Implications of the Global Economic Crisis for Carbon Pricing: A Quantitative Assessment for Coalition Member Countries[1]

Informal Note

May 2020

Context: this note is written for members of the Coalition of Finance Ministers for Climate Action to help them assess the potential role of carbon pricing for achieving climate objectives and raising revenue post-crisis, accounting for the most recent GDP and energy price projections. Macro-fiscal and investment policies needed to address the current public health and economic crisis are beyond the scope of the note. The views expressed in the note are those of the author(s) and do not necessarily represent the views of the IMF, its Executive Board, IMF management, the World Bank, its Board of Executive Directors, the governments they represent, or members of the Coalition of Finance Ministers for Climate Action.

Executive Summary

The health and economic crisis precipitated by the novel coronavirus (COVID19) is unprecedented. But the need to reduce carbon emissions to address the worst effects of climate change in the long-term remains. Even a prolonged global recession would have a minor impact on the accumulated atmospheric stock of greenhouse gas (GHG) emissions and would not obviate the need for transitioning to zero-carbon energy systems by midcentury. As economies stabilize and shutdowns ease, fiscal policymakers should seek to promote a 'green' recovery. Carbon taxes or similar measures can play a critical role in getting energy prices right and ensuring adequate investment in low-carbon technologies.

Carbon taxes can also provide a much-needed revenue stream and may be more acceptable at a time of lower energy prices. Carbon taxes, and more general reform of fossil fuel prices, can contribute to the sustainable macro-fiscal frameworks needed for funding social assistance and post-crisis recovery programs. The changes in energy prices induced by carbon pricing may still be difficult to manage politically, and the appropriate time for reform will vary with national circumstances, but lower oil prices may help with acceptability.

Analysis is needed to assess whether the crisis has affected policy actions required to implement counties' mitigation objectives. The next UN climate meeting, COP26 in Glasgow, now postponed to 2021, should be a pivotal juncture in climate mitigation policy.

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190 parties submitted climate strategies, Nationally Determined Contributions (NDCs), for the 2015 Paris Agreement, and these strategies are now due for revision. Policymakers need technical assessments of the future emissions reductions needed for emissions objectives, carbon pricing or other measures necessitated by such targets, and potential immediate- and medium-term revenues from these reforms. Such assessments need to be based on GDP and energy price projections that account for the economic crisis.

This issue note seeks to provide a transparent and comprehensive assessment for most Coalition member countries of carbon taxes and other mitigation policies, and their environmental, fiscal, and energy price implications. The analysis is based on an IMF-Bank spreadsheet model—the Carbon Pricing Assessment Tool (CPAT)—updated for the most recent (post-COVID) GDP and energy price forecasts and focusing on carbon dioxide (CO_2) emissions from fossil fuel combustion. This analysis is intended to provide quantitative guidance to inform policymakers about the effective stringency of pledges and the policy actions needed, though it should not be used to rank countries. Appropriate mitigation effort will vary across countries depending, for example, on the willingness of electorates to accept higher energy prices, the ease of switching to cleaner energy sources, per capita income, and previous contributions to atmospheric GHGs.

Some key themes of the quantitative analysis include:

- **The emissions reductions embodied in existing mitigation commitments remain substantial and mitigation requirements have changed little as a result of the crisis.** Although projected levels of future GDP have been revised downwards, any emissions savings are modest and may be offset by extra emissions induced by lower energy prices. Reductions below business as usual (BAU) levels (i.e., levels in the absence of new, or tightening of existing, mitigation policies) in 2030 needed to achieve mitigation pledges differ considerably across Coalition countries however, ranging from reductions greater than 35 percent in eleven cases and less than 10 percent in eleven others.

- **Carbon prices implicit in mitigation pledges for 2030 have not changed much as a result of the crisis.** Modelling suggests that needed carbon prices remain substantial but differ considerably across Coalition countries—from over $75 per ton of CO_2 in fourteen cases to less than $25 per ton in thirteen other countries. These differences reflect both differences in the stringency of commitments and in the price responsiveness of emissions. A $50 carbon tax would, for the average Coalition country, have large effects on coal and gas prices, but more moderate effects on retail electricity, gasoline, and diesel prices.

- **Carbon pricing could provide a valuable revenue source**. Potential revenues are expected to be around 0.3-0.6 percent of GDP for a $25 carbon price in 2021, rising to

0.8-1.2 percent of GDP for a $50 carbon price in 2030. These revenue forecasts (relative to GDP) have increased moderately, given lower energy prices have slightly increased the BAU carbon intensity of GDP. Broader reform of fossil fuel prices to reflect the full range of environmental damages, notably local air pollution, would generate substantial additional revenue gains.

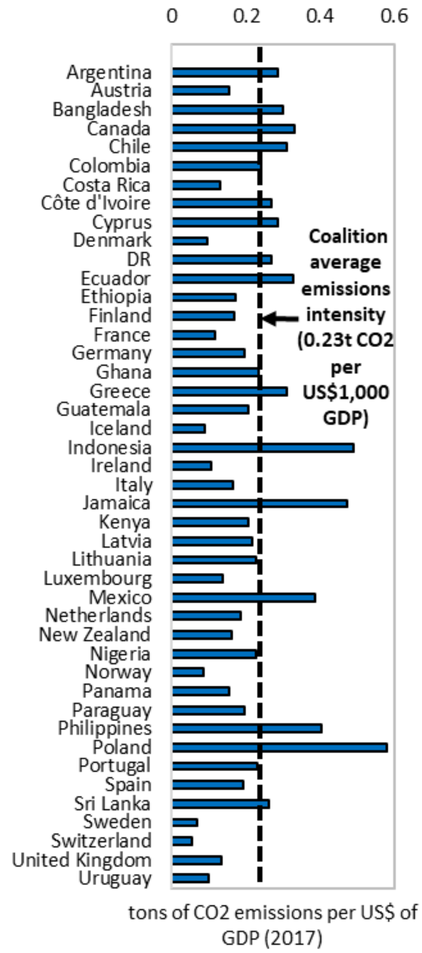
- **The environmental and fiscal advantages of carbon taxes (or equivalent measures) over most other mitigation instruments remain large in relative terms.** Comprehensive carbon taxes are around twice as effective at cutting emissions than pricing systems applied to the power and industrial sectors and have at least twice the revenue potential. The emissions and fiscal advantages of carbon taxes over taxes on individual energy products are especially large in most cases. Nonetheless, combinations of regulations, or tax-and-subsidy schemes known as feebates, can promote many of the mitigation responses of carbon taxes and may have a reinforcing role where the acceptability of pricing is constrained, though they forgo revenue benefits.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) put the 'budget' for containing expected warming to 1.5°C at the equivalent of 10 years of current GHGs, underscoring the need for an immediate and drastic scaling back of global emissions.[2] Even if the crisis substantially dents global emissions any impact on relaxing the allowable carbon budget will be modest.[3]

The landmark 2015 Paris Agreement laid the foundations for meaningful action to stabilize the global climate system. The centerpiece of the Agreement is commitments made by 190 parties to reduce GHGs, as specified in their NDCs. The first-round commitments were consistent with containing projected warming to approximately 3°C,[4] though countries are required to submit revised pledges, preferably with greater ambition, every five years starting with COP 26—in fact, over 70 countries and almost 400 cities recently committed to zero net emissions by mid-century,[5] in line with the 1.5-2°C goal of the Agreement. Current NDCs have intermediate emissions targets, mostly for 2030, though pledges differ in their nominal stringency. Typical first-round pledges among members of the Coalition of Finance Ministers for Climate Action, referred to here as the 'Coalition',[6] are to cut emissions by around 15-35 percent by 2030, relative to historical emissions or BAU emissions projections (see Table A2a, in Annex 2). Overall, Coalition countries represented 16 percent of global CO_2 emissions in 2017, and 30 percent of global GDP, and had about half the global average emissions intensity of GDP (Figure 1).[7]

Figure 1. CO_2 intensity of GDP of Coalition member countries, 2017



Source: IMF & WB staff calculations.

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[2] IPCC (2018).

[3] Put another way, global GHGs must rapidly fall to 50 percent below current levels by 2030 to meet the 1.5°C goal (and continue declining thereafter), or by 25 percent for the 2°C goal (UNEP 2019). IEA (2020) projects global CO_2 emissions will decline 8 percent in 2020 before rebounding with economic recovery.

[4] UNEP (2019).

[5] https://unfccc.int/news/climate-ambition-alliance-nations-renew-their-push-to-upscale-action-by-2020-and-achieve-net-zero.

[6] The Coalition includes 52 countries committed to acting on climate change. See www.cape4financeministry.org/coalition_of_finance_ministers.

