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Still Not Getting Energy Prices Right: A Global and Country Update of Fossil Fuel Subsidies

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Still Not Getting Energy Prices Right: A Global and Country Update of Fossil Fuel Subsidies

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Abstract

This paper provides a comprehensive global, regional, and country-level update of: (i) efficient fossil fuel prices to reflect supply and environmental costs; and (ii) subsidies implied by charging below efficient fuel prices. The methodology improves over previous IMF analyses through more sophisticated estimation of costs and impacts of reform. Globally, fossil fuel subsidies were $5.9 trillion in 2020 or about 6.8 percent of GDP and are expected to rise to 7.4 percent of GDP in 2025. Just 8 percent of the 2020 subsidy reflects undercharging for supply costs (explicit subsidies) and 92 percent for undercharging for environmental costs and foregone consumption taxes (implicit subsidies). Efficient fuel pricing in 2025 would reduce global carbon dioxide global carbon dioxide emissions 36 percent below baseline levels, which is in line with keeping global warming to 1.5 degrees, while raising revenues worth 3.8 percent of global GDP and preventing 0.9 million local air pollution deaths per year. Accompanying spreadsheets provide detailed results for 191 countries.

JEL Classification Numbers: Q31; Q35; Q38; Q48; H23

Keywords: fossil fuel subsidies; efficient fuel prices; supply costs; climate change; local air polution mortlaity; revenue gains; spreadsheet tools.

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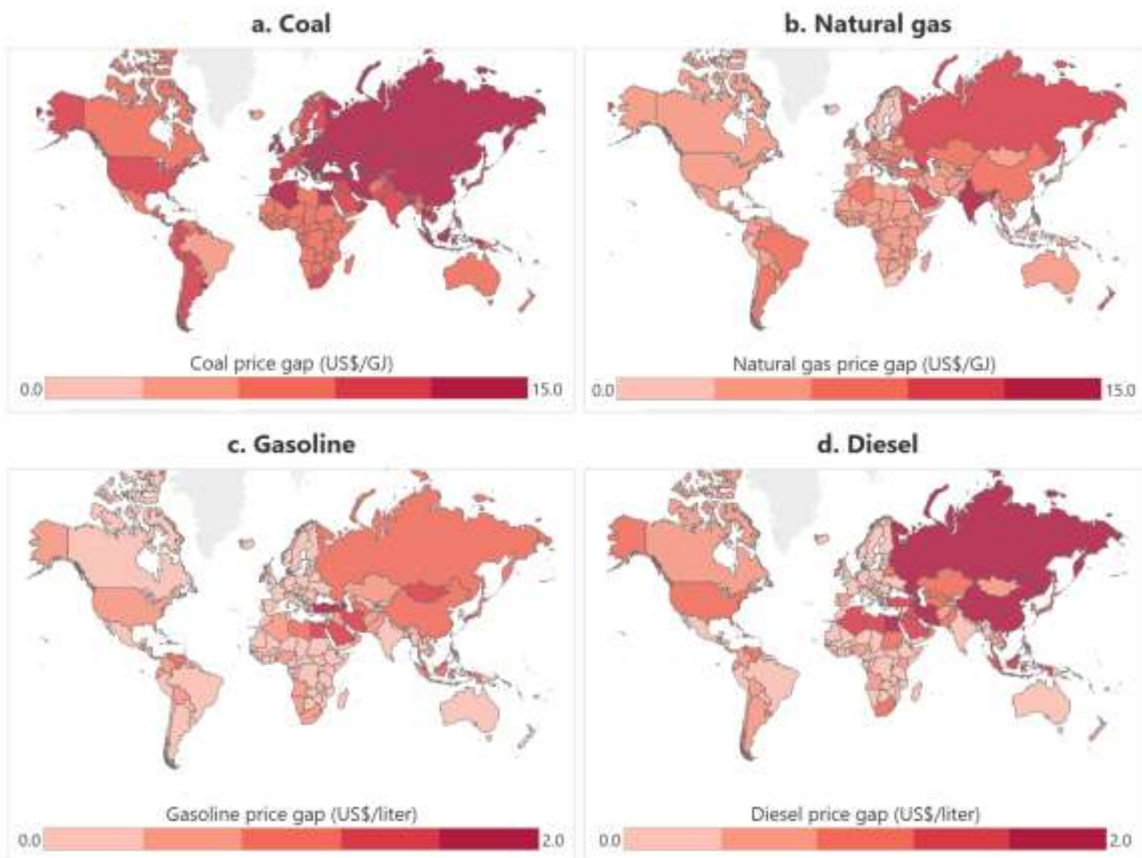
I. Executive Summary

Getting fossil fuel prices right is critical for efficiently allocating an economy's scarce resources and investment across sectors and activities- the efficient price includes both the supply and environmental costs of fuel use. Underpricing leads to overconsumption of fossil fuels, which accelerates global warming and exacerbates domestic environmental problems including losses to human life from local air pollution and excessive and road congestion and accidents. This has long been recognized, but globally countries are still a long way from getting energy prices right.

This updated analysis for 191 countries finds:

- Gaps between efficient prices and user prices for fossil fuels remain large and pervasive. No country is fully pricing all fuels in line with their full supply and environmental costs. The largest price gaps are generally for coal, followed by natural gas, diesel, and gasoline (Figure ES1).

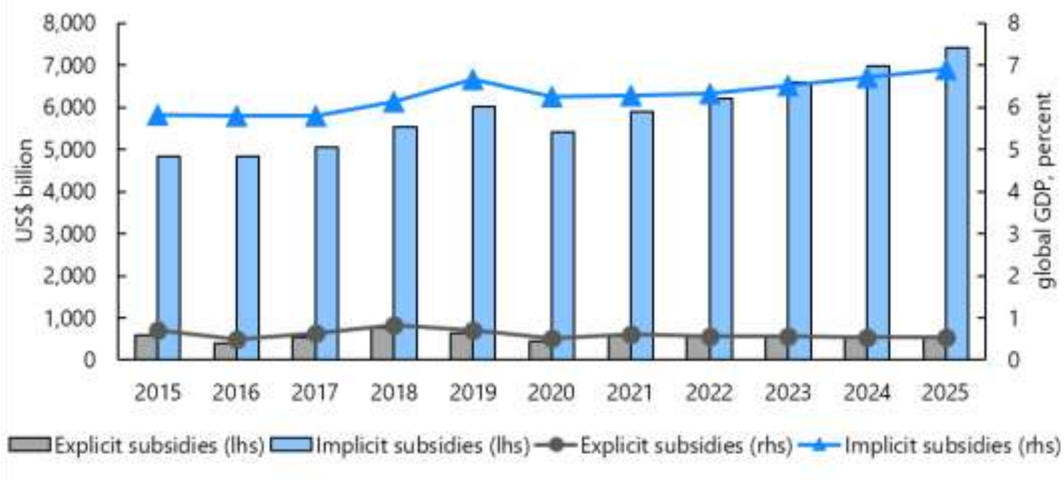
Figure ES1. Gaps between efficient prices and user prices for fossil fuels by country, 2020



Source. IMF staff.

- Globally, fossil fuel subsidies are were $5.9 trillion or 6.8 percent of GDP in 2020 and are expected to increase to 7.4 percent of GDP in 2025 as the share of fuel consumption in emerging markets (where price gaps are generally larger) continues to climb (Figure ES2). Just 8 percent of the 2020 subsidy reflects undercharging for supply costs (explicit subsidies) and 92 percent for undercharging for environmental costs and foregone consumption taxes (implicit subsidies).

Figure ES2. Global Fossil Fuel Subsidies Over Time

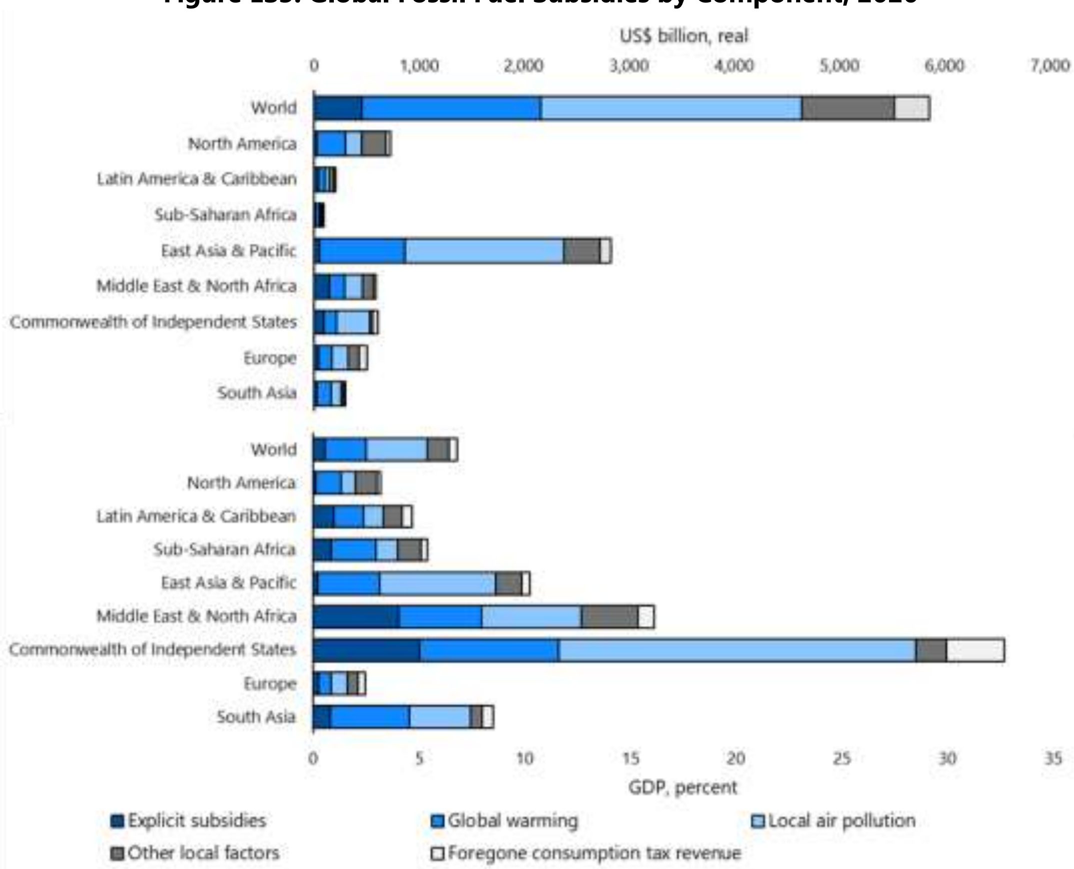


Source. IMF staff.

