fiscal analogue—revenue-neutral feebates—are a promising alternative. These policies involve a sliding scale of fees on firms or products with above average energy/emissions intensity and corresponding rebates for firms or products with below average energy/emissions intensity.³⁶ A limitation of feebates, however, is that they do not promote the full range of mitigation opportunities: for example, they do not encourage people to drive less (unlike fuel taxes which raise the marginal costs of driving).

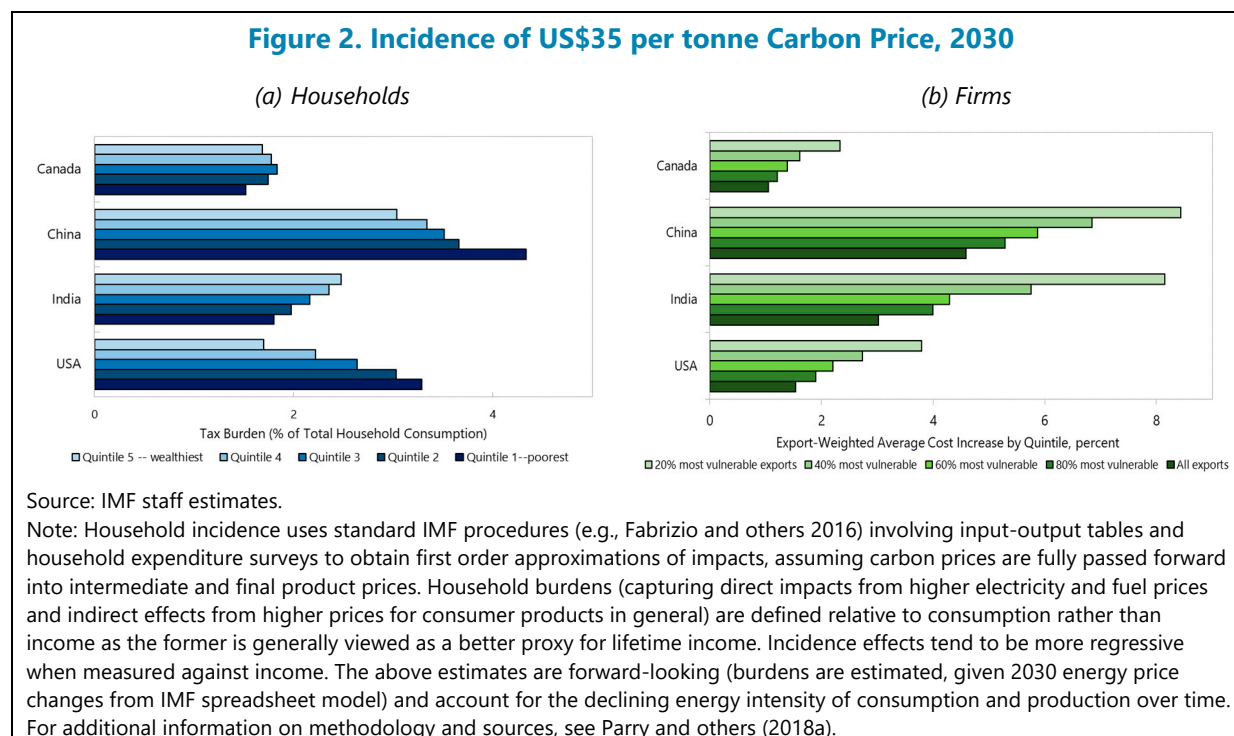
³⁴ See Stern and Stiglitz (2017) and Nordhaus (2017) respectively. Pigouvian tax estimates are however highly sensitive to differing perspectives on intergenerational discounting and treatment of extreme risks (e.g., Stern 2007, Weitzman 2011), and the severity of damage risks varies across countries, raising questions about the practicality of operationalizing them in international agreements.

³⁵ The first estimate is calculated from a spreadsheet tool on energy prices and subsidies described in Coady and others (2019). The second estimate is calculated from a sample of 59 countries (accounting for a quarter of global petroleum production) using 2017 Rystad Energy (2019) data on petroleum volume and value and staff data on fiscal regimes, assuming royalties are minimum taxes from application of ad-valorem royalties, binding cost recovery limits, and government profit petroleum shares.

³⁶ Feebates have been integrated in vehicle tax systems (as in, for example, Denmark, France, Germany, Mauritius, the Netherlands, Norway, Sweden and the United Kingdom—see Bunch and others 2011, Cambridge Econometrics 2013) to promote low-emission vehicles. But they could also be applied to promote more energy-efficient appliances, lightbulbs, air conditioners, machinery, and so on or to lower emissions intensities for power generators.

burdens—around 2-4 percent of their consumption in 2030 for a US\$35 per ton carbon price—is minor, as most of the burden of higher energy prices is borne by higher income groups.

Figure 2. Incidence of US\$35 per tonne Carbon Price, 2030



21. The same applies for burdens on vulnerable firms. Averaged across all exporters (Figure 2b), a US\$35 carbon price in 2030 increases costs moderately in Canada (1.0 percent), the United States (1.5 percent) and India (3.0) and somewhat more significantly in China (4.6 percent) (where, for example, power generation has the highest CO₂ intensity). Of more concern are the most vulnerable exporters (e.g., basic metals), and here the cost increases (for the 20 percent of most vulnerable exporters) are more significant: Canada (2.3 percent), United States (3.8 percent), India (8.2 percent) and China (8.4 percent).⁴²

22. Targeted measures can compensate vulnerable households and workers, though they can bring their own efficiency concerns. Targeting limits revenue diversion from the general budget thereby helping to contain overall policy costs to the economy (Box 1), but there are trade-offs among instruments. For example, payroll tax rebates and earned income tax credits disproportionately benefit low-income households while also promoting labor force participation, but they do not reach the non-working poor. Transfer payments or categorical benefits (e.g., child benefits, and social pensions) can reach the latter, but do not promote extra work effort, may increase administrative burdens, and may (through means-testing) distort work incentives.