[7] 0.23 versus 0.41 tons of CO_2 per US$1,000 of GDP (staff calculations).

It is widely accepted that carbon pricing—charges on the carbon content of fossil fuels or their emissions—could play a central role in implementing mitigation pledges and mobilizing low-carbon investment. As carbon charges are reflected in higher prices for carbon-based fuels and electricity this provides across-the-board incentives to reduce energy use and shift towards cleaner energy sources. Carbon pricing also provides the critical price signal for redirecting investment towards low carbon technologies.[8]

Carbon pricing can, in general, take one of two forms. Carbon taxes are taxes on fuel supply—with rates scaled to the carbon content of the fuels—and are straightforward from an administrative perspective as an extension of fuel excise collection by finance ministries.[9] Emissions trading systems (ETSs) require emissions sources to acquire allowances for their emissions—they are usually implemented by environment ministries who fix the supply of allowances and monitor emissions while allowance trading markets establish emissions prices.

In principle, each instrument can be designed to mimic features of the other. In practice the coverage of ETSs has typically been limited to power generators and industrial firms (with large smokestacks) though they could be extended to cover suppliers of fuels for transportation and buildings. And ETSs could also (for the same emissions coverage and price) raise the same amount of general revenue as carbon taxes through allowance auctions. This has not generally been the practice to date however, as allowances are often given away for free, or if they are auctioned revenues are often earmarked—for example for environmental spending—and hence may offer less fiscal flexibility. Revenues from carbon taxes are sometimes earmarked, though more commonly they are used for broader fiscal reforms or go to the general budget.[10] Pure ETSs provide more certainty over annual emissions from covered sectors but the trade-off is uncertainty over emissions prices (which might deter private investment in low-emission technologies) and revenue. ETSs can, however, be accompanied by price floors (e.g., implemented through a minimum auction price) to make them behave more like taxes, while carbon tax rates can be periodically adjusted to keep emissions in line with future targets.

About 60 carbon pricing schemes have been implemented to date at regional, national, and sub-national levels (Table 1). Prices in 2019 were around \$5 to \$25 per ton[11] in most schemes, but in a few cases (e.g., Scandinavian countries) carbon taxes are much higher. Some countries make use of both carbon taxes and ETSs—for example, Denmark, France, Ireland, Sweden, and Portugal apply carbon taxes to emissions outside of the EU ETS. From a global

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[8] See for example Pigato and others (2020).

[9] Alternatively, carbon taxes can be integrated into fiscal regimes for industries extracting coal, oil, and natural gas with rebates for fuel exports and taxes applied to fuel imports. See Calder (2015) for a discussion of carbon tax administration.

[10] See Carl and Fedor (2016), WBG (2019b).

[11] Aside from Table 1, all monetary values below are expressed in constant 2018 US dollars.

perspective however, carbon pricing schemes are barely scratching the surface of what is needed—existing and prospective pricing schemes cover only a fifth of global GHGs and the explicit carbon price, averaged across global emissions, is only $2 per ton.[12]

Table 1. Selected carbon pricing schemes, 2019

Country/Region	Year Introduced	Price 2019, \$/ton CO2	Coverage of GHGs 2018	
			Million Tons	Percent
Carbon taxes				
Chile	2017	5	47	39
Colombia	2017	5	42	40
Denmark	1992	26	22	40
Finland	1990	65	25	38
France	2014	50	176	37
Ireland	2010	22	31	48
Japan	2012	3	999	68
Mexico	2014	1-3	307	47
Norway	1991	59	40	63
Portugal	2015	14	21	29
South Africa	2019	10	360	10
Sweden	1991	127	26	40
Switzerland	2008	96	18	35
Emissions Trading Systems (ETSs)				
California	2012	16	378	85
China	2020	na	3,232	
European Union	2005	25	2,132	45
Korea	2015	22	453	68
New Zealand	2008	17	40	52
Regional GHG Initi	2009	5	94	21
Carbon price floors				
Canada	2016	15	na	70
United Kingdom	2013	24	136	24

Source: WBG (2019a), IMF (2019a).
Note. Regional GHG Initiative is a cooperative effort among Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont.

Carbon pricing needs to be part of a broader policy package and its appropriate timing depends on national circumstances. Where there are limits on the political acceptability of higher energy prices other (albeit less efficient) mitigation instruments that promote some of the key behavioral responses of pricing while avoiding a significant impact on energy prices have a reinforcing role. These may take the form of regulatory standards for emission rates and energy efficiency, though a more flexible and cost-effective approach is feebates.[13] More generally, mitigation instruments will need to be supported by public investment (e.g., in smart grids, electric vehicle charging stations) and incentives for technology development and deployment. The appropriate time for introducing carbon pricing will depend on prevailing factors such as the urgency of fiscal consolidation and likely opposition from the public.

[12] Calculated from WBG (2019a).

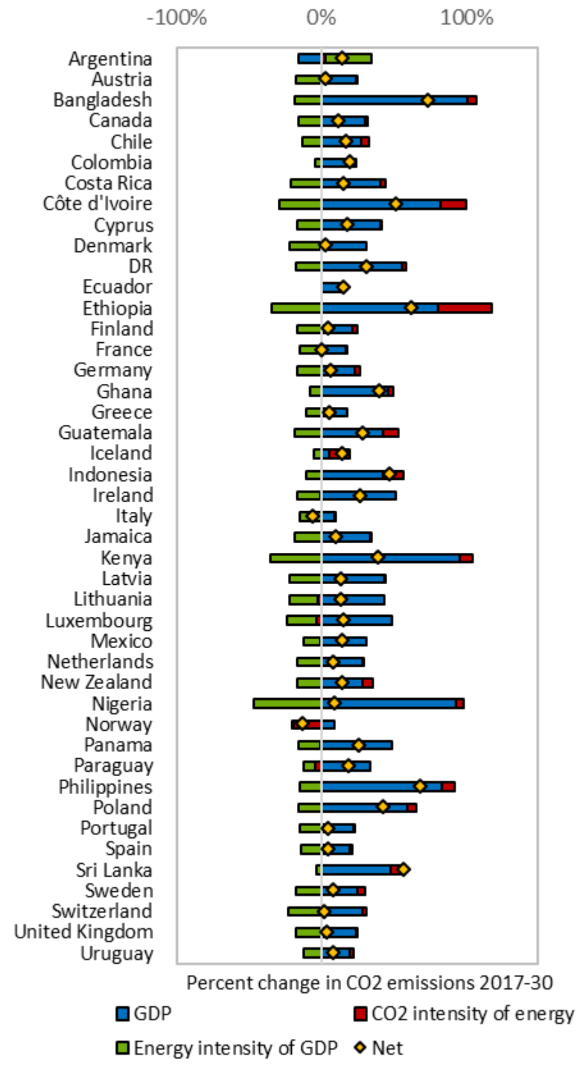
[13] The latter provide a sliding scale of fees on products or activities with above average emission rates and a sliding scale of rebates for products or activities with below average emission rates. For example, if applied to transportation, new vehicle sales would be subject to a fee equal to the product of: (i) a CO_2 price; (ii) the difference between the vehicle's CO_2 per mile and the average CO_2 per mile of the new vehicle fleet; and (iii) the (discounted) lifetime mileage of the average vehicle. Analogous schemes could reduce emission rates from power generation and industries or increase the energy efficiency of products and capital.

2. Quantitative Assessment

The section discusses, for Coalition member countries, the following issues: fossil fuel CO_2 emissions projections under current policies; emission reductions needed for intermediate emissions targets; carbon prices implied by emissions targets; revenues from carbon pricing; energy price implications; comparisons of pricing with other mitigation instruments; and broader energy price reform. Analysis of the distributional burden of carbon pricing across households and industries, trade effects, and sectoral employment effects, can guide the design of measures to assist groups vulnerable to higher energy prices but is beyond the scope of this note.

The analysis is based on an IMF-WB spreadsheet tool described in Annex 1.[14] This tool projects uses of fossil and other fuels by the major energy sectors in a BAU scenario with no new or tightening of existing mitigation policies (e.g., current fuel taxes and EU ETS emissions prices are taken as given). The impacts of carbon taxes on fuel use and emissions depend on assumptions about the price responsiveness of fuel use which are based on empirical and modelling literature, though significant uncertainty surrounds these parameters. Data availability permits analysis for 44 Coalition countries.[15]

Figure 2. Drivers of changes in baseline CO_2 emissions in Coalition countries 2017-30



Source: IMF & WB staff calculations. Components do not necessarily sum to the net change due to multiplication.