Note. 2019 and 2021 onwards use projections for fuel use and fuel prices, respectively.

- Underpricing for local air pollution costs is the largest contributor to global fossil fuel subsidies (Figure ES3), accounting for 42 percent, followed by global warming costs (29 percent), other local externalities such as congestion and road accidents (15 percent), explicit subsidies (8 percent) and foregone consumption tax revenue (6 percent).

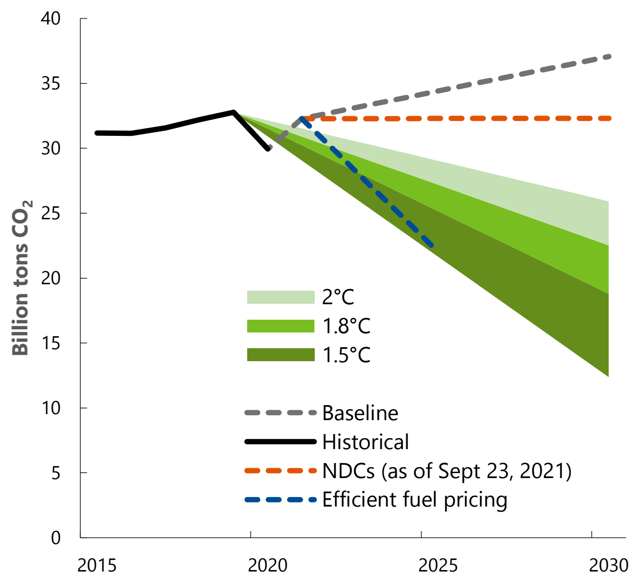
Figure ES3. Global Fossil Fuel Subsidies by Component, 2020



Source. IMF staff.

- Efficient fuel pricing by 2025 would reduce global carbon dioxide (CO_2) emissions 36 percent below baseline levels, equivalent to a 32 percent cut below 2018 levels. This is in line with keeping global warming to 'well below' 2 degrees and towards 1.5 degrees (Figure ES4).

Figure ES4. Global CO2 Pathways for Temperature Targets

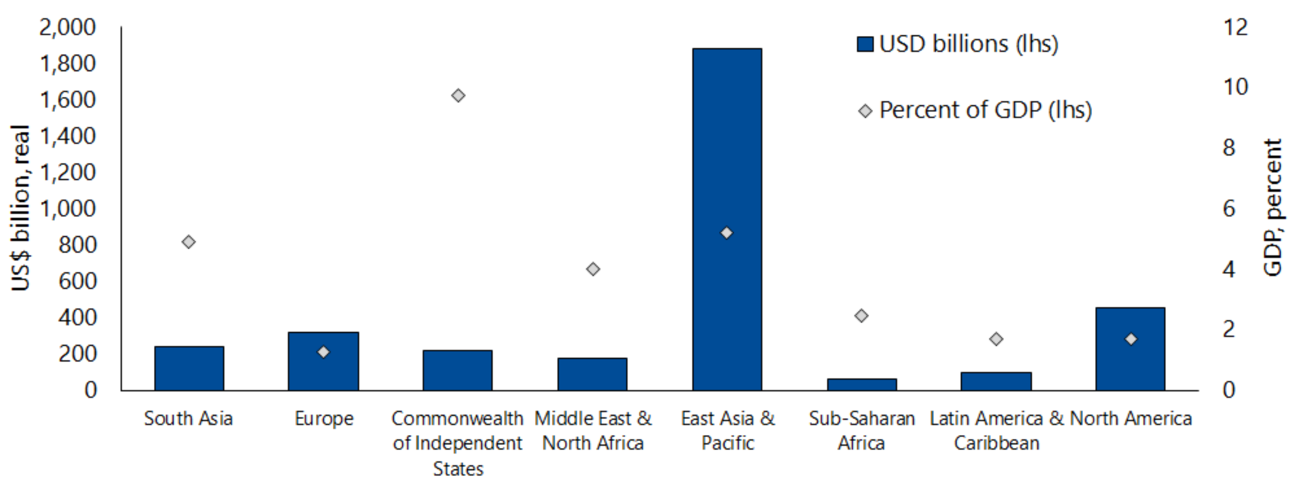


Source. IMF staff and IPCC (2021).

Note. Warming pathways assume energy-related national CO2 emissions are reduced in proportion to total greenhouse gas emissions. NDCs = Nationally Determined Contributions.

- Efficient fuel pricing would raise substantial revenues, worth 3.8 percent of global GDP (Figure ES5), while averting 0.9 million premature deaths per year from local air pollution.

Figure ES5. Global Fossil Fuel Subsidies by Component, 2020



Source. IMF staff.

II. Introduction

Getting fossil fuel prices right is critical for efficiently allocating an economy's scarce resources and investment across sectors and activities. The right price is the socially-efficient price that reflects the full societal costs of fuel use—not just the supply costs (e.g., labor, capital, and raw materials) but also the environmental costs, including carbon dioxide (CO_2) emissions, local air pollution, and broader externalities associated with fuel use (e.g., road congestion), as well as general taxes applied to household products. Underpricing fossil fuels not only undermines domestic and global environmental objectives but is a highly inefficient policy for helping low-income households[2] and has a sizable fiscal cost—too little revenue is raised from fuel taxes, implying other taxes or government deficits must be higher or public spending lower.

Fossil fuel price reform could not be timelier. All 191 parties to the Paris Agreement are submitting revised mitigation pledges ahead of COP26 in November 2021—many have made substantial commitments for 2030 and have specified emissions neutrality targets for mid-century (Table 1, third and fourth columns). Meanwhile, local air pollution concentrations remain stubbornly high, often far above safe levels recommended by the World Health Organization (PM2.5 below 10 µg/m3), and air pollution causes substantial premature mortality in many countries (Table 1, fifth and sixth columns). Government debt, moreover, is now at historically high levels—mostly around 50-100 percent larger (relative to GDP) in 2020 than in 2007 (Table 1, seventh and eighth columns).

The principle that fossil fuel prices should be set efficiently, and that fiscal instruments must be central in 'correcting' the major environmental side effects of fossil fuel use, is well established. Underpinning the policy recommendations is the notion that taxation (or tax-like instruments) can influence behavior—in much the same way that taxes on cigarettes discourage their overuse, appropriate taxes can discourage overuse of environmentally harmful energy sources. Putting this principle in practice, however, requires a practical methodology and associated tools for quantifying the efficient price, fuel by fuel, and country by country. This methodology can then be used to assess the:

- Extent of price changes needed to reach their efficient levels through corrective taxes;
- Environmental, fiscal, health, and economic impacts of price reform; and
- Magnitude of current fossil fuel subsidies, which helps to inform and sharpen domestic and international dialogue on the need for fuel price reform.

Although environmental costs are subject to uncertainty and controversy, they are a key component of the societal costs of fossil fuel use and therefore it is important to factor an unbiased estimate of them into fuel prices. A transparent and practical methodology enables

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[2] Across a wide range of countries, around 90 percent or more of the benefits from lower fuel prices accrue to households in the top four income quintiles (e.g., Coady and others 2015).

individual governments to infer efficient fuel prices, understand their key determinants, and perhaps use their own judgement about some of the underlying parameter values.

Table 1. Climate, Air Pollution, and Fiscal Background, Selected Countries

	Climate Targets			Local air pollution		Fiscal	
Country	**Submission Round[a]**	**Mitigation pledge for Paris Accord[b]**	**Neutrality Target**	**Urban fine particulate conc. ($\mu g/m^3$), 2020**	**Premature deaths from fossil fuel combustion, 2020**	**General government debt (% GDP)**	
						2007	**2020**
Argentina	Second	Net emissions cap of 359 $MtCO_2e$ in 2030	2050[e]	12	18,319	62	103
Australia	Second	Reduce GHGs 26-28% below 2005 by 2030	na	7	5,129	10	63
Brazil	Second	Reduce GHGs 43% below 2005 by 2030	2050	12	84,043	64	99
Canada	First	Reduce GHGs 30% below 2005 by 2030	2050	7	9,779	67	118
China	First	Reduce CO2/GDP 60-65% below 2005 by 2030	2060	49	1,708,644	29	67
Costa Rica	Second	Net emissions cap of 911 $MtCO_2e$ in 2030	2050	18	1,491	27	68
Ethiopia	Second	Reduce GHGs 12.4%(41.1%) below BAU by 2030*	2050[e]	34	78,247	42	55
France	Second	Reduce GHGs 55%[c] below 1990 by 2030	2050	11	22,793	65	113
Germany	Second	Reduce GHGs 55%[c] below 1990 by 2030	2045	11	43,407	64	69
India	First	Reduce GHG/GDP 33-35% below 2005 by 2030	na	78	1,664,565	74	90
Indonesia	First	Reduce GHGs 29%(41%) below BAU in 2030	na	19	196,831	32	37
Iran	First	Reduce GHGs 4%(12%) below BAU in 2030	na	38	52,474	14	43
Italy	Second	Reduce GHGs 55%[c] below 1990 by 2030	2050[e]	15	36,570	104	156
Jamaica	Second	Reduce GHGs 25.4%(28.5%)below BAU by 2030[d]	2050[e]	15	1,538	114	106
Japan	Second	Reduce GHGs 25.4% below 2005 by 2030	2050	13	59,266	173	256
Korea	Second	Reduce GHGs 24.4% below 2017 by 2030	2050	27	24,321	27	49
Mexico	Second	Reduce GHGs 22%(36%) below BAU in 2030	2050[e]	19	61,749	37	61
Morocco	First	Reduce GHGs 17%(42%) below BAU by 2030	na	33	35,944	51	76
Russia	Second	Reduce GHGs 70% below 1990 by 2030	na	12	123,529	8	19
Saudi Arabia	First	Reduce GHGs 130 MtCO2e below BAU by 2030	na	67	18,510	17	32
South Africa	First	Reduce GHGs 398-614 MtCO2e in 2025 and 2030	na	28	34,900	27	77
Turkey	First	Reduce GHGs 20%(25%) below BAU by 2030	na	27	60,233	38	37
United Kingdom	Second	Reduce GHGs 68% below 1990 by 2030	2050	9	24,948	42	104
United States	Second	Reduce GHGs 50-52% below 2005 by 2025	2050	7	114,956	65	127
Vietnam	Second	Reduce GHGs 9%(27%) below BAU by 2030	na	21	71,755	32	47