⁴² Some minor fraction of the burden of carbon pricing may be passed backward in lower producer prices, though the incidence implications become difficult to estimate (Fullerton and Heutel 2011).

Assistance programs are also needed for displaced workers and would typically require a negligible fraction of carbon pricing revenues.⁴³

23. The same applies for compensating vulnerable firms. Efficient resource allocation generally implies that industries unable to compete when energy is efficiently priced should shrink or adapt, though policy adjustment should be gradual with programs to ease transitions, and competitiveness concerns are less pronounced with global action on mitigation. Transitory relief might be provided to vulnerable firms through output-based rebates (or, equivalently, exemptions/credits for infra-marginal emissions or fuel use).⁴⁴

24. Border carbon adjustments (BCAs)⁴⁵ can in principle have beneficial efficiency effects through reducing emissions leakage,⁴⁶ but may have limited effectiveness and raise practical issues. BCAs levy charges on imports and may remit charges on exports to ensure a level playing field given carbon prices levied elsewhere. However, BCAs may have limited impacts on reducing emissions leakage, much of which occurs through changes in global fossil fuel prices rather than firm migration.⁴⁷ Moreover, measuring embodied carbon in traded goods can be contentious, BCAs risk retaliation, there is a possibility of their being used for protectionist purposes, and they could be subject to challenge under World Trade Organization (WTO) rules. Furthermore, non-price mitigation policies in other countries may need to be converted into carbon price equivalents to avoid the possibility of BCAs penalizing countries meeting their Paris pledges through non-pricing measures. Furthermore, it is not obvious that BCAs should impose the same penalty on countries whose mitigation pledges imply very different implicit carbon prices (see below).

25. General guidance on carbon pricing needs to account for potentially challenging political economy issues. Necessary ingredients for the successful reform of carbon and energy pricing might include a comprehensive, gradually-phased, and well-communicated strategy, with clearly specified use of revenues and measures to assist vulnerable groups. But in practice these principles may not be sufficient. For instance, sometimes opposition to higher fuel prices comes from the middle classes and compensating them through adjustments to existing tax and public investment programs may not be transparent, in which case approaches that avoid raising energy prices may be preferred (see Box 1 again). Sometimes it takes dynamic leadership to push reform through, while other times well-designed energy price reforms might be de-railed by a general backlash against broader economic policy or an ideological change in government. Getting reform

⁴³ See, for example, Morris (2016).

⁴⁴ See Fischer and others (2015).

⁴⁵ For example, as proposed by the Climate Leadership Council [\(2019\)](#).

⁴⁶ Keen and Kotsogiannis (2014).

⁴⁷ Estimates of emissions leakage rates (i.e., the fraction of the reduction in domestic emissions offset by increased emissions in other countries) are typically in the range of about 5-20 percent. See Böhringer and others (2012), Burniaux and others (2013).

Box 3. Fiscal Instruments for Promoting Forest Carbon Storage (Concluded)

In contrast, project-based approaches focus on a narrower range of behavioral responses and landowners, contain no automatic pricing mechanism for prioritizing cost-effective projects, and scaling up may be constrained by high administrative costs from contracting on a landowner-by-landowner basis and the need for finance.

A key limitation of feebates is that they require clearly established property rights, so taxes and subsidies can be applied to the relevant individuals or entities, and private landowners currently account for only around 15 percent of tropical forest ownership.⁶ However, marginal land (at the frontier between forest and farmland) and tree farms, both of which are more likely to be privately owned, provide the most important opportunities for enhanced storage.

¹ The discussion here is largely based on Mendelsohn and others (2012) and Parry (2019).

² IPCC (2014).

³ This is larger than forestry's current and future emissions share because forestry emissions are relatively more responsive to pricing than energy emissions (e.g., Favero and others 2017, Mendelsohn and others 2012, IPCC 2014).

⁴ Reducing emissions from deforestation and forest degradation, where the '+' also rewards forest conservation and management practices that sequester carbon. See www.un-redd.org.

⁵ See for example www.forestcarbonpartnership.org/readiness-fund-0.

⁶ Whiteman and others (2015), Figure 1.

Table 3. Potential Contribution of Emissions Sources to Mitigation and the Practicality of Exploiting them with Fiscal Instruments

	Emissions Source	Share of Globally Efficient Mitigation, 2030	Administrative Ease of Emissions Taxes/Feebates	
GHG mitigation potential	Fossil fuel (CO ₂)	65.8%	Generally straightforward extension of capacity for fuel tax collection	Decreasing practicality of fiscal instruments
	Cement (CO ₂)	4.5%	Requires new capacity but administrative costs low	
	F-gases	5.3%		
	Acid feedstocks (N ₂ O)	0.4%	Requires significant new capacity; may not be feasible for capacity-constrained countries	
	Forestry (CO ₂)	13.3%		
	Fuel extraction (CH ₄)	6.0%		
	Landfills (CH ₄)	2.1%	Regulatory approaches (e.g., specifying methane capture at landfills or treatment systems for water) may be most practical given public management	
	Wastewater (CH ₄)	0.8%		
	Livestock (CH ₄ , N ₂ O)	1.0%		
	Rice (CH ₄ , N ₂ O)	0.7%	Generally best incorporated through offsets	
	Other agriculture (CH ₄ , N ₂ O)	0.2%		

Sources: IMF staff calculations combining results for: (i) a US\$70 per tonne carbon price imposed in 2030 for fossil fuels (see below, assuming BAU global emissions increase in the same proportion as for G-20 countries and have the same price responsiveness); (ii) forestry (from IPCC 2014, Figure 11.13); (iii) cement (from van Ruijven and others 2016, Figure 9); and (iv) non-CO₂ GHGs (EPA 2014). Where needed, results are roughly scaled to be consistent with a US\$70 emissions price. See Appendix II for details.

Note: Agriculture accounts for nearly half of BAU non-CO₂ GHG emissions, but practical mitigation opportunities for this sector are limited (e.g., for small-scale operations).