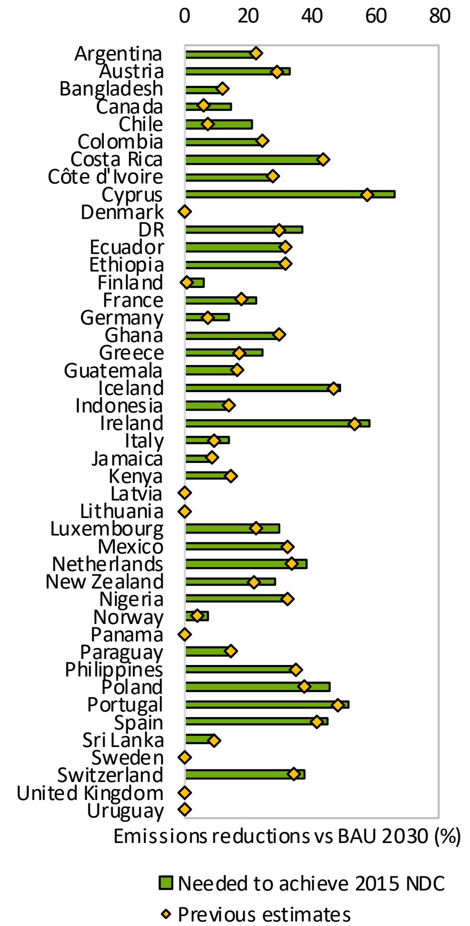
Future BAU emissions growth depends on GDP growth, changes in the energy intensity of GDP, and changes in the carbon intensity of energy. Figure 2 shows projected changes in the BAU between 2017 and 2030 (2017 is the last year for which cross-country fuel use data is comprehensively available). GDP is expected to rise across Coalition countries

[14] The tool has been used in previous cross-country reports on climate mitigation policies including IMF (2019a and b).

[15] Cross-country databases on fuel use (see Annex 1) do not include the following Coalition members: Equatorial Guinea, Fiji, Madagascar, Maldives, Marshall Islands, Monaco, Tonga, and Uganda.

by a simple average of 38 percent to 2030, though growth is faster in populous developing countries like Philippines (84 percent), Nigeria (93 percent), Kenya (96 percent), and Bangladesh (101 percent). Increases in GDP raises emissions, as does the increasing CO_2 emissions intensity of energy as countries like Indonesia (15 percent) and Ethiopia (37 percent) scale up their energy systems.[16] However, the energy intensity of GDP is expected to fall by an average of 15 percent over this period, reflecting improving energy efficiency and the demand for energy rising less than in proportion to GDP. Overall, CO_2 emissions are expected to increase across the Coalition by an average of 20 percent over this period, but the increase exceeds 30 percent in 10 cases. Only two countries (Italy and Norway) are expected to reduce emissions in the baseline.

Figure 3. Emissions reductions needed by 2030 to achieve current NDCs



Source: IMF & WB staff calculations. Pre-COVID estimates exclude recent downward revisions to GDP and international energy price forecasts. Needed emissions reductions are based on submissions for the 2015 Paris Agreement and do not account for subsequent revisions to pledges or variation within blocs (e.g., in the EU).

The effective stringency of mitigation pledges is significant but varies across Coalition countries (Figure 3). Reductions below BAU levels in 2030 needed to achieve (first-round) mitigation pledges range from reductions greater than 40 percent in eleven cases to less than ten percent in eight cases.[17] In part, these differences may reflect countries' varying preferences for being leaders on climate change. Separately, some advanced countries have, or are planning to introduce, stricter domestic climate plans.[18]

The emissions reductions needed to meet mitigation pledges have not changed significantly (Figure 3). In level terms, IMF GDP projections for Coalition countries have been revised downwards by a GDP-weighted average of 3 percentage points by 2024 over previous

[16] For most countries, there is little change in the CO_2 intensity of energy given that renewables as a share of total energy start from a low base and in the BAU there is no assumed change in the stringency of policies to promote renewables.

[17] Mitigation pledges in NDCs typically specify targets for total GHGs rather than fossil fuel CO_2 emissions. The above calculations assume CO_2 emissions need to be reduced in the same proportion to total GHGs except for countries with large forestry and land use change contributions.

[18] For example, Denmark, Germany, and the UK have recently adopted national targets to cut emissions 70, 55, and 57 percent below 1990 levels by 2030, respectively. These plans are separate to the Paris Agreement NDCs.

forecasts.[19] The overall impact on emissions is fully counteracted, however, by an increase in emissions due to lower oil, natural gas, and to a lesser extent coal price forecasts for 2030.[20] On a simple average basis, emissions reductions required to meet current NDCs are 28 percent below BAU levels in 2030, about 2 percentage points above their pre-COVID forecasts.

Carbon prices implicit in mitigation pledges vary from over $75 per ton in 2030 in fourteen cases, between $25 and $75 in thirteen cases, and below $25 in seventeen countries. Figure 4 compares emissions reductions under different carbon taxes in 2030 to reductions required for mitigation pledges. The cross-country differences in prices needed to meet mitigation pledges reflect differences in the stringency of commitments as just discussed, but also in the price responsiveness of emissions. For example, emissions reductions below BAU levels from a $50 carbon price exceed 25 percent for countries consuming a lot of coal (e.g., Indonesia and Poland) and are less than 10 percent in some countries where coal use is minimal or zero (e.g., Costa Rica, Ethiopia, Panama). The need for other mitigation instruments to reinforce carbon pricing will be especially important in cases where emissions reductions under carbon pricing alone fall short of target reductions, even under high carbon prices. Cross-country dispersion in needed carbon prices also underscores the case for international coordination mechanisms like carbon price floors.[21]

Comprehensive carbon pricing can mobilize a valuable revenue stream. In 2021, a $25 per ton carbon tax in 2021 would raise revenues of around 0.2-0.7 percent of GDP for most Coalition countries. In 2030, a $50 tax would raise revenues (Figure 5) of around 0.6-1.3 percent of GDP. Cross-country differences reflect (most importantly) differences in BAU emissions intensity in 2030 (Figure 1) but also differences in the price-responsiveness of emissions. Revenues are about 65-80 percent higher under the $50 per ton carbon tax in 2030 compared with the $25 tax (they are less than double, due to tax base erosion).[22] Ultimately, carbon pricing revenues would need to be replaced by other revenue sources as economies are de-carbonized, but this is an issue for the longer term.

Carbon pricing has substantial impacts on coal and natural gas prices, but more moderate impacts on electricity and gasoline prices (Table A2b in Annex 2). On average coal prices increase 144 percent above BAU prices for a $50 CO_2 price in 2030 while natural gas prices increase 46 percent. In contrast, retail electricity and gasoline prices increase on average about 10 percent. There are significant differences across countries however due to differences in BAU prices (e.g., BAU prices for coal and natural gas are relatively high for

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[19] The new revised GDP projections extend to 2024 and beyond that GDP is assumed to grow at the same annual average rate as in the last year of the projection period.
[20] Projected (real) oil prices are $50/barrel in 2030 (compared with $66 in 2019 and a previous forecast for 2030 of $74). See Annex 1 for sources for energy price forecasts.
[21] See IMF (2019b) for a discussion of international carbon price floors and how they could equitably scale up mitigation action among large emitters.
[22] The calculations above account for revenue losses from the erosion of pre-existing fuel tax bases.

European countries) and, in the case of electricity, differences in the carbon intensity of production (e.g., price increases exceed 30 percent in countries with large shares of coal or natural gas generation like Chile, Indonesia, Mexico, Philippines, Poland).