Sources: UNFCCC (2021), IMF (2021), IMF staff calculations.

Notes: [a]First and second round are 2015/16 and 2020/21 new or updated NDCs. [b]Targets conditional on international support are in brackets. [c]EU wide target. [d]Jamaica's reduction targets are limited to the energy sector (supply and end-use) and land-use change and forestry. [e]Target has been discussed but is not yet featured in policy documents. NDCs= Nationally Determined Contributions. na= not applicable. µg= micrograms. m^3= cubic meters.

In a series of previous reports, IMF staff developed such a methodology by compiling, from various sources, extensive country-level data on fuel prices, taxes/subsidies, fuel use, and a diverse range of parameters underlying environmental costs (e.g., local air pollution emissions rates, local population exposure to pollution). The first report (Parry and others 2014) found that most fossil fuel products, in most countries, were underpriced, with the degree of underpricing generally most severe for coal.

Subsequent papers (Coady and others 2015, 2019) updated data sources, refined the methodology, and provided country, regional, and global estimates of fossil fuel subsidies.

Importantly, Coady and others (2015) introduced the concepts of narrow or 'pre-tax' subsidies and broad or 'post-tax' subsidies where the former reflected (most importantly) underpricing for supply costs and (less importantly) subsidies for fossil fuel producers, while the latter also included underpricing for (most importantly) environmental costs and (less importantly) general consumption taxes. Coady and others (2019), for example, put global post-tax subsidies at a striking $4.7 trillion in 2015[3], or 6.3 percent of world GDP, with only 5 percent of this figure reflecting pre-tax subsides. This paper uses a slightly different terminology[4], referring to explicit subsidies as undercharging for supply costs and producer subsidies (i.e., pre-tax subsidies), and implicit subsidies as undercharging for environmental costs and general consumption taxes (i.e., post tax subsidies less pre-tax subsidies).

In principle, fine-tuned instruments can more effectively address some of the environmental costs of fossil fuel use, compared with a per unit fuel charge[5]—for example, fees on local air emissions from coal plants promote use of end-of-pipe abatement technologies as well as switching from coal to other fuels, while coal taxes promote only the latter response. Institutional capacity constraints (e.g., for monitoring emissions) may however limit the viability of fine-tuned instruments. In the interim, raising fuel prices provides a 'second-best' response and, moreover, may be combined with other measures (e.g., rebates for coal plants with abatement technologies) to better mimic the effects of fine-tuned instruments.[6]

Increasing fossil fuel prices is also difficult politically, not least because of the burden it imposes on vulnerable groups. A comprehensive strategy, for example with measures to assist low-income households, displaced workers, trade-exposed firms/regions, and the use of revenues from price reform to boost the economy in an equitable way, can improve acceptability.[7] Most likely however, countries will need a balance between higher fossil fuel prices and reinforcing sectoral measures that are less efficient but avoid significantly higher energy prices (e.g., feebates to alter the relative price of clean/polluting vehicles or activities). Again, however, having some sense of the efficient set of fuel prices can guide the setting of implicit prices in these reinforcing instruments and it provides a benchmark for assessing the trade-offs involved in alternative packages of pricing and sectoral measures.

This paper provides a comprehensive update of: (i) efficient fossil fuel prices by country; (ii) fossil fuel subsidies at the country, regional, and global level; and (iii) the environmental, fiscal, and economic impacts of fuel price reform. Selected results are presented below, while a full set of

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[3] In 2015 US$. All other monetary figures below are expressed in 2021 US$.

[4] Based on the suggestions of colleagues at the IMF and other international organizations.

[5] To efficiently price a fuel, the per-unit tax is set at the gap between supply costs and the efficient price.

[6] The effect of regulations and other non-pricing policies is incorporated in efficient fuel price estimates through, for example, data on emission rates and supply costs.

[7] Clements and others (2013), Coady and others (2018).

country-level results is available from accompanying spreadsheets.[8] Besides utilizing all the latest data, the paper improves over prior methodologies by:

- Using more refined, country-specific estimates of fuel prices and supply costs, including prices disaggregated by end-use sector, more granular, country-specific import and export-parity prices (with less reliance on international reference prices), and additional fuels such as liquified petroleum gas (LPG);
- Making use of new of methodologies for quantifying local air pollution damages by country that account for meteorological factors affecting local air quality;
- Integrating the analysis into the Carbon Pricing Assessment Tool (CPAT)—see Annex A—which enables future projections of efficient prices, fuel consumption, and impacts of subsidy reform (projections have greater salience for prospective policy reforms); and
- Expanding coverage to 191 countries.

The main results of the discussion can be summarized as follows:

- *Underpricing of fossil fuels is still pervasive across countries and is often substantial, especially for coal.* Coal has high carbon and local air pollution damages (though the latter vary considerably across countries). At the global level, 99, 52, 47, and 18 percent of coal, (road) diesel, natural gas, and gasoline consumption is priced at below half of its efficient level in 2020, respectively.
- *At the global level, total (explicit plus implicit) fossil fuel subsidies are $5.9 trillion in 2020, or 6.8 percent of GDP.* Assuming current policies, projected (total) subsidies rise to 7.4 percent of GDP in 2025 with the growing share of global fossil fuel consumption in emerging market economies (EMEs), where local pollution costs tend to be larger. Explicit subsidies were $0.45 trillion in 2020 (and are larger than reported in prior IMF studies due to methodological improvements)[9] but implicit subsidies remain by far the most important component accounting for 92 percent of the total.
- *Underpricing for local air pollution and climate damages are the two biggest sources of subsidies, accounting for 42 and 29 percent of the global total in 2020, respectively*. Other components include undercharging for broader externalities (15 percent), supply costs (8 percent), and general and consumption taxes (6 percent).
- *The power generation sector is the largest recipient of subsidies*, receiving 61 and 33 percent of coal and natural gas subsidies, respectively. Electricity subsidies are evenly split across industrial and residential users (due to retail prices that are below cost-recovery levels).

[8] See www.imf.org/en/Topics/climate-change/energy-subsidies and https://www.imf.org/-/media/Files/Topics/Environment/energy-subsidies/fuel-subsidies-template-2021.ashx

[9] For example, electricity subsidies reflecting end-user prices below cost-recovery levels were estimated for all countries, rather than relying on third-party estimates that covered a narrow set of countries.

- *By region East Asia and the Pacific accounts for 48 percent of total energy subsidies.* And by country, China remains the biggest subsidizer in absolute terms, followed by the US, Russia, India, and the EU.
- *With efficient fuel prices in 2025,* projected global CO_2 emissions are reduced 36 percent below baseline levels, fossil fuel air pollution deaths 32 percent (saving 0.9 million lives annually), tax revenues are higher by 3.8 percent of global GDP, and there are net economic benefits (environmental benefits less economic costs) of 2.1 percent of global GDP.

The rest of the paper is divided into two main sections, the first covering conceptual and measurement issues and the second presenting the main findings.

III. Conceptual and Measurement Issues

This section first provides a brief recap of efficient fuel prices and fossil fuel subsidies from a conceptual perspective,[10] and then discusses the measurement of environmental costs. Computational procedures and other data are discussed in Annex A and B.

A. Conceptual Issues—a Quick Recap

(i) Defining Efficient Fuel Prices

The efficient price per unit of a fossil fuel product is given by:

{[unit supply cost] + [unit environmental cost]} × [1 + general consumption tax rate, if applicable]

Each component is discussed below.

Supply costs. For a non-tradable product (which is largely the case for electricity), the supply cost is the domestic production cost, inclusive of any transportation, processing, distribution costs, and margins. In contrast, for an internationally tradable product the supply cost is the opportunity cost of consuming the product domestically rather than selling it abroad—this is measured here by the import- or export-parity price (for fuel importing and exporting countries respectively), with adjustments for domestic margins.