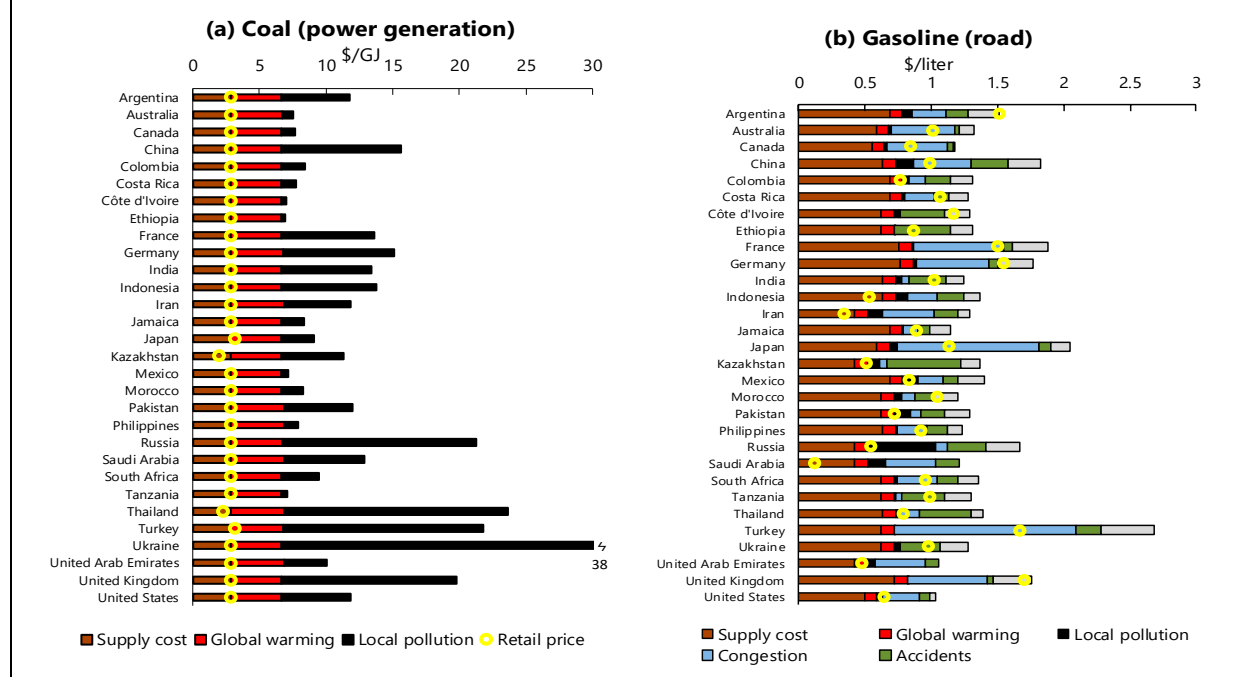
27. Carbon pricing could be embedded in part of a broader reform of energy prices to comprehensively reflect the full range of environmental impacts, including local air pollution.

Even with carbon charges, significant additional taxes on coal use may be warranted in countries with high local air pollution, mortality rates from coal combustion, and where road fuels are pervasively underpriced (despite their often being subject to high excises—see Box 4).

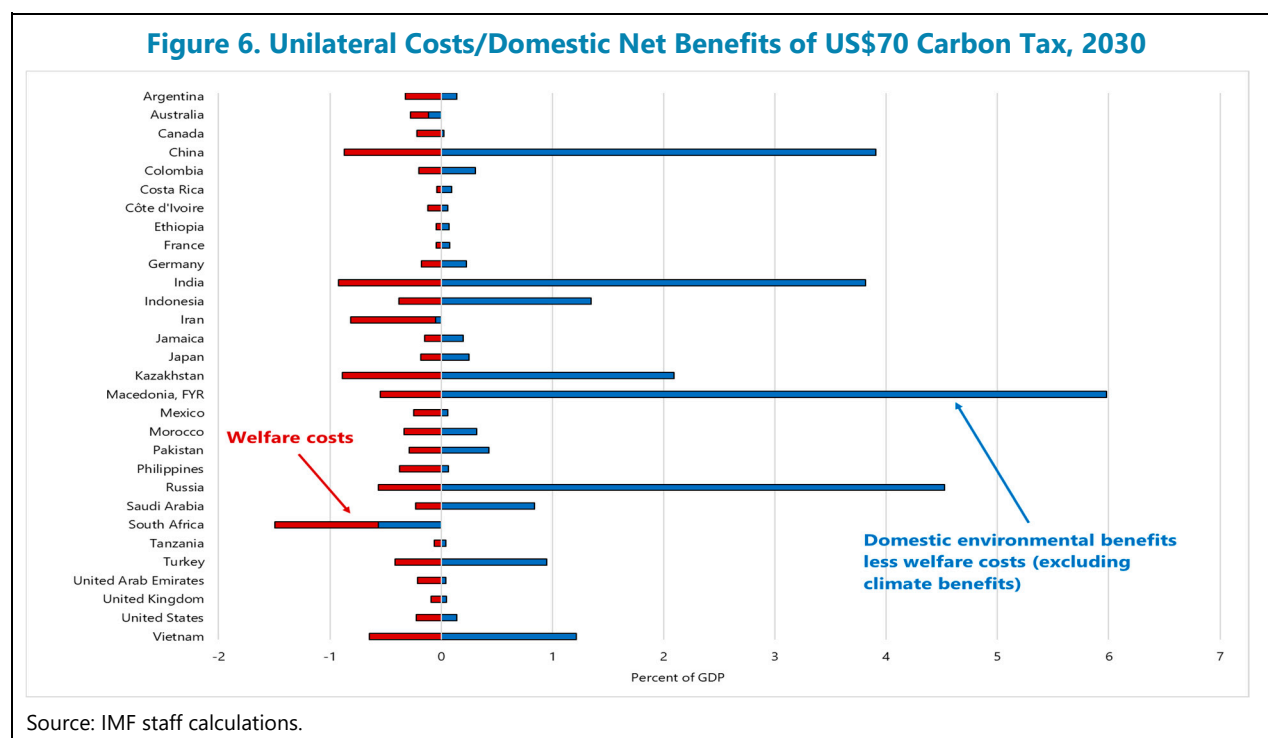
28. Carbon pricing in large developing countries could catalyze, and efficiently allocate, private sector finance but is less urgent in low-income, low-emitting countries. Unlike under carbon pricing, top-down finance provides no automatic mechanism for ensuring that the most cost-effective projects are selected first. Also, high transaction costs may prevent funding for small-scale opportunities (e.g., adoption of energy efficient vehicles, appliances, or lighting). Although low-income, low-emitting countries contributed mitigation pledges for the Paris Agreement (Appendix I), their individual (and collective) contribution to global emissions is minimal and their capacity for enforcing carbon pricing may be weak (e.g., in some cases because it might promote informal use of charcoal and firewood). Developing capacity and financing adaptation strategies is generally the more important priority for these countries.