Figure 4. Potential CO_2 emissions reductions from carbon taxes in 2030

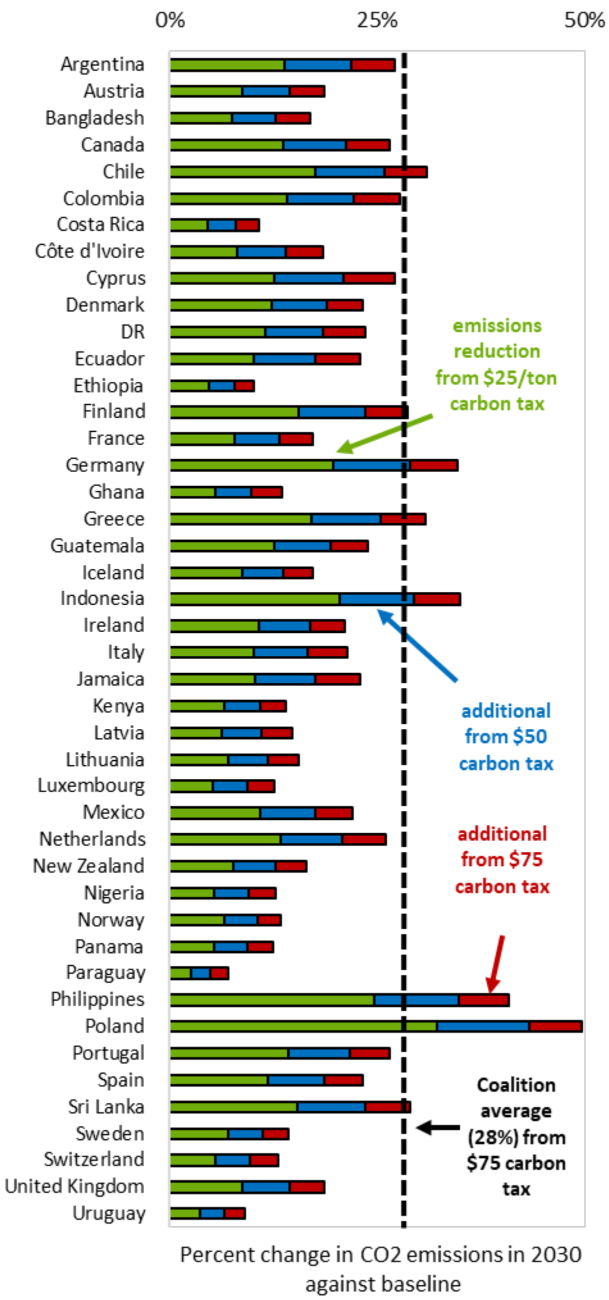
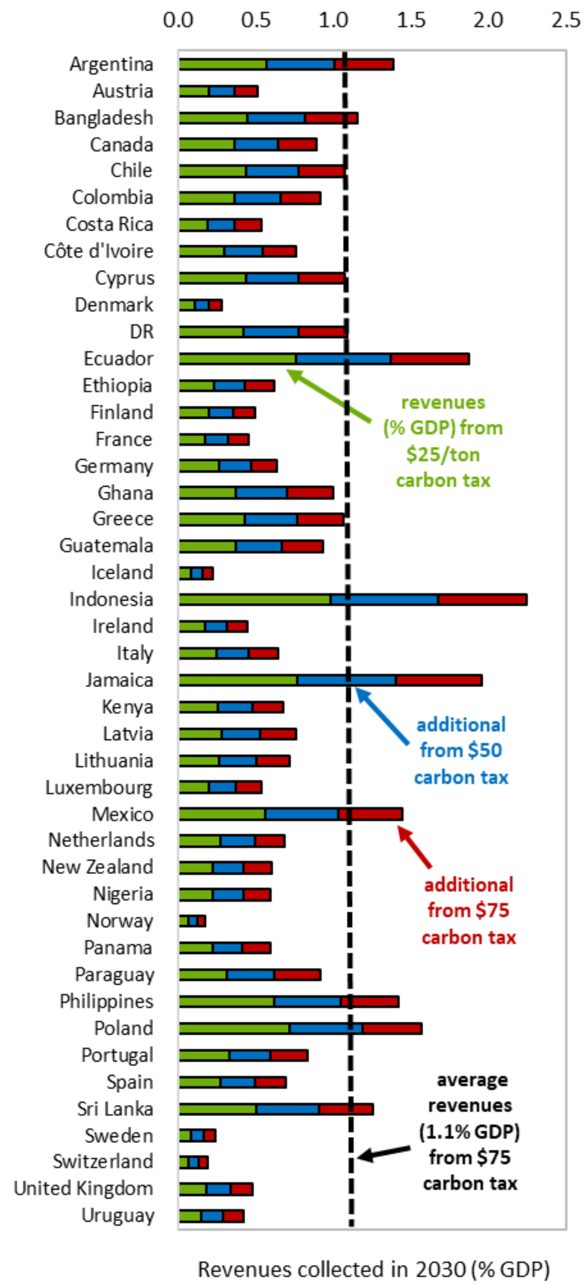


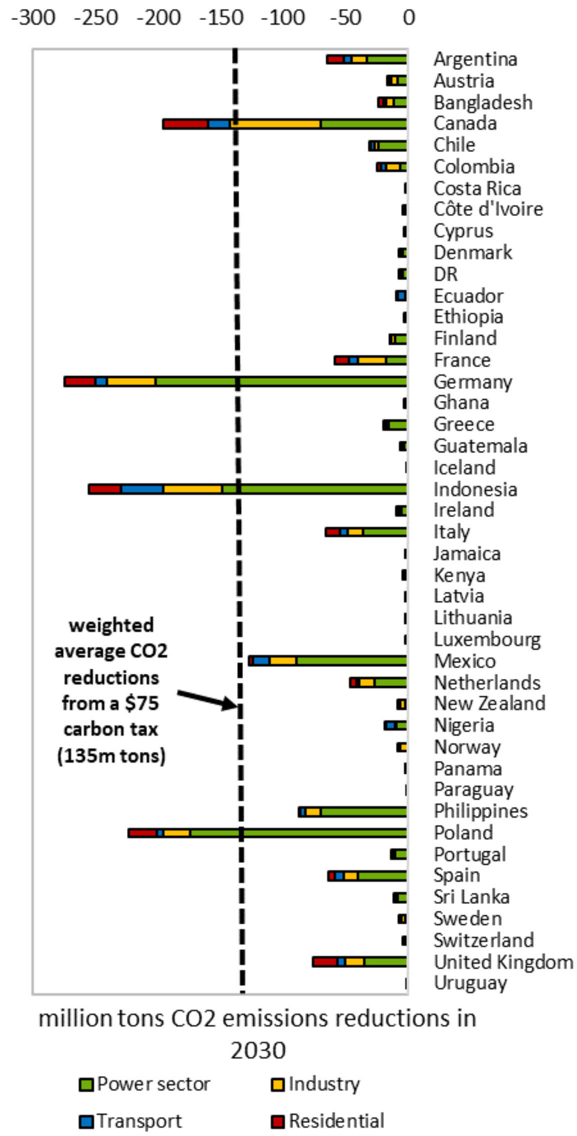
Figure 5. Potential revenues from carbon taxes in 2030



Source: IMF and WB staff calculations. Coalition average emissions reductions and revenue are calculated by weighting individual countries by their shares in total BAU emissions and revenue in 2030.

The mitigation potential of carbon pricing differs across sectors (Figure 6). The power sector, where there are generally more alternatives for switching away from carbon-intensive fuels like coal, accounts for the largest share of mitigation potential. Under a uniform carbon price applied to all Coalition members, on a simple average basis the power sector would account for about 45 percent of total emissions reductions, followed by industry (25 percent), transport (19 percent), and residential (9 percent) sectors. Accordingly, countries with large abatement potential (see Figures 4 and 6) tend to be those whose composition of CO_2 emissions comprises a significant amount of coal (Figure 7). However, achieving the Paris Agreement's long-term temperature goals requires full decarbonization of all sectors, including those that are harder to abate like transport and housing. By providing the long-term price signals needed to spur investment in low-carbon technologies, including in these sectors, carbon pricing can support decarbonization efforts beyond 2030.

Figure 6. Emissions reductions by sector under a $75 carbon tax in 2030

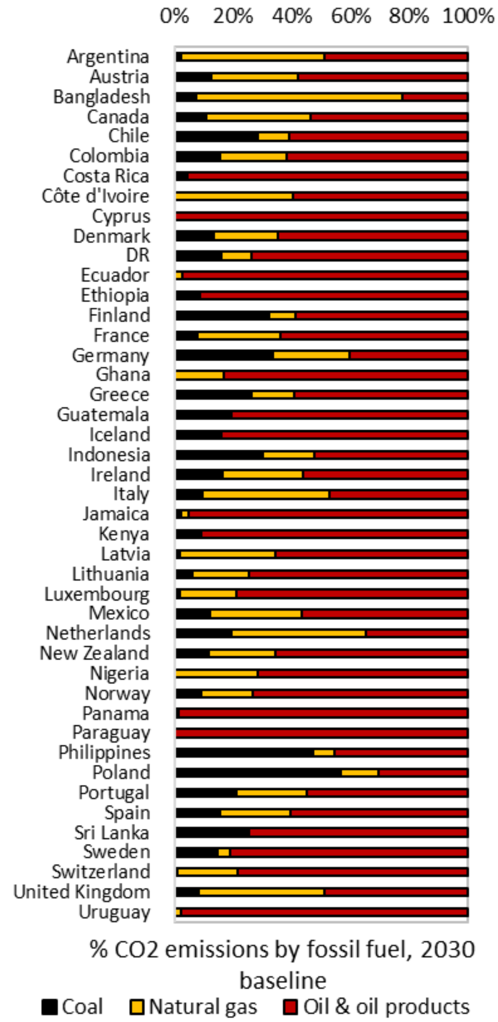


Source: IMF and WB staff calculations. Average reductions are weighted by 2030 BAU emissions.