Environmental costs. The environmental costs of coal, natural gas, and liquid fuel combustion include global climate and local outdoor ('ambient') air pollution damages. For all fuels, the climate damage is the fuel's CO_2 emissions factor times the damage per unit of CO_2 emissions. CO_2 emissions factors for a given fuel vary only modestly across countries when expressed per

[10] For more detailed discussion see Parry and others (2014) on efficient fuel pricing and Coady and others (2015, 2019) on fossil fuel subsidy definitions.

unit of energy, though the emissions factor is about 25 and 45 percent lower per unit of energy for liquid fuels and natural gas than for coal, respectively.[11]

The major local air pollutants from coal include: (i) directly emitted fine particulate matter, with diameter less than 2.5 micrometers ($PM_{2.5}$), which is small enough to enter to the lungs and bloodstream; (ii) sulfur dioxide (SO_2) and nitrogen oxide (NO_x), which react in the atmosphere to form $PM_{2.5}$ indirectly; and (iii) (low-lying) ozone formed, for example, from volatile organic compounds (VOCs) like benzene.[12] The local pollution damage per unit of fuel use is the fuel's emissions factor for each pollutant, times the damage per unit of emissions, and aggregated over all pollutants. Emissions factors can vary substantially across countries depending on the use of end-of-pipe control technologies and fuel quality (e.g., bituminous coal has higher sulfur content than lignite and anthracite). Burning natural gas produces only one local pollutant, NO_x.

For road fuels, CO_2 emissions per liter are about 16 percent higher for diesel than for gasoline—for both fuels CO_2 emissions can be moderately reduced by blending them with biofuels (our data accounts for this but not for partially offsetting land-use CO_2 emissions). Combusting gasoline and diesel can also produces direct $PM_{2.5}$, SO_2, NO_x and VOCs and again emission rates vary across countries depending on the stringency of (new and used) vehicle emission rate standards and fuel quality—emission rates are generally much lower for gasoline than diesel.

More broadly, use of road fuels in vehicles is associated with other externalities, most importantly traffic congestion and accidents and (less importantly) wear and tear on the road network (the nature of these externalities is discussed below). In principle, all three externalities are most efficiently addressed through various km-based charging systems (e.g., km-based fees rising and falling over the rush hour on congested roads or that vary with driver/vehicle accident risk), however until such systems are comprehensively implemented (which no country has done to date) fuel taxes remain a valid (albeit blunt) second-best instrument.[13] Efficient fuel taxes are however lower to the extent tax-induced reductions in fuel use come from improvements in fleet average fuel economy and shifting to electric vehicles (EVs), rather than reduced vehicle km travelled. Externalities for non-road uses of other oil products and LPG (e.g., for home heating, off-road vehicles, petrochemicals) are limited to CO_2 and local pollution and are calculated separately. For oil product consumption that could not be allocated to one of the four oil products analyzed—gasoline, on-road diesel, LPG and kerosene—the local air pollution and climate externalities are assumed to be equal to the average of the four oil products, weighted by consumption.

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[11] EIA (2021).

[12] Fuel combustion causes other local pollutants, but their damages are relatively modest. For example, carbon monoxide does not harm human health when it is produced in open spaces.

[13] Parry and others (2014). Indeed, excluding km-based externalities from efficient fuel tax computations leads to perverse policy implications (e.g., that EU countries should dramatically cut fuel taxes).

Finally, environmental costs from electricity consumption are taken to be zero—global and local pollution are attributed to the fuel inputs, while only a tiny share of electricity consumption is presently used for road vehicles (hence the associated congestion and accident externalities are tiny when expressed relative to total electricity consumption).[14]

General consumption taxes. Standard IMF guidance is to apply the same value added tax (VAT), or general consumption taxes, to all household products as this avoids distorting relative consumer prices—and the VAT should be applied to the full social cost (supply and environmental cost). Under this approach, revenue is raised from general consumption taxes without distorting relative prices and hence the choice between different goods (accounting for the full social cost of producing them).[15]

(ii) Defining Explicit and Implicit Fossil Fuel Subsidies

The explicit subsidy for a fuel, in a sector, in a country, is defined by:

{[sectoral unit supply cost] - [price paid by fuel user]} × [sectoral fuel consumption]

And the total explicit and implicit subsidy is defined by:

{[sectoral efficient fuel price] - [price paid by fuel user]} × [sectoral fuel consumption]

Given the focus here on underpricing, if a user price exceeds the supply cost the explicit subsidy is counted as zero (rather than negative) and where the price exceeds the efficient level the total subsidy is counted as zero. Subsidies are then aggregated across sectors (power generation, industry, transportation, and residential), fuels (coal, natural gas, gasoline, diesel, kerosene, LPG, and other oil products), and countries. Under the above definition, undercharging for VAT is counted as an implicit subsidy. Producer subsidies (e.g., favorable tax treatment for fossil fuel extraction) are included in explicit subsidies, though they play a relatively small role.

B. Measurement Issues—an Update

This subsection considers in turn the quantification of climate, local air pollution, and broader externalities and some caveats—other data, including a new method for collecting prices and supply costs are described in Annex B.

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[14] There are a variety of other externalities associated with production and use of fossil fuels that are beyond the scope of the analysis because: (i) they are generally small when expressed per unit of fuel consumption (e.g., despoiling of the natural environment during fuel extraction, oil spills, emissions leakage during fuel distribution and storage; (ii) in some cases the nature of the externality is not well defined (e.g., oil security, indoor air pollution where those affected by the pollution also cause it); and (iii) some of these problems are better addressed through policies other than fuel taxes. See NRC (2009), Ch. 2 and Parry and others (2014), Ch. 2.

[15] See for example Crawford and others (2010).

(i) Climate Change

Three alternative approaches have been used in the economics literature to value CO_2 emissions:

- The social cost of carbon (SCC), which measures the present discounted value of the worldwide damage (e.g., to agriculture, coastal activities, ecosystems, human health) from future warming associated with an extra metric ton of CO_2 emissions. Despite three decades of study, however, SCC estimates remain contentious, not least because they are highly sensitive to: (i) assumptions about intergenerational discounting; and (ii) the modelling of low probability, but catastrophic climate change (e.g., due to possible tipping points within the climate system). One recent assessment puts the SCC at $51 per ton in 2021 in a central case, rising to $62 by 2030,[16] but others dispute this.[17]
- The price on global CO_2 emissions consistent with a least-cost trajectory to meet global temperature stabilization goals. Again, there is a sizable modelling literature, but with uncertainties reflecting alternative scenarios for: (i) the growth of global CO_2 emissions in the baseline; and (ii) the price responsiveness of CO_2 emissions. A widely cited review put the value of CO_2 emissions consistent with a 2°C warming target at $40-80 per ton in 2020, rising to $50-100 per ton by 2030.[18]
- The prices implicit in national mitigation pledges. These have been estimated on a country level basis, though: (i) estimates vary substantially across countries from well over $75 per ton in 2030 in some countries, to between $25-75 in others, and well below $25 in some cases; and (ii) national mitigation pledges currently fall well short of what is needed at the global level to be on track with temperature stabilization goals.[19]

For the purposes of this study, which presents cross-country comparisons, it is helpful to have a common carbon price across countries, and the second approach above seems the more solid for this purpose given that it is grounded in temperature goals that are the centerpiece of the Paris Agreement, which was signed by 195 parties. The analysis below assumes a carbon price of $60 per ton in 2020—a lower bound value given the goal to limit warming to well below 2°C (prices for intervening or earlier years are inferred assuming prices rise annually at $1.5 per ton).

(ii) Local Air Pollution

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[16] US IAWG (2021).

[17] Notably on the modelling underlying these estimates – see Pindyck (2017), Stern (2006), Weitzman (2011).

[18] Stern and Stiglitz (2017). Updated estimates in Parry and others (2021) suggest little change in the needed global prices for 2030.

[19] For example, IMF (2019a, b), Parry and others (2021).

The dominant component of local air pollution costs, and the focus here, is elevated mortality risks for exposed populations inhaling (direct and indirect sources of) $PM_{2.5}$.[20]

The Global Burden of Disease (GBD) regularly reports estimates of premature deaths from local air pollution by country and risk—the most recent global total was 4.5 million for outdoor air pollution in 2019 with 92 and 8 percent due to $PM_{2.5}$ and ozone respectively and two-thirds of deaths among people aged 65 and over (who have higher prevalence of pre-existing conditions).[21] In aggregate, about 60 percent of outdoor air pollution deaths are attributed to fossil fuels, but (unlike the approach below) GBD does not decompose the contribution from individual fuels.[22] Estimates of air pollution costs by fuel product used below are based on several sources of information.

First, the baseline rates of mortality for illnesses that are worsened by exposure to local air pollution. This is available by type of illness, age class (25-64 and 65 and above), and region (urban/rural) for 204 countries and county groupings from GBD. These illnesses include ischemic heart disease (28 percent of the global total premature deaths in 2019), stroke (26 percent), chronic obstructive pulmonary disease (20 percent), lower respiratory infections (11 percent), and trachea/bronchitis/lung cancers (6 percent), with the remainder attributed to other sources. Baseline mortality rates vary significantly across countries—they can be relatively high in countries with higher prevalence of heart and lung disease (e.g., from alcohol and cigarette abuse) and lower in countries where people are relatively less likely to live long enough to suffer from pollution-related illness.

Second, the emissions factors for local air pollutants from use of fossil fuels in different sectors. These are obtained from the International Institute for Applied Systems Analysis for years 2020 onwards.[23] There is extensive cross-country documentation of emission rates for the power and transport sector (where there are data gaps they are filled using comparable countries), but this is less true of the industrial and residential sectors—where there are data gaps for these sectors power sector emission rates are used.[24] The emission rates for power and transport represent an average over newer sources (that may have advanced emissions control technologies) and older sources (that do not). In general, these emissions factors tend to decline over time as older

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[20] Mortality risks typically account for 85 percent or more of the total estimated damages from outdoor air pollution (e.g., NRC 2009, Ch. 2). Other damage categories include, for example, non-fatal illness, impaired visibility, crop damage, building corrosion.

[21] IHME (2020). Indoor air pollution caused another 2.3 million deaths.