Box 4. Reflecting the Full Range of Environmental Costs in Energy Prices

To be economically efficient, fuel prices should in principle reflect supply costs, environmental costs—not just global warming, but also local air pollution and, in the case of road fuels, traffic congestion, accidents, and road damage. For fuels consumed by households, general consumption taxes should also be reflected in fuel prices. Although environmental costs are uncertain and contentious, undercharging for an unbiased estimate of them involves inefficiencies, just as with undercharging for supply costs. And although other instruments are needed (e.g., incentives for flue gas desulfurization technologies in coal plants, peak period congestion pricing on busy roads) these lower, but do not eliminate, the fuel tax required to efficiently reflect environmental costs.¹



in air pollution mortality but also reductions in motor vehicle traffic congestion and accident externalities. Figure 6 presents estimates of these co-benefits, net of the costs, though there are considerable uncertainties surrounding them (e.g., over how much pollution is inhaled by exposed populations, the health impacts of such exposure, and people's valuations of health risks) and co-benefits vary dramatically across countries (e.g., with population density and local air emission rates).⁵⁷



38. On net in Figure 6, only Australia, Iran, and South Africa are worse off under carbon pricing (excluding global warming benefits), 18 countries are no worse off or moderately better off (with net benefits of 0-0.5 percent of GDP), and several countries are considerably better off. For example, net benefits exceed 2 percent of GDP in China, India, Kazakhstan, FYR Macedonia, and Russia. One implication is that, up to a point, it is in many countries' own interests to move ahead unilaterally with carbon pricing.⁵⁸ Another is that countries with more severe air pollution problems may want to price emissions somewhat more aggressively than others. The same may apply for those with greater needs for revenue mobilization.

⁵⁷ For a discussion of the methodologies for quantifying co-benefits see Parry and others (2015b).

⁵⁸ The prospects for net benefits diminish at higher levels of mitigation as domestic environmental benefits are approximately proportional to fuel reductions, while economic costs increase by more than in proportion to fuel reductions.

40. Other instruments also raise far less revenue. For example, coal taxes raise less than one-third of the revenue raised by (equivalently-scaled) carbon taxes in all but 4 of the 30 countries in Table 6. And even if allowances are fully auctioned, the revenue potential of ETSs is generally around only 30-50 percent that of the carbon tax.

Table 6. Revenue from Other Policies, 2030
(as a fraction of revenue from US\$70 carbon tax)

Country	Coal Tax	ETS	Electricity Output Tax	Electricity CO ₂ Tax	Road Fuel Taxes	Energy Efficiency Combination
Argentina	0.01	0.27	0.24	0.22	0.16	0.00
Australia	0.24	0.43	0.39	0.39	0.20	0.00
Canada	0.08	0.15	0.14	0.12	0.25	0.00
China	0.70	0.54	0.35	0.35	0.08	0.00
Colombia	0.11	0.24	0.16	0.14	0.37	0.00
Costa Rica	0.04	0.10	0.01	0.01	0.68	0.00
Côte d'Ivoire	0.00	0.32	0.34	0.26	0.33	0.00
Ethiopia	0.07	0.21	0.00	0.00	0.40	0.00
France	0.12	0.08	0.06	0.05	0.26	0.00
Germany	0.28	0.24	0.20	0.20	0.17	0.00
India	0.56	0.56	0.42	0.42	0.13	0.00
Indonesia	0.21	0.37	0.28	0.28	0.31	0.00
Iran	0.01	0.22	0.21	0.21	0.10	0.00
Jamaica	0.02	0.50	0.31	0.31	0.19	0.00
Japan	0.27	0.49	0.43	0.41	0.12	0.00
Kazakhstan	0.32	0.38	0.26	0.26	0.08	0.00
Macedonia, FYR	0.37	0.49	0.40	0.39	0.28	0.00
Mexico	0.07	0.34	0.30	0.30	0.30	0.00
Morocco	0.18	0.38	0.35	0.30	0.30	0.00
Pakistan	0.09	0.34	0.24	0.24	0.25	0.00
Philippines	0.33	0.50	0.53	0.40	0.25	0.00
Russia	0.16	0.31	0.28	0.28	0.05	0.00
Saudi Arabia	0.00	0.47	0.43	0.38	0.14	0.00
South Africa	0.71	0.41	0.31	0.31	0.17	0.00
Tanzania	0.05	0.19	0.13	0.13	0.61	0.00
Turkey	0.32	0.35	0.29	0.29	0.14	0.00
United Arab Emirates	0.03	0.42	0.40	0.39	0.08	0.00
United Kingdom	0.11	0.21	0.18	0.18	0.20	0.00
United States	0.17	0.31	0.32	0.29	0.28	0.00
Vietnam	0.48	0.59	0.39	0.39	0.16	0.00

Source: IMF staff calculations.

Note: Other policies are scaled such that they impose the same CO₂ price on emissions affected by each policy.

D. International-Level Mitigation

Two key issues for carbon pricing at the multilateral level are discussed below—coordination over pricing of domestic, and international transport, emissions and fuels.