Other mitigation instruments are less effective at reducing CO_2 than comprehensive carbon pricing (Table A2c in Annex 2). Policies are compared for the same CO_2 price increase ($50 per ton in 2030) they impose on emissions covered by the policy. ETSs are typically around 40-60 percent as effective as broad carbon pricing, not because of the instrument itself but rather its assumed coverage (based on general practice to date) of power generators and large industry. Road fuel taxes have effectiveness of mostly around 5-20 percent of carbon taxes as these fuels typically account for a minor proportion of emissions and carbon charging has a relatively modest impact on retail prices. In some coal-intensive countries (e.g., Philippines, Poland), taxing coal alone can be nearly as effective as a broad carbon tax. A combination of measures (feebates, regulations) that promote fuel switching in power generation and major opportunities for energy efficiency improvements has around 60-75 percent of the effectiveness of broad carbon pricing.

Other instruments also raise far less revenue (Table A2d in Annex 2). For example, coal taxes raise less than one-third of the revenue raised by comprehensive carbon taxes in most Coalition countries. Even if allowances are fully auctioned, the revenue potential of ETSs limited to the power and industrial sectors is generally below half of that for the carbon tax. And although feebates and regulations have smaller impacts on energy prices, a tradeoff is that they forgo revenue opportunities.

Figure 7. CO_2 emissions by fossil fuel in 2030 BAU



Source: IMF & WB staff calculations. Oil products include gasoline, kerosene, diesel, and liquified petroleum gases.

Broader price reform would be needed for fossil fuel prices to reflect supply costs and the full range of environmental costs. Combustion of coal and diesel fuel causes local air pollution which is harmful to public health, though the resulting costs vary considerably across countries depending, for example, on population exposure to pollution, use of emissions control technologies, and people's willingness to pay to avoid health risks (local air pollution damages from gasoline and natural gas tend to be small). More generally, use of road fuels in vehicles is indirectly associated with traffic congestion and accidents. There are more effective instruments for addressing domestic environmental problems, but reflecting environmental costs in fuel prices improves economic welfare in the interim, until these instruments have been widely implemented.[23] As illustrated for Coalition countries in Figure A2a in Annex 2, fossil fuels are pervasively underpriced across Coalition countries—despite high rates of road fuel excise in many cases[24] —though the degree of underpricing varies not only across countries but also across fuel types. For example, underpricing is generally more pronounced for coal than for natural gas, and for diesel than gasoline.

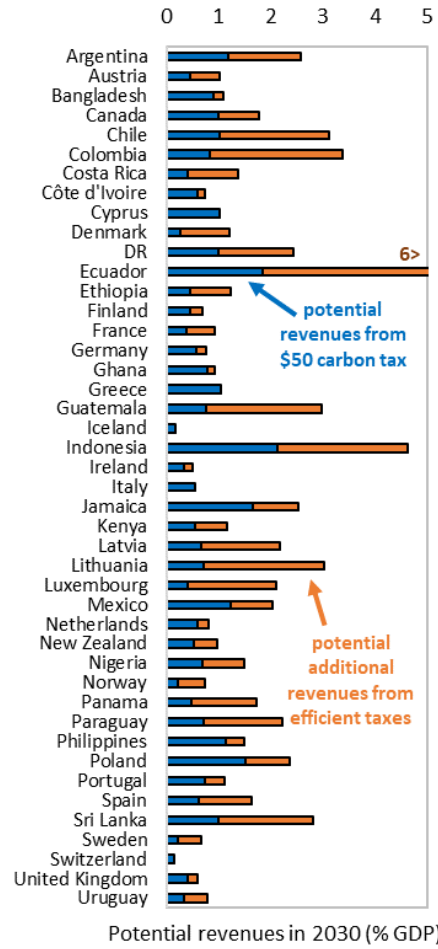
Comprehensive energy price reform would yield substantial additional revenues for Coalition countries. For the most part, retail prices are equal to or greater than supply costs

[23] Congestion, for example, is most efficiently addressed through peak period charges on busy roads and local air pollution though charges on emissions out of the smokestack. See Parry and others (2014) for an extensive discussion of efficient policies, second-best fuel taxes, and methodologies for measuring environmental costs at the country level.

[24] see OECD (2018) for more detail on energy taxes in different countries.

across fuel products and Coalition countries, so there is little scope for revenue gains from eliminating subsidies from undercharging for supply costs. A broader definition of subsidies, however, would reflect the difference between current prices and efficient prices needed to reflect supply and all environmental costs [25] —subsidy reform in this broader sense (i.e., moving from current to efficient fossil fuel prices) would, in contrast, yield large revenue gains. This can be seen in Figure 8 where revenues from full price reform in 2021 add, on a simple average basis, slightly more than double revenues from a $50 carbon tax. Such major reform may be unrealistic, at least in such a short time frame, but the estimates serve to underscore the ample space for reforming energy prices in an economically efficient direction while also contributing significantly to fiscal needs.

Figure 8. Potential revenues in 2021 from a broader energy price reform



Source: IMF & WB staff calculations.

Conclusion

This note suggests that, if anything, the global economic crisis may have strengthened the case for phasing in carbon pricing as economies recover. Carbon pricing will help to ensure that climate considerations are adequately integrated into private investment decisions as the economy picks up while revenues from carbon pricing can help protect fiscal space. If fossil fuels are underpriced, that is, prices fail to fully reflect both supply and environmental costs, there is a danger that recoveries will lock in carbon-intensive capital (e.g., fossil fuel power plants) that will ultimately become stranded. Stimulus packages will need to be sustainably funded to re-assure capital markets and carbon pricing can help with this by establishing a robust stream of new revenues over the medium term, helping to lower borrowing costs as countries incur greater debt. Raising funds through other sources would not contribute to environmental objectives.[26]

The note presents extensive cross- country analysis to help Coalition members understand the impacts of pricing and trade-offs with other instruments. This analysis

[25] See Coady and others (2019) on different notions of energy subsidies.

[26] See Jones and Keen (2009) for a discussion of carbon pricing reform in the context of economic recovery programs.

underscores that the economic crisis has had little effect on the need for emissions reductions and the emissions and fiscal impacts of carbon pricing.

The burden of increased energy prices on businesses and households is a critical concern, though a comprehensive reform may increase their acceptability. For most carbon pricing designs, near-term burdens of higher energy prices are not large: typically less than 1 percent of production costs for industries on average, and around 1 percent of consumption for the average household, for a $25 carbon price in 2021.[27] Carbon pricing may also be more acceptable at a time of lower energy prices—for example, carbon prices of around $65 per ton could be introduced without raising projected 2021 retail road fuel prices above 2019 price levels (though coal and natural gas prices would rise above 2019 levels). A comprehensive strategy to enhance acceptability could include extensive consultation with stakeholders and communication to the public; assistance programs for households, workers, firms, and regions vulnerable to higher energy prices; visible, equitable, and productive use of carbon pricing revenues; and complementary investments (e.g., in renewables) to enhance the credibility of reform.

The timing of carbon pricing reform is also critical. For some debt-constrained countries, recovery programs may be funded by a combination of international support and domestic revenue mobilization and carbon pricing may be a less economically depressing domestic source than broader taxes on work effort and investment. For countries able to borrow, carbon taxes can contribute to debt stainability over the medium to long term, and their introduction might be delayed until economic recovery is well underway. Carbon price reform in some countries may need to wait, for example, if there is currently a risk of provoking social unrest or domestic energy producers have been badly hit by lower energy prices.

Beyond carbon pricing, climate considerations need to be factored into the spending side of stimulus plans. Recovery plans could be assessed on their decarbonization potential as well as their implications for short-term recovery. And public investment projects could focus on low-carbon infrastructure (e.g., renewables, smart grids), developing and adopting new technologies (e.g., batteries for storing electricity, carbon capture and storage), adaptation (e.g., more robust roads and drainage systems), while avoiding investments in carbon intensive sectors (e.g., coal generation plants).[28]

[27] Inferred from calculations in IMF (2019b).
[28] See IMF (2020).

Annex 1. Spreadsheet Tool for Mitigation Analysis: the Carbon Pricing Assessment Tool (CPAT)

IMF-Bank staff[29] have developed a spreadsheet model, the Carbon Pricing Assessment Tool (CPAT) providing, on a country-by-country basis for 150 countries, projections of fossil fuel CO_2 emissions and assessments of the emissions, fiscal, economic, public health and other impacts of carbon pricing and other mitigation policies.