[22] See for example Karagulian and others (2015)—other sources include burning crop residue and natural dust. Considerable uncertainties surround local air pollution deaths however, for example, Vohra and others (2021) estimated global outdoor air pollution deaths from fossil fuels at 10 million in 2012.

[23] Based on the Greenhouse Gas—Air Pollution Interactions and Synergies (GAINS) model. See Wagner and others (2020).

[24] This likely gives conservative emission rate estimates as control technologies for the industrial and household sectors are less common than for the power sector.

capital is retired, though on-road emission rates for diesel vehicles have been revised upwards (given recent evidence that these rates exceeded new vehicle standards).

The third source of information is a measure of population exposure to local pollution. This study averages results from two different methodologies—one based on 'intake fractions', and the other local air quality modeling—where each have their own strengths and weaknesses.

The intake fraction is the proportion of (direct and indirect) $PM_{2.5}$ emitted from a fuel product that, on average, is inhaled by exposed populations—estimates here use intake fractions from Parry and others (2014). For coal and natural gas plants, these fractions are from spatial data on the location of power plants in different countries[25] matched to granular data on population density at different distances from each plant (up to 2,000 km away, within and across borders), and regression coefficients indicating how intake fractions at different distances vary with population density. For vehicle and building emissions (which generally remain close to ground level rather than being transported through the atmosphere), intake fractions were extrapolated nationwide from a database of (ground-level) intake fractions for over 3,000 urban areas. Intake fractions tend to be high in densely populated countries and where emissions sources are located inland, and lower on the coast as a large portion of emissions dissipate without harming local populations. Fixed coefficients are used to translate intake fractions into increased rates of mortality from pollution-related illness based on linearizing concentration response functions.[26]

The local air quality modelling approach involves computational modelling of how emissions released from a particular location affect air quality (from $PM_{2.5}$ and ozone) and mortality risk in other regions. The results here are based on TM5-FASST, a downscaled 'source-receptor' model applied at the country level.[27] The air quality modelling approach is more sophisticated than the intake fraction approach in that it accounts for: (i) local meteorological and topographical factors influencing ambient pollution concentrations; and (ii) possible non-linearities in concentration response functions. On the other hand, air quality modelling is less granular for the application of fossil-fuel related sources like power plants—this implies less precision in measuring population sizes potentially exposed to fossil fuel-related pollution.

The final source of information is attaching a monetary value to health risks which is contentious, but necessary to factor health risks into energy prices. The approach draws on the OECD (2012) meta-analysis of several hundred stated preference studies on health risk valuations in different

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[25] Data was available for 110 countries—intake fractions for other countries were inferred from those for comparable countries in the region.

[26] These functions indicate how mortality rates for illnesses increase with higher pollution concentrations.

[27] TM5-FASST (the TMF-FAst Scenario Screening Tool, see Van Dingenen and others 2018) is based on a linearized version of TM5, a detailed model of emissions transport and atmospheric chemistry leading to pollution formation. The original source-receptor matrices in TM5-FASST are separated into 56 regions which are downscaled to obtain country-specific matrices and supplemented with local source apportionment studies which estimate the contribution of sources such as fossil fuels to baseline concentrations.

countries which (after updating for inflation and real per capita income growth) implies a value of around $4.6 million per death avoided for 2020 in the average OECD country. This figure is extrapolated to other countries based on their per capita income relative to the OECD average and an assumed unitary elasticity for the mortality value with respect to per capita income.[28]

(iii) Broader externalities for transportation[29]

As regards road congestion, it is standard to assume that motorists factor average delays into their driving decisions but not marginal delays (i.e., their impact on adding to congestion, slowing speeds, and adding to delays for other road users). Assessing how much fuel taxation is warranted by congestion requires a nationwide measure of marginal congestion costs. In the absence of a consistent cross-country database on nationwide delays, the analysis here relies on an earlier rudimentary set of average delay estimates per vehicle km extrapolated from a city-level database. Average delays are then multiplied by: (i) estimated relationships between marginal and average delays; (ii) vehicle occupancy (averaging over cars and buses); (iii) people's value of travel time (VOT) (assumed to be 60 percent of the nationwide average market wage in 2020); (iv) fuel economy (to express costs on a per liter basis); and (v) the portion of the fuel demand elasticity that comes from reduced driving (and therefore affects congestion) versus the portion that comes from improved fuel economy/shifting to EVs (that does not affect congestion).[30]

With regards traffic accidents, a portion of the costs are commonly viewed as internal to drivers (e.g., own-driver injuries in single vehicle collisions) while other costs are external (e.g., injury risks to pedestrians, elevated risks to occupants of other vehicles from multi-vehicle collisions, property and medical costs borne by third-parties). Externalities are measured[31] by apportioning country-level data on traffic fatalities into external versus internal risks, monetized them using the above approach for mortality valuation, extrapolating non-fatality accident costs to other countries from several country case studies, and expressing the result per unit of fuel use (making adjustments for the km-based portion of fuel price elasticities). Coady and others (2019)

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[28] See Robinson and others (2018), Tables 3.1 and 3.3. and Viscusi and Masterman (2017). Extrapolations are based on purchasing power parity income, which takes local price levels into account to more accurately reflect people's willingness to pay for risk reductions out of their own income. Mortality valuations may also differ across countries with differences in life expectancy, health, religion, culture, economic and social support and so on, however the effects of these factors are not well understood (Robinson and others 2018).

[29] Where data is unavailable for quantifying the externalities below (e.g., for many African countries) values are inferred from an average of countries with a similar per capita income level in the region.

[30] Checks against more reliable estimates from detailed data on travel delays by road class, which are available for the UK and US, suggests the average delay estimates are broadly reasonable. Further adjustments are made to account for the relatively weaker responsiveness of driving on congested roads (which is dominated by commuting) to fuel taxes than driving on free flowing roads and the share of buses and trucks in the vehicle fleet (which contribute more to congestion per vehicle km). See Parry and others (2014), Ch. 5.

[31] See Parry and others (2014), Ch 5.

updated accident externalities with more recent traffic fatality data and these estimates are used after updating to 2020 for fatality/injury valuations.

Finally, externalities from wear and tear on the road network imposed by high axle-weight vehicles are taken from the update in Coady and others (2019), which are based on highway maintenance expenditures and an assumption that half of these expenditures are attributed to vehicle use as opposed to weather and natural deterioration.

(iv) Caveats

The significant uncertainties surrounding the valuation of environmental costs should be borne in mind—for example, each of the sequential linkages between the burning of a fuel and changes in the mortality rates for exposed populations all involve plenty of data uncertainties and there are differing views on how to value the associated health risks. Nonetheless, environmental costs are just as real as supply costs, and undercharging for an unbiased (albeit uncertain) estimate of them is tantamount to undercharging for the true social costs of consumption. The estimates presented here should be viewed as indicative—the implications of alternative views on underlying parameters should be largely transparent from the discussion and the online spreadsheet tools.

IV. Results

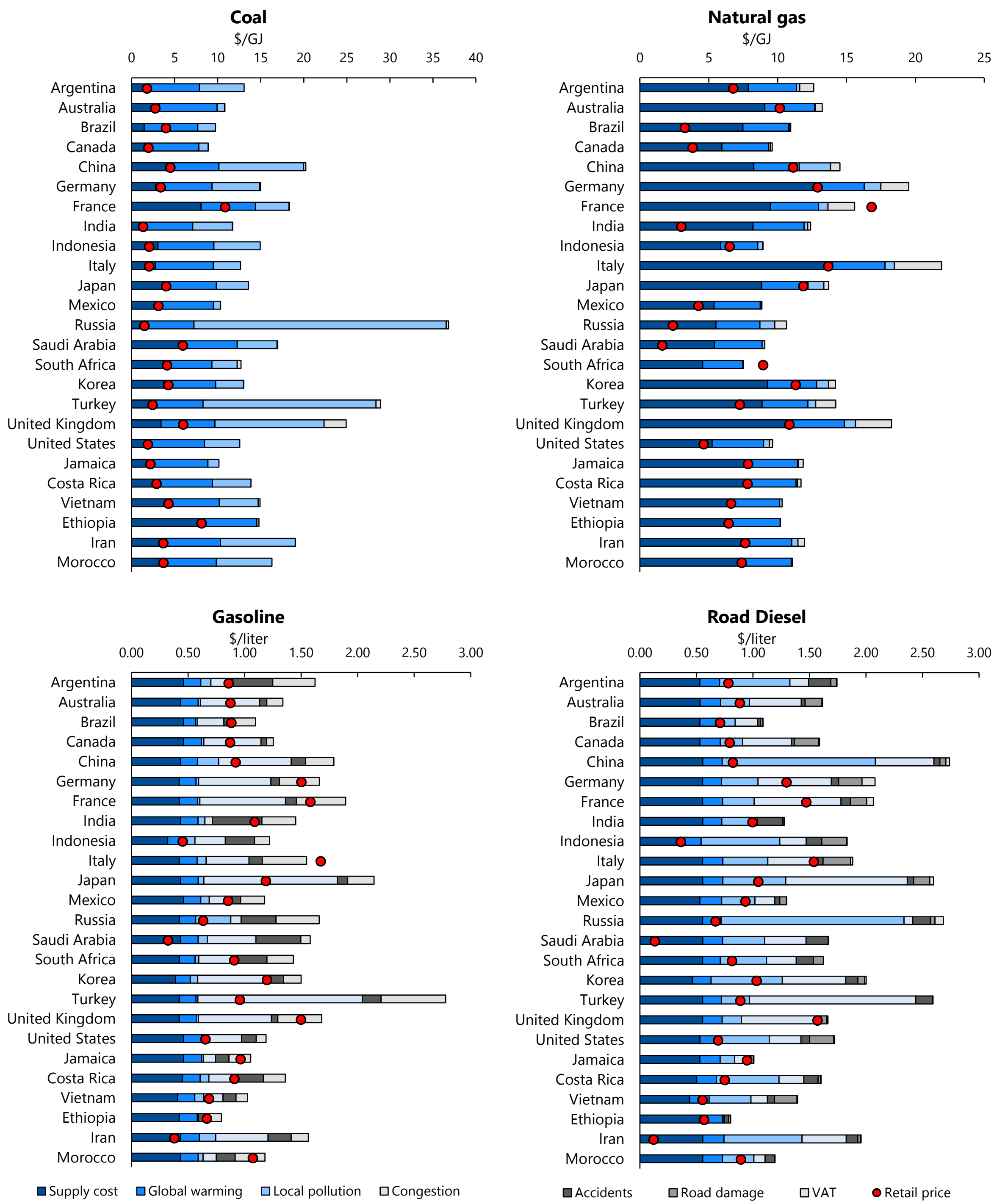
Three sets of results are presented below: (i) a comparison of current and efficient prices for fossil fuel products for selected countries; (ii) the size of fossil fuel subsidies over time and by product, component, and sector at global and regional level; and (iii) the environmental, fiscal, and economic welfare impact of fuel price reform at global and regional level. Results are mostly presented for 2020, the last year of available price data,[32] though historical and future trends and reform impacts projections are also presented. Full country results are available online.