Carbon Price Floors

41. At an international level, the Paris mitigation process might be reinforced with a carbon price floor arrangement among willing (ideally large-emitting) countries. This arrangement would guarantee a minimum effort level among participants and provide some

reassurance against losses in international competitiveness.⁶⁰ Parties need to agree on one central parameter—the common floor price. Coordination over price *floors* rather than price *levels* provides some flexibility to accommodate dispersion in prices implied by countries' mitigation pledges.

42. Provisions in the Paris Agreement might encourage broad participation in a price floor agreement. By recognizing internationally transferred mitigation outcomes (ITMOs) across national governments, one interpretation of the Paris Agreement⁶¹ is that countries needing prices lower than the floor price to meet their mitigation pledges could benefit from setting the floor price and selling ITMOs at this price to other countries (for whom the floor price would be insufficient to meet their pledge). For example, calculations from the above tool suggest that India would gain external revenues of approximately 0.6 percent of GDP in 2030 from joining a price floor of US\$35 per tonne and selling ITMOs.⁶²

43. Price floor requirements could accommodate both carbon taxes and ETSs and participants may have a self-interest in agreeing on a robust price floor. ETSs could be accommodated through: (i) scaling emissions caps (as in Canada—see below) such that expected emissions prices under the ETS at least equal the floor requirement; (ii) combining it with a variable tax (as in the U.K.) equal to any gap between the required floor and the ETS price; or (iii) using minimum price auctions (as in regional U.S. schemes) with the auction price equal to the international floor. Individual participants may support a robust floor price (e.g., one designed to meet NDC pledges at the global level) as this reduces the emissions of other participants, thereby conferring collective benefits for all.⁶³

44. Focusing the arrangement on increases in 'effective' carbon prices provides flexibility and accounts for changes in energy taxes. Domestic carbon pricing may provide exemptions or favorable rates to selective emissions sources (see above) and its effectiveness might also be offset (or enhanced) by changes in pre-existing energy taxes. Effective carbon prices account for direct carbon pricing and energy taxes.⁶⁴ Focusing the arrangement on these prices allows countries flexibility in meeting the requirement (e.g., through setting higher carbon prices for covered sources to compensate for exemptions). To some extent, pre-existing energy taxes may be motivated by domestic environmental or fiscal considerations, varying with country circumstances, so there is little basis for equating effective carbon prices across countries. Instead, the agreement could focus on a

⁶⁰ The agreement may also help non-participants, and participants for whom the minimum price is not binding, raise carbon prices, as demonstrated in a broader environmental context (e.g., Kanbur and others 1995).

⁶¹ UNFCCC (2016), Article 6.2.

⁶² Further incentives—more powerful than for BCAs—might be provided through general trade sanctions imposed by a club of carbon pricing countries on those without carbon pricing (e.g., Nordhaus 2015), though this raises some of the same WTO- and Paris-related complexities as for BCAs.

⁶³ See Cramton and others (2017) and Weitzman (2015).

⁶⁴ Specifically, the effective tax is the carbon tax that would have the same impact on economy wide emissions as the combined effect from any carbon pricing schemes and pre-existing energy taxes.

put at US\$140-300 billion in 2030 and US\$280-500 billion by 2050, compared with international adaptation finance in 2014 of around US\$23 billion.⁷³ For small island states, adapting to climate change and natural disasters, for example, in Fiji is estimated to require physical investments of around 100 percent of GDP over the next 10 years, which implies almost doubling currently budgeted plans.⁷⁴ Initial Climate Change Policy Assessments (CCPAs) undertaken by the Fund and World Bank, suggest that annual public investment needs to meet adaptation strategy requirements are around 2-3 percent of GDP. Additional pressures will also arise on social spending (e.g., health care, and social safety nets). This will be challenging in countries with constrained fiscal space but finding space for small cost-effective investments can still enhance resilience.

53. Further mobilization of official and private financing for adaptation is, therefore, essential. Additional contributions to climate finance agencies will be crucial and implementation will also help to moderate climate-related migration into donor countries. The measures outlined below to build fiscal management institutions in climate-vulnerable states should help ease their access to project and other finance, including well-governed Public Private Partnerships. Technical assistance from development partners has also proved to be valuable in easing access to these funds.⁷⁵ Revenue measures to promote energy efficiency, such as those described in the previous sections, are also important in climate-vulnerable states and can provide valuable additional fiscal space for adaptation investments.

54. Resilience building needs to go well beyond physical, climate-proofing investments—effective fiscal institutions are critical. A parallel paper⁷⁶ emphasizes that effective Disaster Resilience Strategies (DRS) require: (i) physical resilience; (ii) financial resilience; and (iii) emergency response systems. Critical components of a successful DRS are that: it is embedded within a sustainable macro-fiscal framework (requiring mobilization of sustainable financing); available options to transfer risk away from the budget are fully exploited; climate resilience is built into investment planning; and fiscal institutions are strong enough to effectively implement the DRS. As the other elements are covered in the parallel paper (and go well beyond fiscal aspects), the focus here is on the last element—supplementing the recommendations of the parallel paper by drawing on recent capacity development work.

55. Resilience building in Small Developing States (SDSs) and Low-Income Countries (LICs) is hampered by significant capacity gaps. These countries are particularly vulnerable to climate change and natural disasters and it is critically important that they invest in resilience.⁷⁷ ~~CCPA~~**Climate Change Policy Assessments (CCPAs)** provide insights on specific ways in which capacity constraints

⁷³ UNEP (2016).

⁷⁴ WBG (2017).

⁷⁵ For instance, effective working partnerships between GIZ and the Grenada Ministry of Climate Resilience have helped two successful applications to the Green Climate Fund.

⁷⁶ IMF (2019a).

⁷⁷ IMF (2016), Marto and others (2017, ~~2018~~), Bonato and others (2018a).