This tool starts with use of fossil fuels and other fuels by the power, industrial, transport, and household sectors and then projects fuel use forward using:

- Projections of GDP;
- Assumptions about the income elasticity of demand[30] and own-price elasticity of demand for electricity and other fuel products;
- Assumptions about the rate of technological change that affects energy efficiency and the productivity of different energy sources; and
- Changes in future international energy prices.

In these projections current fuel taxes and carbon pricing are held constant in real terms.

The impacts of carbon pricing and other mitigation policies on fuel use and emissions depends on: (i) their proportionate impact on future energy prices; (ii) a simplified representation of fuel switching within the power generation sector; and (iii) various price elasticities for electricity use and fuel use in other sectors.

The model is parameterized using data compiled from the International Energy Agency (IEA) on recent fuel use by country and sector and carbon emissions factors by fuel product. Data on energy taxes, subsidies, and prices by energy product and country is from IMF sources. Prices are projected forward using a combination of 2020 prices (50 percent weighting) and an average of IEA, US Energy Information Administration, IMF and World Bank projections for international energy prices (50 percent weighting). Assumptions for fuel price responsiveness are chosen to be broadly consistent with empirical evidence and results from energy models. See IMF (2019a), Appendix III, for a mathematical description of the model and documentation of parameter values.

One advantage of the model is its flexibility in incorporating a large number of countries, a wide range of alternative mitigation policies (e.g., comprehensive and partial carbon pricing, taxes on electricity and individual fuels, feebates and other policies to improve energy

[29] The CPAT team includes Ian Parry, Simon Black, Dirk Heine, Ira Dorband, Paulina Schulz, Stephen Stretton, Victor Mylonas, Karlygash Zhunussova, Helene Naegele, and Daniela Zingler.

[30] That is, the percent increase in demand for a product per one percent increase in income (or GDP).

efficiency and reduce emission rates), and sensitivity analyses with respect to parameter values and policy stringency. Another advantage is that the model is highly transparent as differences across policies and countries can be explained in terms of basic economic concepts that are familiar to policymakers.

One limitation of the model is that, for analytical tractability, it does not explicitly incorporate the gradual turnover of energy capital which limits the response of fuel use to pricing in the short to medium term (e.g., while vehicle fleets turn over). This assumption is reasonable, however, given the focus on longer term policies for 2030, which presumably are anticipated and phased in progressively (nearer-term impacts of policies are analyzed using smaller energy price elasticities). The model abstracts from the possibility of mitigation actions (beyond those induced by current policies) in the BAU, which is a common approach to provide clean comparisons of mitigation instruments to the BAU. More detailed modelling of prospective policies may be needed at the national level however, as individual countries tailor their own, idiosyncratic strategies to implement mitigation objectives.

Another caveat is that, while the assumed fuel price responses are plausible for modest fuel price changes, they may not be for dramatic price changes that might drive major technological advances, or non-linear adoption of technologies like carbon capture and storage (for this reason, results are not reported for carbon prices above $75 per ton). The model also does not account for the possibility of upward sloping fuel supply curves, general equilibrium effects (e.g., changes in relative factor prices that might have feedback effects on the energy sector), and changes in international fuel prices that might result from simultaneous mitigation action in large emitting countries. However, parameter values in the spreadsheet are chosen such that the results from the model are broadly consistent with those from far more detailed energy models that take these sorts of factors into account.[31]

[31] IMF (2019a), Appendix III.

Annex 2: Supplementary Figures and Tables

Table A2a. Coalition Countries[32]: 2015 Paris Mitigation Contributions and Emissions Data

Country	Paris Mitigation contributions (2015 NDCs)	2030 BAU		
		share of global CO2	tons CO2/$1000 real GDP	tons CO2 per capita
Argentina	Reduce GHGs 15% (30%) below BAU in 2030	0.53	0.4	4.1
Austria	Reduce GHGs 40% below 1990 by 2030	0.16	0.13	6.6
Bangladesh	Reduce GHGs 5% (20%) below BAU in 2030	0.34	0.24	0.7
Canada	Reduce GHGs 30% below 2005 by 2030	1.46	0.28	13.8
Chile	Reduce GHG/GDP 30% (35-45%) below 2007 by 2030	0.24	0.26	4.5
Colombia	Reduce GHGs 20% (30%) below BAU by 2030	0.25	0.23	1.8
Costa Rica	Reduce GHGs 44% below BAU by 2030	0.02	0.11	1.5
Côte d'Ivoire	Reduce GHGs 28% below BAU in 2030	0.05	0.23	0.6
Cyprus	Reduce GHGs 40% below 1990 by 2030	0.02	0.23	7.2
Denmark	Reduce GHGs 40% below 1990 by 2030	0.07	0.07	4.5
DR	Reduce GHGs (25%) below 2010 by 2030	0.07	0.23	2.4
Ecuador	Reduce GHGs 20.4-25% (37.5-45.8%) below BAU in 2025	0.08	0.29	1.5
Ethiopia	Reduce GHGs (64%) below BAU in 2030	0.04	0.1	0.2
Finland	Reduce GHGs 40% below 1990 by 2030	0.11	0.16	7.7
France	Reduce GHGs 40% below 1990 by 2030	0.73	0.1	4.2
Germany	Reduce GHGs 40% below 1990 by 2030	1.76	0.17	8.4
Ghana	Reduce GHGs 15% (45%) below BAU in 2030	0.04	0.17	0.4
Greece	Reduce GHGs 40% below 1990 by 2030	0.16	0.28	5.9
Guatemala	Reduce GHGs 11.2% (22.6%) below BAU in 2030	0.04	0.17	0.8
Iceland	Reduce GHGs 40% below 1990 by 2030	0.01	0.07	5.5
Indonesia	Reduce GHGs 29% (41%) below BAU in 2030	1.52	0.37	1.9
Ireland	Reduce GHGs 40% below 1990 by 2030	0.11	0.09	7.6
Italy	Reduce GHGs 40% below 1990 by 2030	0.76	0.15	5.0
Jamaica	Reduce GHGs 7.8% (10%) below BAU by 2030	0.02	0.41	2.3
Kenya	Reduce GHGs (30%) below BAU in 2030	0.05	0.13	0.3
Latvia	Reduce GHGs 40% below 1990 by 2030	0.02	0.18	4.1
Lithuania	Reduce GHGs 40% below 1990 by 2030	0.03	0.19	4.9
Luxembourg	Reduce GHGs 40% below 1990 by 2030	0.02	0.11	11.8
Mexico	Reduce GHGs 25% (40%) below BAU in 2030	1.21	0.33	3.4
Netherlands	Reduce GHGs 40% below 1990 by 2030	0.42	0.17	9.3
New Zealand	Reduce GHGs 30% below 2005 by 2030	0.08	0.13	5.5
Nigeria	Reduce GHGs 20% (45%) below BAU in 2030	0.22	0.13	0.3
Norway	Reduce GHGs 40% below 1990 by 2030	0.09	0.08	5.9
Panama	Forestry target only	0.03	0.11	2.4
Paraguay	Reduce GHGs 10% (20%) below BAU in 2030	0.02	0.13	0.9
Philippines	Reduce GHGs (70%) by 2030 relative to BAU of 2000-2030	0.43	0.26	1.2
Poland	Reduce GHGs 40% below 1990 by 2030	0.86	0.46	9.0
Portugal	Reduce GHGs 40% below 1990 by 2030	0.11	0.18	4.5
Spain	Reduce GHGs 40% below 1990 by 2030	0.61	0.16	5.3
Sri Lanka	Reduce GHGs 4% (20%) in energy, 3% (10%) in other sectors below BAU by 2030	0.07	0.19	1.1
Sweden	Reduce GHGs 40% below 1990 by 2030	0.1	0.06	3.3
Switzerland	Reduce GHGs 50% below 1990 by 2030	0.1	0.05	4.1
United Kingdom	Reduce GHGs 40% below 1990 by 2030	0.95	0.13	5.3
Uruguay	Reduce GHG/GDP 25% (40%) below 1990 by 2030	0.02	0.09	1.9

Source. IMF (2019a), Annex I, WBG (2019a), Annex III.

[32] Due to data limitation, does not include the following Coalition members: Equatorial Guinea, Fiji, Madagascar, Maldives, Marshall Islands, Monaco, Tonga, and Uganda.