A. Comparing Current and Efficient Fossil Fuel Prices

Figure 1 shows estimates of current and efficient fuel prices, with the latter broken down by component, for coal, natural gas (averaged over uses by power, industry, and households, weighted by consumption), gasoline, and (road) diesel (the latter averaged over light- and heavy-duty vehicles) for 25 countries, including all the Group of Twenty (G20) countries, and for year 2020. Figure 2 indicates the cumulative fraction of global fuel consumption (aggregating over 191 countries) that is underpriced at or below a given ratio of the current fuel price to the efficient price. Estimates of fuel taxes include carbon taxes and emissions trading systems (ETSs). Some noteworthy points from both figures are discussed below.

[32] The last year for observed fuel consumption is 2018 so fuel use for 2020 is projected, though subsidy estimates are not very sensitive to year-to-year variation in fuel consumption.

Figure 1. Current and Efficient Fuel Prices, 2020



Source. IMF staff.

Notes. Prices for coal and natural gas average over fuel consumption in the power generation, industrial, and residential sectors, while prices for gasoline and diesel are for road fuel consumption only (diesel averages over uses in light- and heavy-duty vehicles). Congestion, accident, and road-damage externalities are scaled by the fraction of fuel price elasticities reflecting changes in driving (as opposed to changes in fuel economy).

(i) Coal and Natural Gas

Even when coal is compared on an energy equivalent basis, supply costs (averaged across sectors) differ significantly across counties (e.g., with local productivity, labor costs, accessibility of extraction sites, transportation costs to end users) from around $1.5 per gigajoule (GJ) in Russia and the United States to $7 per GJ (e.g., Jamaica, Ethiopia). This variation is largely irrelevant for our purposes, however, as fuel user prices are typically at least as large as supply costs, implying no explicit subsidies.

Generally, the pricing of environmental costs for coal use is modest at best, as indicated by the generally small difference between coal prices and supply costs in Figure 1. This largely reflects a lack of coal excises[33] and carbon pricing—though pricing in Canada, the EU, and Korea amounted to coal taxes of $2.1, 3.1, and 2.3 per GJ in 2020 (and prices, especially in Europe, have risen since 2020).

Nonetheless, global warming damages alone are equivalent to $6.3 per GJ or around 100-300 percent of supply costs. Local air pollution damages can also be large, but there is substantial variation across countries due to differences in local emission rates, population exposure to pollution, and health risk valuation—local air pollution damages exceed 150 percent climate of damages in 4 cases in Figure 1 (e.g., China, Russia) but are less than 50 percent of climate damages in 6 cases (e.g., Australia, Canada, Mexico). Coal is mostly an intermediate product, so the VAT component to the efficient coal price is modest at best.

Supply costs for natural gas (again averaged across sectors) also vary significantly by country (given the fragmented global market for natural gas), from around $5 per GJ in the US to around $12 per GJ in (gas-importing) Japan and Korea. Prices fall short of supply costs in nine countries in Figure 1 (most prominently in Canada, India, Russia, and Saudi Arabia) and exceed supply costs in another seven cases (most prominently Australia, China, France, Italy, Japan, and South Africa)[34] and in two of those cases prices (moderately) exceed their efficient levels.

Carbon damages are around one third to one half of supply costs for natural gas, much lower than for coal, reflecting both higher supply costs per GJ for gas and lower emission rates per GJ. And unlike for coal, local air pollution damages from natural gas are generally modest (below $1 per GJ in all but four cases). The VAT component of efficient natural gas prices is also modest when averaged over electricity, industrial, and household uses (though for household consumption alone it contributes around 10-20 percent of the efficient price).

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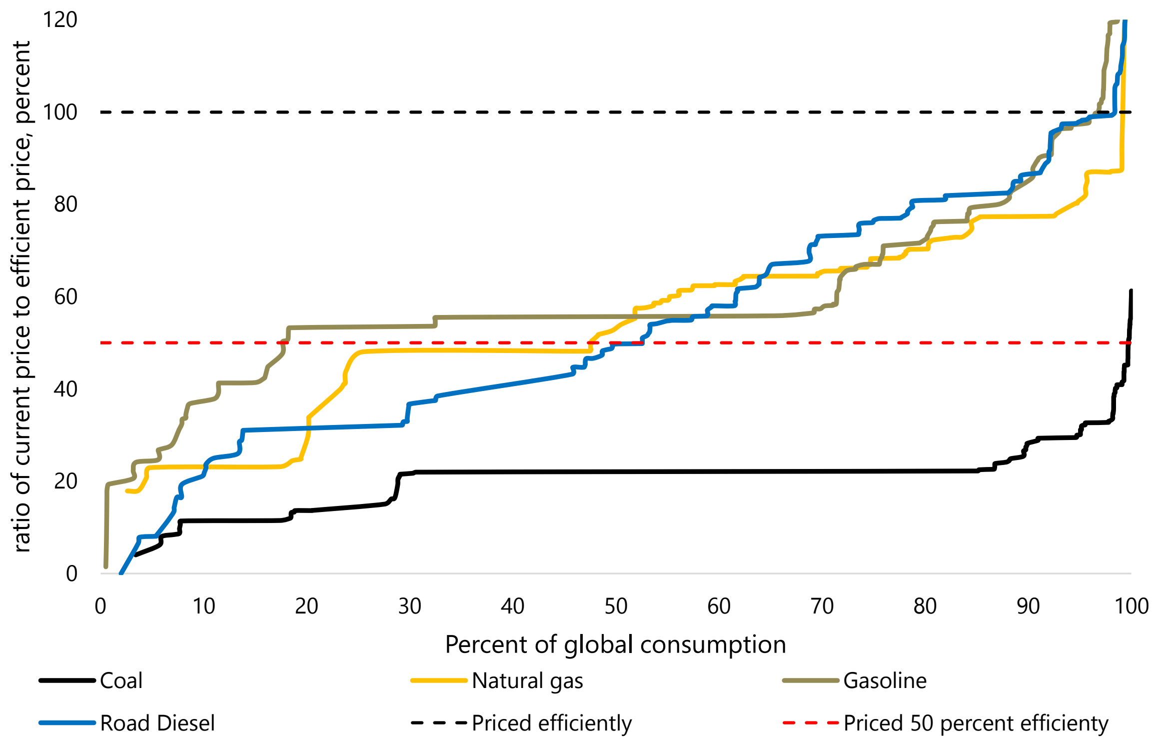
[33] 22 out of the 191 countries in our database impose excises on coal, but at generally modest rates.

[34] 42 countries in our full database impose excises on natural gas, but again at generally modest rates.

Figure 2. Fossil Fuel Pricing and Consumption Relative to Efficient Prices



Source. IMF staff.

Note. The flat portion of the gasoline curve is consumption for China and the US (47 percent of the global total) where the gap to efficient prices for both countries is about the same. The flat portion for coal is China.

In short, there is substantial and pervasive underpricing for the environmental costs of coal use, and to a lesser extent, natural gas. Taking a consumption-weighted average across all countries in our database (Figure 2), 99 and 47 percent of coal and natural gas consumption respectively is priced at below half of its efficient level.

Going forward, carbon damages per GJ of fuel use will rise (given the rising price on CO_2 emissions on trajectories consistent with least-cost global temperature stabilization). More likely than not, local air pollution damages per GJ may decline over time with declining emission rates (e.g., as dirtier plants with laxer regulations are retired)[35] though this trend may be partially offset with growth in urban population exposure and in real per capita income (the latter increases mortality risk valuations).

[35] Local air pollution damages in China and India would be 60 and 80 percent lower respectively if air emission rates in these countries were comparable to those in Australia and the US.

(ii) Gasoline and Diesel

There is little variation in supply costs for road fuels across countries, given the integrated world market for petroleum products—supply costs in 2020 were around $0.50 per liter for both fuels across countries illustrated in Figure 1 in 2020. Road fuel prices exceed supply costs in all but two countries (Iran and Saudi Arabia), as most countries impose excises on road fuels. Indeed, for gasoline, prices exceed supply costs by around 50 percent or more in all but five countries in Figure 1, and by over 100 percent in 13 countries (France, Germany, Italy, UK, etc.). Most countries impose lower taxes per liter on road diesel than gasoline[36]—indeed road diesel prices exceed supply costs by 50 percent or more in only 12 countries in Figure 1.