Investment Management Assessment (PIMA) tool⁸² allows assessment of the strength and effectiveness of infrastructure governance systems. Experience with implementing the PIMA tool in SDSs has been relatively limited, with full assessments undertaken only for Kiribati, Guyana and Timor-Leste. However, when combined with the light assessments undertaken in the context of CCPAs, some clear conclusions emerge (see Figure 8). Critical areas of weakness are in allocation (especially in project selection and appraisal) and in project management and monitoring. Reforms to be prioritized in addressing these weaknesses would focus on: (i) strengthening fiscal institutions to facilitate medium-term planning for public investment; (ii) building the capacity to undertake rigorous project appraisal and selection; and (iii) establishing appropriate mechanisms to oversee project implementation and facilitate the reporting of government assets.

ROLE OF THE FUND

62. Climate change is potentially macro-critical, and the Fund has a role in providing analysis of (and guidance on) energy pricing and macro-fiscal policies consistent with countries' climate strategies submitted for the Paris Agreement. The Fund:

- *Is unique among UN agencies:* given its focus on macro and fiscal policies, universal membership, and regular interactions with finance ministries;
- *Adds value at the country level* (using tools described above)—in delivering macro projections and their emissions implications; evaluating the fiscal, domestic environmental, and economic impacts of mitigation policies; and assessing broader energy price reform;
- *Could analyze progress on NDCs* (again with the above tools)—through consistent, cross-country comparisons of mitigation pledges; likely progress under existing policy commitments; and tracking of effective carbon prices;
- *Can provide advice on macroeconomic and financial policy consistent with climate considerations*—for example, in developing policy frameworks to mobilize needed climate investments and in assessing risks to the financial system; and,
- *Can draw on others with appropriate expertise as needed*—for example, the World Bank (on tracking pricing schemes), the UN Environment Programme (on gaps between current pledges and temperature goals), and the UN Framework Convention on Climate Change (on climate finance flows).

63. The Fund can also emphasize the opportunities from green and climate-resilient economies. Low-carbon transitions can be consistent with strong growth, given: the productivity gains from emerging energy-efficient and renewable technologies; the local health benefits of diminished fossil fuel combustion; the broader fiscal reform, debt reduction, or investment in SDG

⁸² IMF (2015b). The PIMA identifies 15 desirable criteria for sound decision-making at the planning, allocation, and implementation stage and ranks countries based on whether these criteria are fully, partially, or not met.

Appendix I. Climate Strategies in NDCs¹

Appendix Table 1. AFR Countries: Paris Mitigation Contributions and CO₂ Emissions Data

Country	Paris Mitigation Contribution ^a	2030 BAU		
		Share of Global CO ₂	Tonnes CO ₂ /\$ 1000 Real GDP	Tonnes CO ₂ per Capita
Angola	Reduce GHGs 35% (50%) below BAU in 2030	0.04	0.13	0.4
Benin	Reduce GHGs 3.5% (17.9%) below BAU in 2030	0.02	0.43	0.5
Botswana	Reduce GHGs 15% below 2010 by 2030	0.02	0.32	3.1
Cameroon	Reduce GHGs (32%) below 2010 by 2035	0.02	0.12	0.2
Congo, Democratic Republic of the	Reduce GHGs (17%) below BAU in 2030	0.01	0.04	0.0
Congo, Republic of	Reduce GHGs (48%) below BAU in 2025; (55%) in 2035	0.01	0.26	0.4
Côte d'Ivoire	Reduce GHGs 28% below BAU in 2030	0.05	0.23	0.6
Eritrea	Reduce GHGs 39.2% (80.6%) below 2010 by 2030	0.00	0.06	0.1
Ethiopia	Reduce GHGs (64%) below BAU in 2030	0.04	0.10	0.1
Gabon	Reduce GHGs (50%) below BAU in 2025	0.01	0.16	1.5
Ghana	Reduce GHGs 15% (45%) below BAU in 2030	0.04	0.17	0.4
Kenya	Reduce GHGs (30%) below BAU in 2030	0.05	0.13	0.3
Mauritius	Reduce GHGs (30%) below BAU in 2030	0.01	0.22	3.3
Mozambique	Reduce GHGs 76.5 million tonnes by 2030	0.03	0.31	0.3
Namibia	Reduce GHGs (89%) below BAU in 2030	0.01	0.23	1.6
Niger	Reduce GHGs 3.5% (34.6%) below BAU in 2030	0.01	0.23	0.1
Nigeria	Reduce GHGs 20% (45%) below BAU in 2030	0.22	0.13	0.3
Senegal	Reduce GHGs 13% (31%) below BAU in 2030	0.03	0.22	0.4
South Africa	Reduce GHGs 398-614 million tonnes in 2025 and 2030	0.99	0.97	5.6
South Sudan	No target	0.00	0.30	0.0
Tanzania	Reduce GHGs 10-20% below BAU by 2030	0.04	0.15	0.2
Togo	Reduce GHGs 11.14% (20%) below BAU in 2030	0.01	0.30	0.3
Zambia	Reduce GHGs 25% (47%) below BAU in 2030	0.01	0.11	0.2
Zimbabwe	Reduce per capita GHGs (33%) below BAU in 2030	0.03	0.39	0.6
AFR Simple Average		0.07	0.24	0.9
AFR 2030 Emissions Weighted Average		0.62	0.64	3.5
AFR 2030 Energy Use Weighted Average		0.25	0.28	1.2
AFR 2030 GDP Weighted Average		0.26	0.30	1.4

Source: UNFCCC (2018b), IMF staff calculations.

Notes: ^a Some countries have specified both conditional and unconditional pledges, where the former are contingent on external finance and other support—in these cases the conditional pledges are in parentheses. CO₂ refers to fossil fuel emissions only.