Table A2b. Impact of $50 Carbon Tax on Energy Prices, 2030

Country	coal		natural gas		electricity		gasoline	
	BAU price, $/GJ	% price increase	BAU price, $/GJ	% price increase	BAU price, $/kWh	% price increase	BAU price, $/liter	% price increase
Argentina	2.3	265	3.6	72	0.09	27	0.8	15
Austria	4.6	103	9.9	26	0.13	4	1.2	10
Bangladesh	2.3	205	10.3	26	0.16	22	1.0	13
Canada	2.3	217	3.6	68	0.10	9	0.8	16
Chile	2.3	209	3.6	69	0.09	43	1.0	13
Colombia	2.3	208	3.6	64	0.10	6	0.6	29
Costa Rica	2.3	230	3.6	74	0.12	0	0.9	13
Cote D'Ivoire	2.5	182	5.6	103	0.10	59	1.0	3
Cyprus	3.0	48	9.9	27	0.18	18	1.2	9
Denmark	4.3	96	10.0	28	0.15	2	1.5	8
DR	2.3	199	3.6	77	0.11	33	0.9	12
Ecuador	2.3	203	3.6	77	0.13	8	0.4	36
Ethiopia	2.3	205	8.6	31	0.10	0	0.8	16
Finland	5.2	114	9.8	24	0.15	7	1.5	7
France	4.3	96	10.0	28	0.12	2	1.4	7
Germany	4.6	103	10.0	27	0.12	16	1.4	7
Ghana	2.3	203	8.6	30	0.12	12	0.5	29
Greece	4.7	105	9.9	26	0.13	24	1.6	7
Guatemala	2.3	188	3.6	74	0.13	22	0.4	34
Iceland	2.3	223	8.6	31	0.12	0	1.3	6
Indonesia	2.3	208	10.3	22	0.08	101	0.3	40
Ireland	4.5	100	10.0	28	0.13	13	1.4	8
Italy	4.6	103	10.0	28	0.14	12	1.6	7
Jamaica	2.3	175	3.6	77	0.18	23	0.8	14
Kenya	2.3	205	8.6	31	0.14	3	0.9	13
Latvia	4.9	109	10.0	27	0.13	3	1.2	9
Lithuania	4.8	108	9.3	15	0.15	0	1.2	10
Luxembourg	4.6	103	10.0	28	0.14	-2	1.2	9
Mexico	2.3	197	3.6	79	0.11	42	0.7	17
Netherlands	4.6	102	9.9	26	0.12	23	1.6	3
New Zealand	2.3	244	7.8	27	0.12	3	1.2	9
Nigeria	2.3	205	8.6	29	0.14	9	0.4	22
Norway	2.3	191	8.6	37	0.10	-1	1.7	4
Panama	2.3	205	3.6	74	0.12	4	0.6	8
Paraguay	2.3	213	3.6	74	0.11	-6	1.0	14
Philippines	2.3	210	10.3	27	0.09	64	0.8	14
Poland	4.7	104	9.7	23	0.11	50	1.1	10
Portugal	4.5	100	9.9	27	0.13	14	1.5	7
Spain	4.7	104	9.9	27	0.13	10	1.2	8
Sri Lanka	2.3	175	10.3	26	0.14	40	0.9	15
Sweden	4.2	93	9.6	20	0.13	0	1.5	7
Switzerland	2.3	217	8.6	33	0.11	0	1.4	8
United Kingdom	5.1	112	10.0	28	0.14	7	1.4	7
Uruguay	2.3	0	3.6	77	0.14	0	1.3	9
Simple Average	3.1	167	6.9	50	0.12	17	1.0	15

Source: IMF & WB staff calculations. Baseline prices are retail prices estimated in Coady and others (2019) and include preexisting energy taxes. BAU prices for coal and natural gas are based on regional reference prices. BAU prices for electricity and gasoline are from cross-country databases. Impacts of carbon taxes on electricity prices depend on the emission intensity of power generation. GJ = gigajoule; kWh = kilowatt-hour.

Table A2c. CO_2 emissions from alternative policies relative to $50 carbon tax, 2030

	coal tax	pricing for power/industry	electricty output tax	electricity CO_2 tax	road fuel taxes	energy efficiency & fuel switching combination
Argentina	0.04	0.46	0.16	0.42	0.04	0.63
Austria	0.47	0.38	0.02	0.33	0.08	0.66
Bangladesh	0.19	0.59	0.27	0.51	0.03	0.62
Canada	0.26	0.40	0.03	0.37	0.07	0.67
Chile	0.67	0.78	0.20	0.75	0.07	0.77
Colombia	0.29	0.47	0.05	0.45	0.11	0.70
Costa Rica	0.23	0.19	0.00	0.13	0.43	0.56
Côte d'Ivoire	0.00	0.54	0.18	0.50	0.17	0.66
Cyprus	0.00	0.57	0.15	0.56	0.09	0.70
Denmark	0.58	0.66	0.00	0.66	0.04	0.83
DR	0.43	0.68	0.27	0.62	0.06	0.67
Ecuador	0.00	0.35	0.06	0.33	0.27	0.63
Ethiopia	0.31	0.37	0.00	0.24	0.22	0.62
Finland	0.78	0.80	0.07	0.77	0.03	0.85
France	0.24	0.28	0.00	0.24	0.08	0.62
Germany	0.72	0.71	0.13	0.68	0.02	0.77
Ghana	0.00	0.38	0.11	0.34	0.30	0.62
Greece	0.72	0.82	0.23	0.81	0.03	0.79
Guatemala	0.61	0.62	0.10	0.61	0.20	0.76
Iceland	0.58	0.46	0.00	0.30	0.06	0.65
Indonesia	0.68	0.72	0.27	0.68	0.12	0.71
Ireland	0.55	0.71	0.19	0.69	0.05	0.75
Italy	0.31	0.56	0.13	0.53	0.05	0.70
Jamaica	0.08	0.59	0.09	0.52	0.10	0.72
Kenya	0.31	0.40	0.00	0.30	0.25	0.65
Latvia	0.07	0.63	0.11	0.60	0.06	0.74
Lithuania	0.24	0.19	0.00	0.14	0.15	0.57
Luxembourg	0.08	0.23	0.00	0.16	0.23	0.58
Mexico	0.18	0.60	0.31	0.55	0.10	0.62
Netherlands	0.55	0.67	0.24	0.64	0.01	0.70
New Zealand	0.44	0.43	0.01	0.35	0.11	0.67
Nigeria	0.00	0.35	0.08	0.32	0.26	0.62
Norway	0.25	0.23	0.00	0.16	0.03	0.58
Panama	0.36	0.47	0.03	0.45	0.08	0.71
Paraguay	0.00	0.04	0.00	0.03	0.88	0.52
Philippines	0.82	0.85	0.24	0.81	0.05	0.79
Poland	0.91	0.77	0.28	0.75	0.01	0.73
Portugal	0.55	0.72	0.11	0.70	0.05	0.80
Spain	0.46	0.62	0.08	0.61	0.05	0.77
Sri Lanka	0.66	0.71	0.23	0.70	0.12	0.73
Sweden	0.49	0.28	0.00	0.23	0.06	0.62
Switzerland	0.06	0.17	0.00	0.12	0.15	0.56
UK	0.33	0.55	0.10	0.54	0.04	0.72
Uruguay	0.00	0.18	0.00	0.14	0.26	0.57
Simple average	**0.35**	**0.50**	**0.10**	**0.46**	**0.13**	**0.68**