Carbon damages amount to $0.15 and $0.17 per liter for gasoline and diesel respectively, about one third of supply costs. Local air pollution damages are generally small relative to carbon damages for gasoline. In contrast, for diesel vehicles local air pollution damages were typically 1-3 times as large as carbon damages in 2020. Congestion and accident externalities combined are relatively large for gasoline, together warranting charges of around $0.5-$1.0 per liter—congestion tends to be the larger externality in densely populated advanced countries (partly because of high VOTs) and accidents in developing countries (partly because of high incidences of pedestrian fatalities).

For diesel, combined congestion and accident externalities per liter are somewhat smaller as a significant portion of diesel fuel is used in heavy-duty vehicles which are driven fewer km on a liter of fuel (though a partially offsetting factor is the higher congestion costs per km for these vehicles as they take up more road space). The VAT component of the efficient fuel price is significant for gasoline (around $0.2-0.4 per liter) but less so for road diesel (where a substantial portion of consumption is an intermediate product).

Across all countries (Figure 2), underpricing of road fuels is pervasive—for example, 70 percent of global gasoline consumption is priced at less than 60 percent of efficient levels, while 50 percent of diesel fuel is priced at less than half the efficient level. Going forward, local pollution damages for gasoline and diesel vehicles will likely decline as newer vehicles subject to stricter emissions standards permeate the fleet—more importantly however, transportation tax systems will need to be overhauled in many countries as they progressively phase out gasoline and diesel vehicles.

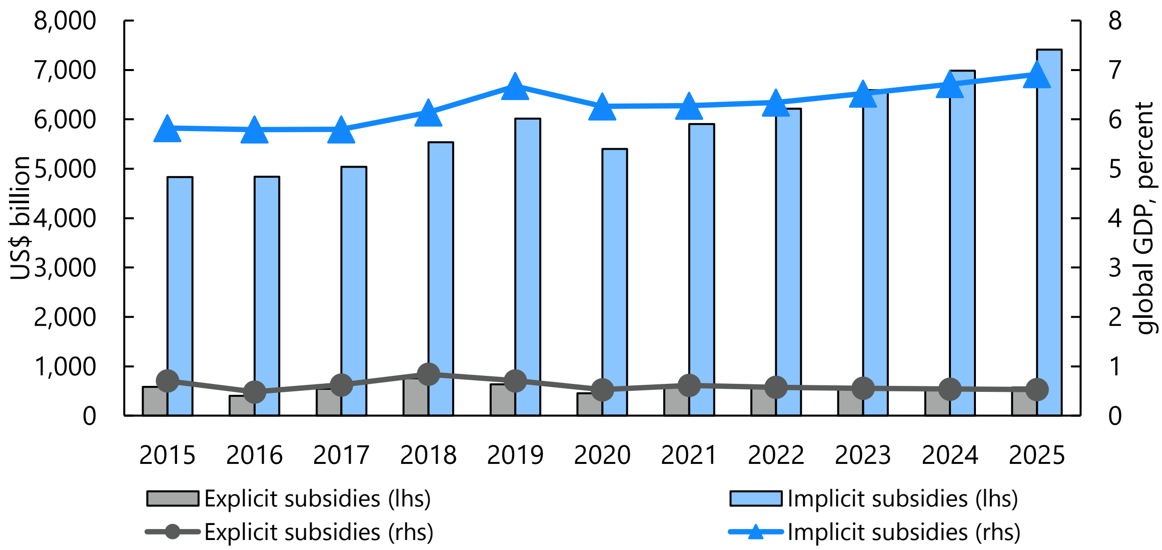
[36] One reason is to limit fuel costs for commercial users and another is that diesel vehicles are more fuel efficient—the latter is misplaced however, because carbon and local air emission rates per liter are higher for diesel than gasoline.

B. Fossil Fuel Subsidies

(i) The Global Picture

At the global level (see Figure 3), fossil fuel subsidies amounted to $5.9 trillion in 2020, or 6.8 percent of GDP, rising (on current policies) to 7.4 percent of GDP in 2025. In 2020, explicit and implicit subsidies accounted for 8 and 92 percent of the total respectively.

Figure 3. Global Fossil Fuel Subsidies



Source. IMF staff.

Note. Figures from 2019 and 2021 onwards use projections for fuel use and fuel prices, respectively.

In absolute terms, explicit subsidies peaked in 2018 at $760 billion, then fell to $450 billion in 2020, but are projected to rise and then remain at about $600 billion from 2021 to 2025. These fluctuations are largely driven by changes in international oil and natural gas prices—as international prices fall (as they did in 2019 and 2020 before rising after that) this lowers the gap between supply costs (which depend on international prices for traded products) and domestic prices in countries regulating domestic fuel prices. Estimates of explicit subsidies are larger than in previous IMF studies[37] due to methodological improvements (a larger number of countries for which price data are collected rather than assumed equal to supply costs and electricity supply costs are estimated using the CPAT model—see Annex A and B).

Implicit subsidies are projected to mildly increase in absolute terms, and as a percent of global GDP, out to 2025. Although fuel use/GDP and local air emission rates are generally falling over

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[37] For example, for 2017 explicit subsidies are $575 billion in Figure 3 above compared with $295 billion in Coady and others (2019), Figure 2.

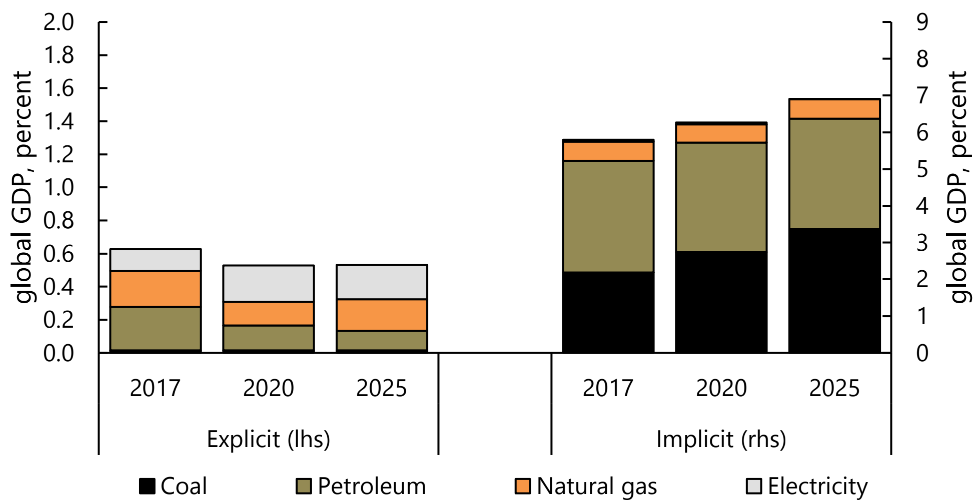
time,[38] emerging market economies (EMEs) account for a progressively rising share of global fuel consumption and local environmental costs per unit of fuel use tend to be larger in these countries.[39] Annex C compares energy subsidy estimates with those form other studies.

(ii) Breakdown by Fuel Product

Petroleum, natural gas, and electricity accounted for 28, 27 and 42 percent of the explicit global subsidy in 2020 (Figure 4), while coal accounted for just 3 percent (as coal prices generally cover supply costs). For petroleum and natural gas, explicit subsidies primarily reflect the setting of domestic prices below international prices in energy exporting countries, while the subsidy for electricity largely reflects the failure to fully reflect generation costs in domestic tariffs. Globally, only 8 percent of the explicit subsidy in 2020 reflects support for fossil fuel producers (92 percent is consumer-side subsidies).

The breakdown by fuel product looks dramatically different for total (explicit plus implicit) subsidies in 2020. Here coal accounts for 41 percent of the global total in 2020, reflecting underpricing for carbon and local air pollution damages. Petroleum accounts for 46 percent of the global subsidy, largely reflecting the failure of excises on petroleum products to fully reflect environmental costs and broader externalities. Natural gas (where environmental costs are more moderate) and electricity (where environmental costs are attributed to fuel inputs) account for 9 and 4 percent of the global subsidy, respectively.

Figure 4. Global Fossil Fuel Subsidies by Fuel



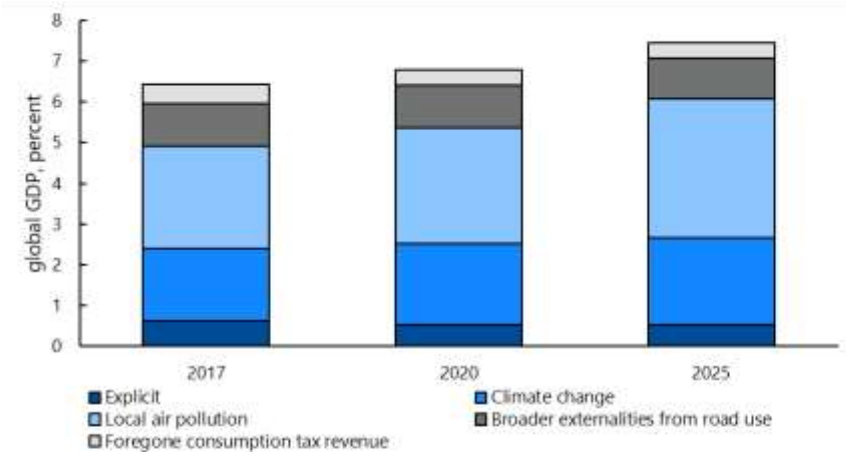
[38] The former due to improving energy efficiency and, for the most part, below unitary income elasticities for energy products.

[39] For example, the share of global subsidies from EMEs increases from 60 to 69 percent between 2015 and 2025, and for BRICs (Brazil, Russia, India and China) from 44 to 54 percent.

(iii) Breakdown by Component

Broken down by component (see Figure 5), undercharging for local air pollution, global warming, broader externalities from road use, supply costs, and general consumption taxes account for 42, 29, 15, 8, and 6 percent respectively of total (explicit and implicit) subsidies in 2020. For coal, local air pollution and global warming account for 58 and 40 percent of total subsidies respectively, while for petroleum underpricing for local air pollution and broader externalities account for 39 and 33 percent of the total subsidy respectively, and global warming a smaller 16 percent. In contrast, for natural gas global warming is 59 percent of the total subsidy.