¹ For purposes of the Mitigation Analysis (see Appendix [DIV](#)): i) CO₂ reduction targets for fossil fuels are taken to be proportional to those for total GHGs; ii) where both conditional and unconditional targets are specified, the average of the two is used to compute a single, representative percent reduction in emissions; iii) for countries with sizeable forestry sectors (e.g. Brazil, Indonesia), it is assumed that forestry emissions are twice as responsive to carbon pricing as energy sector emissions (e.g. if forestry and energy emissions each account for 50% of total emissions, two-thirds of the emissions reductions are assumed to come from the forestry sector and the remaining one third from the energy sector). Thus, in the case of Brazil, the percent reduction in fossil fuel CO₂ emissions is assumed to be one-third of the percent reduction stated in the corresponding NDC; iv) for countries with emissions intensity targets (e.g., China, India), the CO₂ emissions in 2030 when those targets are met are compared with the model's BAU projection to infer the percent CO₂ reduction.

include, for example, thermal destruction and catalytic decomposition applied to the tail gas streams—emissions could be reduced by an estimated 79 percent in 2030 with a US\$50 carbon equivalent price.⁸ Taxes on acid manufactures could be applied based on default emission rates with rebates provided to entities demonstrating emissions mitigation.

Fuel Extraction

Oil and Gas. Upstream GHG emissions from oil and gas extractive operations fall into two main categories. First, is flaring or venting of natural gas, primarily from oil reservoirs (all of which contain a certain amount of gas either dissolved or capped over the deposit). The gas must be separated before oil enters the pipeline and flaring/venting avoids treatment costs, though venting is less common for safety reasons. Flaring reduces GHGs as it reduces the share of emissions released as methane rather than CO₂. Second is fugitive emissions which are unintentional methane leaks primarily from natural gas wells, processors, pipes, and storage sites.

Estimates from satellite images suggest flaring from oil and gas wells contributes about 0.5 percent to global GHGs, with the largest sources including Russia (25 percent), Nigeria (11 percent), Iran (8 percent), and Iraq (7 percent).⁹ Fugitive and venting emissions are difficult to detect as measurement facilities are not widespread—but studies (based on assumed emissions factors) project (Appendix Figure 1) they will account for around 16 percent of global non-CO₂ GHGs in 2030, with the huge bulk (about 90 percent) from fugitive sources.¹⁰

Possibilities for mitigating emissions include reinjecting gas (after compressing it) for enhanced oil recovery or storage (though the feasibility of this varies with the sedimentary rock); using methane for on-site or regional power generation; and compressing the gas, or liquifying it, for sale—globally these measures could reduce BAU emissions from field operations in 2030 under a US\$100 CO₂ price by an estimated 60 percent.¹¹

If fugitive and venting emissions could be monitored on a continuous basis, an emissions tax would be the ideal instrument—monitoring technologies are advancing though currently provide only discrete measurements at a limited number of sites.¹² One possibility for the interim might be to tax fuel suppliers based on a default leakage rate but allow rebates to firms that are able to demonstrate lower leakage/venting rates through mitigation and installing their own continuous emission monitoring systems. CO₂ emissions from flaring are feasible to tax (as, for example, in Norway) because they are measurable, though safeguards may be needed to avoid creating perverse incentives for more venting.

⁸ EPA (2014).

⁹ CL (2013).

¹⁰ See also ERA (2015).

¹¹ EPA (2014).

¹² Metering technologies include satellites, aircraft, drones and remote sensing from vehicles.

Coal. Underground coal mining operations raise similar issues, though here the main emissions source is venting, accounting for a projected 6 percent of global BAU non-CO₂ GHGs in 2030. Potential abatement measures include recovery for pipeline injection, power generation, process heating, flaring, and catalytic or thermal oxidation of ventilation air methane—and globally these measures could reduce BAU emissions in 2030 under a US\$100 CO₂ price by an estimated 60 percent.¹³ Again, tax rates could be based on default emission rates with appropriate rebates for entities demonstrating methane recovery.

Landfills and Wastewater

Landfills produce methane through the bacterial decomposition of organic waste and this accounts for 7 percent of projected BAU non-CO₂ GHGs in 2030 (Figure A1). Abatement measures include capturing the methane for flaring, for use in energy, and diverting waste for recycling and re-use—and emissions could be reduced by an estimated 60 percent in 2030 with a US\$100 carbon equivalent price.¹⁴ Given that landfills are predominantly managed by the public sector, and the limited range of mitigation responses, a regulatory approach may be more suitable than emissions taxation.

Domestic and industrial wastewater treatment activities can lead to venting and fugitive methane emissions when organic material decomposes and account for 4 percent of projected BAU non-CO₂ GHGs in 2030 (Figure A1). Most developed countries use aerobic wastewater treatment systems to minimize methane emissions, but many developing countries rely on systems such as septic tanks, latrines, open sewers, and lagoons. Besides switching to aerobic treatment plants, emissions can also be reduced through upgrading infrastructure and equipment—emissions could be reduced by an estimated 36 percent in 2030 with a US\$100 carbon equivalent price.¹⁵ Again however, these responses may be best induced through the public-sector planning process rather than emissions taxation.

Agriculture

Livestock. Cow and sheep operations generate methane emissions as a by-product of digestive processes in animals and nitrous oxide emissions result from nitrification and denitrification of manure—these emissions sources account for 20 percent of BAU non-CO₂ GHGs in 2030 (Appendix Figure 1). Options for reducing methane emissions include, for example, improved feed conversion efficiency, antibiotics, vaccines, changing diet, and intensive pasture management, while nitrogen oxide emissions might be reduced through small digesters and covered lagoons—emissions could

¹³ EPA (2014).

¹⁴ EPA (2014).

¹⁵ EPA (2014).

be reduced by an estimated 10 percent in 2030 with a US\$30 carbon equivalent price though there is limited scope for further abatement opportunities.¹⁶ Pricing livestock emissions is administratively challenging however, for example, a tax could be imposed per head of cattle or sheep (perhaps with reduced rates for lower emitting animal types and where there was proof of emissions-reducing diets), but this would be administratively complicated.