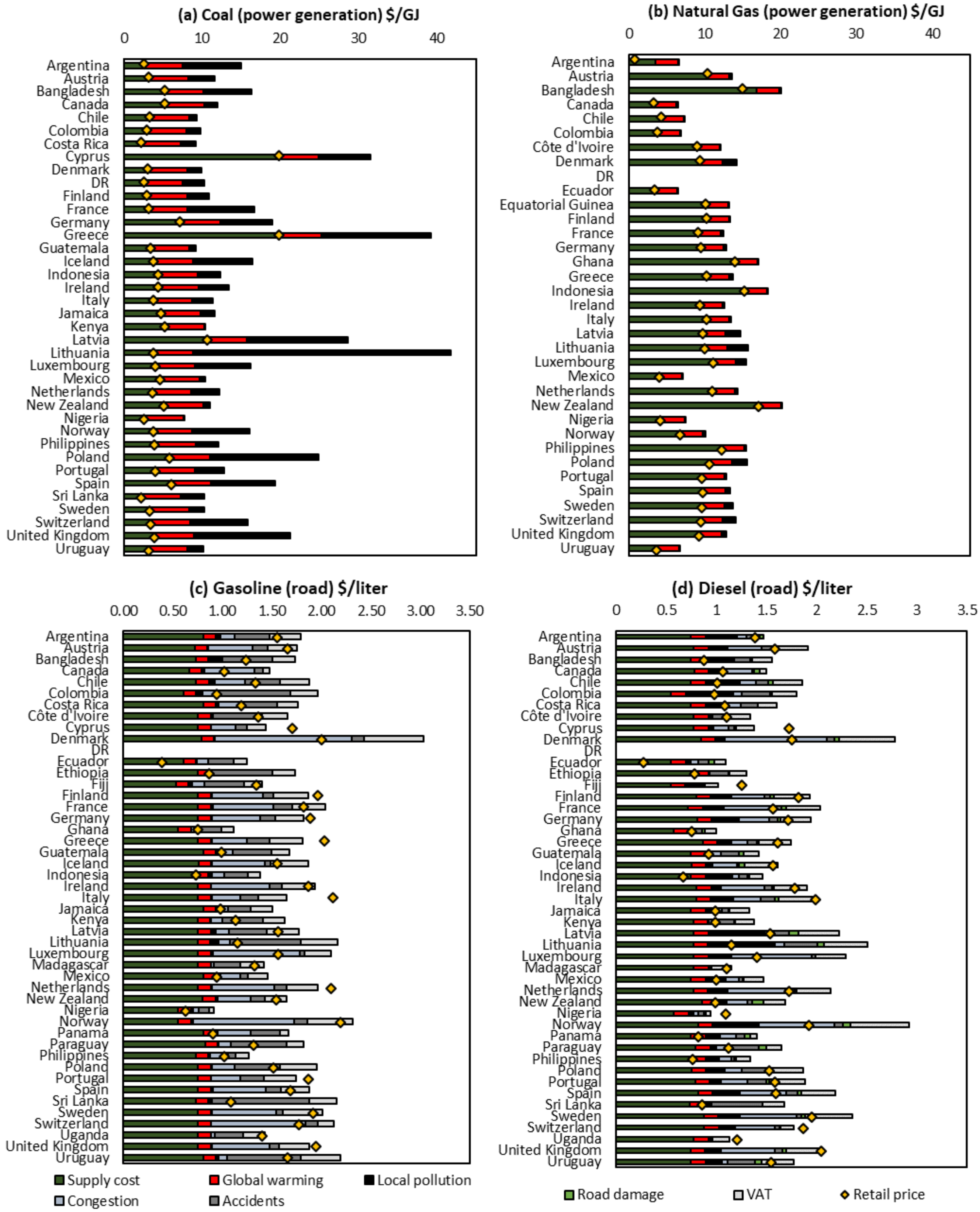
Source. IMF (2019b) where available for Colation countries.
Note. Policies are compared for the same CO_2 price increase ($50 per ton in 2030) they impose on emissions covered by the policy. For example, the coal tax increases the price of coal by $50 times tons of CO_2 per unit of coal use.

Table A2d. Revenue from alternative policies relative to $50 carbon tax, 2030

	coal tax	pricing for power & industry	electricty output tax	electricity CO_2 tax	road fuel taxes	energy efficiency & fuel switching combination
Argentina	0.01	0.27	0.24	0.22	0.16	0
Austria	0.19	0.13	0.10	0.10	0.30	0
Bangladesh	0.04	0.47	0.44	0.43	0.05	0
Canada	0.08	0.15	0.13	0.12	0.25	0
Chile	0.22	0.42	0.35	0.30	0.29	0
Colombia	0.11	0.24	0.16	0.14	0.37	0
Costa Rica	0.04	0.10	0.01	0.01	0.68	0
Côte d'Ivoire	0.00	0.31	0.27	0.25	0.33	0
Cyprus	0.03	0.40	0.37	0.35	0.24	0
Denmark	0.02	-0.01	-0.07	-0.06	0.31	0
DR	0.13	0.49	0.45	0.42	0.18	0
Ecuador	0.00	0.25	0.19	0.18	0.37	0
Ethiopia	0.07	0.21	0.00	0.00	0.40	0
Finland	0.28	0.33	0.27	0.23	0.22	0
France	0.12	0.08	0.05	0.05	0.26	0
Germany	0.28	0.24	0.24	0.20	0.17	0
Ghana	0.00	0.29	0.20	0.20	0.43	0
Greece	0.22	0.38	0.38	0.33	0.20	0
Guatemala	0.18	0.28	0.22	0.20	0.40	0
Iceland	0.15	0.15	0.00	0.00	0.26	0
Indonesia	0.21	0.37	0.31	0.28	0.31	0
Ireland	0.17	0.29	0.27	0.25	0.25	0
Italy	0.12	0.25	0.24	0.22	0.20	0
Jamaica	0.02	0.47	0.28	0.27	0.20	0
Kenya	0.07	0.20	0.06	0.06	0.49	0
Latvia	0.06	0.27	0.27	0.25	0.25	0
Lithuania	0.10	0.05	0.02	0.02	0.33	0
Luxembourg	0.06	0.02	0.01	0.00	0.48	0
Mexico	0.07	0.34	0.31	0.30	0.30	0
Netherlands	0.19	0.29	0.27	0.25	0.06	0
New Zealand	0.10	0.14	0.08	0.07	0.32	0
Nigeria	0.00	0.13	0.13	0.12	0.45	0
Norway	0.06	0.09	0.01	0.01	0.14	0
Panama	0.04	0.17	0.11	0.11	0.19	0
Paraguay	0.00	0.02	0.00	0.00	0.93	0
Philippines	0.33	0.50	0.41	0.40	0.25	0
Poland	0.50	0.32	0.34	0.27	0.18	0
Portugal	0.17	0.27	0.27	0.24	0.25	0
Spain	0.13	0.20	0.19	0.17	0.24	0
Sri Lanka	0.25	0.45	0.44	0.40	0.36	0
Sweden	0.20	0.11	0.04	0.04	0.26	0
Switzerland	0.01	0.04	0.01	0.01	0.36	0
UK	0.11	0.21	0.19	0.18	0.20	0
Uruguay	0.00	0.12	0.04	0.04	0.47	0
Simple average	**0.12**	**0.24**	**0.19**	**0.17**	**0.30**	**0**

Source. IMF (2019b).
Note. Policies are compared for the same CO_2 price increase ($50 per ton in 2030) they impose on emissions covered by the policy. For example, the coal tax increases the price of coal by $50 times tons of CO_2 per unit of coal use.

Figure A2. Social and private costs of fuels vs. retail prices in Coalition countries, 2018



Source. Coady and others (2019), updating for inflation. The assumed carbon damage is $50 per ton of CO2 for all countries.

References

Calder, Jack, 2015. “Administration of a U.S. Carbon Tax.” In *Implementing a U.S. Carbon Tax: Challenges and Debates*, edited by I. Parry, A. Morris, and R. Williams, Routledge, New York.

Carl, Jeremy, and David Fedor, 2016. “Tracking Global Carbon Revenues: A Survey of Carbon Taxes versus Cap-and-Trade in the Real World.” *Energy Policy* 96, 50-77.

Clements, Benedict, David Coady, Stefania Fabrizio, Sanjeev Gupta, Trevor Alleyne, and Carlos Sdralevich, editors, 2013. Energy Subsidy Reform: Lessons and Implications. International Monetary Fund, Washington, DC.

Coady, David, Ian Parry, Nghia-Piotr Le, and Baoping Shang. 2019. “Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates.” Working Paper 19/89, International Monetary Fund, Washington, DC.

IEA. 2020. “Global Energy Review 2020: The Impacts of the Covid-19 Crisis on Global Energy Demand and CO_2 Emissions.”

IMF, 2019a. *Fiscal Policies for Paris Climate Strategies—From Principle to Practice*. International Monetary Fund, Washington, DC.

IMF, 2019b. *Fiscal Monitor: How to Mitigate Climate Change.* International Monetary Fund, Washington, DC.

IMF, 2020. *Greening the Recovery*. Special Series on Fiscal Policies to Respond to COVID-19. International Monetary Fund, Washington, DC.

IPCC, 2018. *Global Warming of 1.5 ºC*. Intergovernmental panel on Climate Change.

Jones, Benjamin and Michael Keen, 2009. *Climate Policy and the Recovery*. IMF Staff Position Note 09/28. Washington, DC.

OECD (2018), *Effective Carbon Rates 2018: Pricing Carbon Emissions Through Taxes and Emissions Trading*, OECD Publishing, Paris, https://doi.org/10.1787/9789264305304-en.

Parry, Ian W.H., Dirk Heine, Shanjun Li, and Eliza Lis, 2014. *Getting Energy Prices Right: From Principle to Practice*. International Monetary Fund, Washington, DC.

Pigato, Miria, Simon J. Black, Damien Dussaux, Zhimin Mao; Miles McKenna, Ryan Rafaty, and Simon Touboul, 2020. *Technology Transfer and Innovation for Low-Carbon Development. International Development in Focus*. World Bank, Washington, DC.

UNEP. 2019. *Emissions Gap Report 2019*.

WBG, 2019a. *State and Trends of Carbon Pricing 2019*. World Bank Group, Washington, DC.

WBG, 2019b. *Using Carbon Tax Revenues*. World Bank Group, Washington, DC.