Rice. Rice cultivation is a source of methane and nitrous oxide emissions and flooding of paddy fields causes further emissions from decomposition of organic material—combined emissions account for 6 percent of projected BAU non-CO₂ GHGs in 2030 (Appendix Figure 1). Abatement options include, for example, changing tillage practices, direct seeding, and shifting to dry-land production and emissions could be reduced by an estimated 28 percent in 2030 with a US\$30 carbon equivalent price though again there is limited scope for further abatement opportunities.¹⁷

Other cropland. Land management (e.g., tillage, fertilizer use) in production of crops like barley, maize, sorghum, soybeans, and wheat ~~influences~~ results in nitrous oxide emissions and methane fluxes—these emissions sources account for 3 percent of BAU non-CO₂ GHGs in 2030 (Appendix Figure 1). Abatement possibilities include, for example, no-till cultivation, changing fertilizer use, and crop residue incorporation—emissions could be reduced by an estimated 12 percent in 2030 with a US\$30 carbon equivalent price.¹⁸

¹⁶ EPA (2014).

¹⁷ EPA (2014).

¹⁸ EPA (2014).

where a^{\wedge} denotes a BAU value and Γ_t^{ji} is the price distortion in a fuel market.

In (13), Γ_t^{ji} consists, for non-road fossil fuels, of local air pollution costs, equal to premature mortalities per unit of fuel use times $VMORT_t$, the value per premature mortality— Γ_t^{ji} is defined net of any pre-existing fuel taxes but these are modest at most for non-road fuels.⁹ For road fuels, there is an additional environmental cost equal to the external costs of traffic congestion, accidents, and road damage expressed per unit of fuel use, β_t^{Ti} . The latter is multiplied by the term in parentheses, which amounts to the fraction of the induced change in fuel use due to changes in vehicle km driven as opposed to (long run) improvements in fuel economy.¹⁰

In (14), ΔF_t^{ji} is the change in fuel use, relative to its BAU level F_t^{ji} .

From equation (12), the welfare change from the tax increase for a fossil fuel in a sector consists of: (i) the reduction in use of a fuel product in a particular sector times the pre-existing price distortion associated with that product/sector and aggregated over fuels/sectors, less (ii) the ‘Harberger triangle’, equal to the reduction in fuel use times one-half of the tax increase, where the latter is the product of the fuel’s CO₂ emissions factor and the CO₂ price at time t .

The above formula is also used to calculate the net welfare change from the ETS, coal tax, road fuel taxes, and energy efficiency policies, where the charges apply to fuel use (or virtually to energy efficiency) and sectors as described above.

Parameterization

Fossil Fuels

Supply prices for coal, natural gas, gasoline, diesel, and oil products for 2016–2018 by country are from the IMF (2019b)¹¹ and reflect international reference prices of the finished product (e.g., gasoline) adjusted, where appropriate, using standard (absolute) markups for transport and distribution costs. The international (crude) component of these prices is projected forward using actual and projected international energy prices obtained by averaging over projections in IMF (2018)¹¹ and EIA (2018), Tables 12, 13 and 15.

For electricity (generally a non-traded good), the supply cost for 2016–2018 in the IMF database is the domestic production cost or cost-recovery price, with costs evaluated at international reference

⁹ Local air pollution causes a range of other impacts beyond mortality (morbidity, impaired visibility, building corrosion, crop damage, lake acidification, etc.) but previous studies suggest their combined costs tend to be modest relative to mortality costs (e.g., US-EPA 2011, WBG/SEPAC 2007).

¹⁰ See Parry and others (2014b), Ch. 5.

¹¹ IMF See www.imf.org/external/np/fad/subsidies/data/subsidiestemplate.xlsx

¹¹ These projections go to 2023 and are extrapolated to 2030.

prices. Electricity prices are projected forward using (A6), and changes in fuel prices and generation shares in a future year relative to 2016 levels.

For all countries, 2016–2018 prices to fuel users are available from the IMF and the difference between these prices and supply prices, after the latter (for household fuels) have been marked up for general sales taxes, gives the estimated fuel tax (or subsidy). Pre-existing fuel taxes are taken as constant (in real terms) from 2019 onwards in the BAU while any subsidies (primarily for natural gas in Argentina and road fuels in Saudi Arabia) are assumed to phase out progressively by 2030.

Power Sector Electricity Consumption

This is obtained for 2016 from IEA (2018c) focusing on domestic generation.

Income elasticity of demand for electricity-using products. Empirical studies for different countries suggest a range for this elasticity of around 0.5–1.5.¹² A baseline value of 0.75 is used (aside from India where a value of 0.9 is used to make an adjustment for the progressive expansion in grid access among lower income households).

Price elasticities for electricity. A simple average across the 26 estimates of long-run electricity demand elasticities reported for different countries in Jamil and Ahmad (2011), Table 1, is about -0.5, and nearly all estimates lie within a range of about -0.15 to -1.0.¹³ A study for China suggests an elasticity of -0.35 to -0.5.¹⁴ Evidence for the United States suggests the long-run price elasticity for electricity demand is around -0.4, with about half the response reflecting reduced use of electricity-consuming products and half improvements in energy efficiency.¹⁵ Values of -0.25 are assumed for both the usage and energy consumption rate elasticities for all countries, implying a total electricity demand elasticity of -0.5.

¹² For example, Jamil and Ahmad (2011), Table 1, report 26 estimates of long-run income elasticities for electricity from 17 studies, almost all of them lying within the above range. Many energy-climate models assume an income elasticity of unity (Webster et al. 2008, Table 1), though a review for industrializing countries suggests an elasticity of around 0.6 (Huntington and others 2017).

¹³ See Madlener and others (2011) for further discussion and Webster and others (2008), Table 1, for a summary of energy demand elasticities assumed in energy climate models, most of which are between -0.3 and -0.7. A meta-analysis by Labandeira and others (2017) of studies from around the world reports a mean long-run price elasticity for electricity of -0.4. A review of a limited number of studies for China, India, and Mexico by Huntington and others (2017) puts the long run electricity demand elasticity at -0.46. Studies for residential electricity demand in the United States suggest a long-run elasticity of around -0.3 to -0.8 (Alberini and Filippini 2011), pp. 889 and 895.

¹⁴ Zhou and Teng (2013⁴).

¹⁵ For example, Myers and others (2009), Parry, Evans and Oates (2014), Sanstad and McMahon (2008).

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