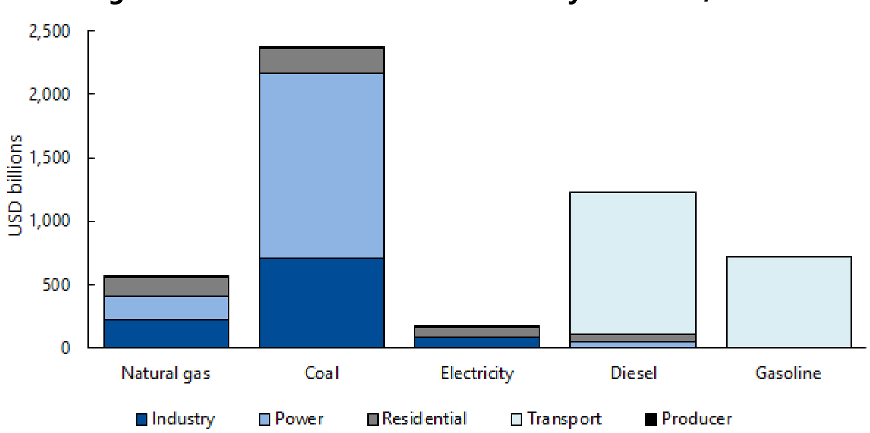
Figure 5. Global Fossil Fuel Subsidies by Component



(iv) Breakdown by End-Use Sector

Breaking down subsidies by end use sector (Figure 6), coal use in power generation (about 2/3 of total coal use) is the most significant, accounting for 25 percent of global subsidies in 2020, followed by use of diesel and gasoline in transportation (19 and 12 percent respectively), and coal use in industry (12 percent). Natural gas consumption and subsidies are concentrated in the power generation and industrial sectors, while electricity subsidies are nearly evenly split between the industrial and residential sectors. Producer subsidies are relatively small across fuels.

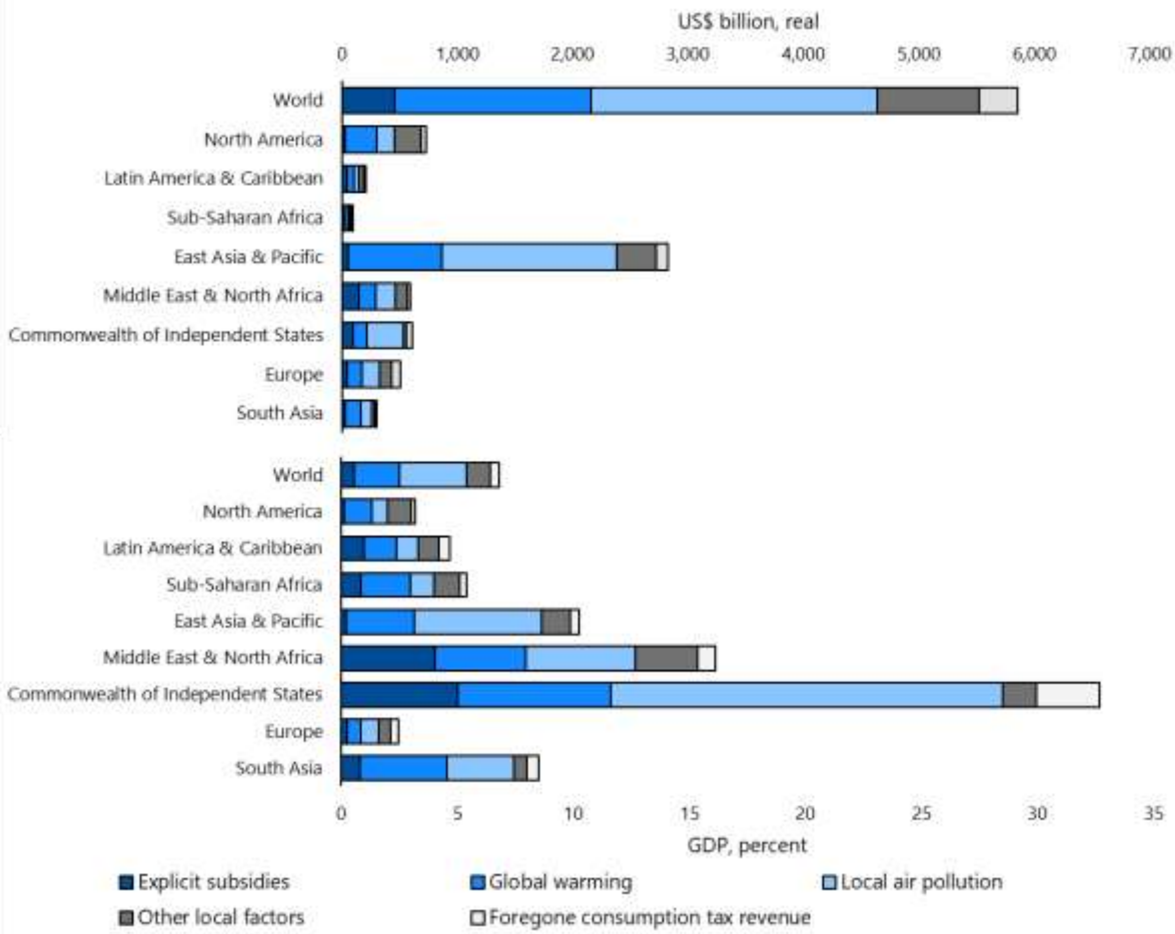
Figure 6. Global Fossil Fuel Subsidies by End-User, 2020



(v) Breakdown by Region and Country

Explicit subsidies are mostly concentrated in the Middle East and North Africa (MENA) region and Commonwealth of Independent States (CIS), accounting for 33 and 21 percent of the subsidy in 2020 (Figure 7), respectively, followed by Europe, the East Asia and Pacific (EAP), and Latin America and the Caribbean (LAC) at around 10 percent each, and South Asia, North America and Sub-Saharan Africa (SSA) accounting for 3-6 percent of explicit subsidies each—see Annex D for a list of countries in each region.

Figure 7. Global Fossil Fuel Subsidies by Component



The regional breakdown is quite different for total (explicit plus implicit) subsidies. Here EAP accounts for 48 percent of the subsidy, North America 12 percent, MENA and CIS 10 percent, Europe 9 percent, and others below 6 percent. Relative to regional GDP however, total (explicit plus implicit) subsidies for Europe are smallest at about 2 percent, while these subsidies are 32 percent of regional GDP in CIS and 16 and 10 percent respectively in MENA and EAP. The large subsidies primarily reflect, in CIS, high externality costs from coal, petroleum and natural gas use; in South Asia, low taxes and high externalities coal and natural gas use; and in MENA, substantial undercharging for supply and environmental costs of petroleum.

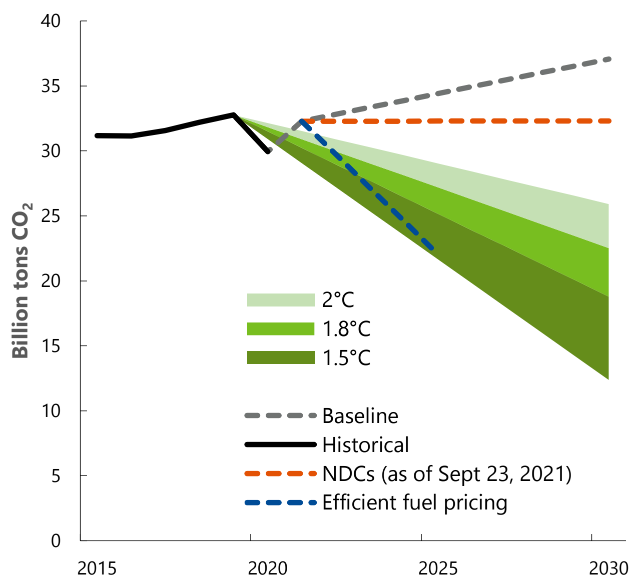
By country (see Annex E), China contributes by far the most to total (explicit plus implicit) subsidies ($2.2 trillion) in 2020, followed by the United States ($660 billion), Russia ($520 billion), the European Union ($279 billion), and India ($247 billion) . In per capita terms, subsidies are highest in Singapore ($5,411), Qatar ($4,839), Luxembourg ($4,704), Saudi Arabia ($4,548), Russia ($3,559), and Kuwait ($3,415).

C. Reform Benefits

This section discusses the impacts of increasing fuel prices to their efficient levels—a comparative static exercise that compares projected environmental, fiscal, health, and economic welfare outcomes for 2025 when prices of all fuel products for all countries are at their efficient levels with business as usual (BAU) outcomes when current fuel taxes/subsidies and carbon pricing are held fixed in real terms at their 2021 levels.

(i) Climate and Other Environmental Impacts

Figure 8. Global CO2 Pathways for Temperature Targets



Source. IMF staff and IPCC (2021).

Note. Warming pathways assume energy-related national CO2 emissions are reduced in proportion to total greenhouse gas emissions. NDCs = Nationally Determined Contributions.

Raising fuel prices to their efficient levels reduces projected global fossil fuel CO_2 emissions 36 percent below BAU levels in 2025—or 32 percent below 2018 emissions (Figure 8). This reduction is in line with the 25-50 percent reduction in global GHGs below 2018 levels needed by 2030 to be on track with containing global warming to the Paris goal of 1.5-2°C.[40] Globally, around 74 percent of the CO_2 reduction comes from reduced use of coal, while 21 and 3 percent respectively are from reductions in consumption of petroleum and natural gas—this reflects the

[40] IPCC (2018).

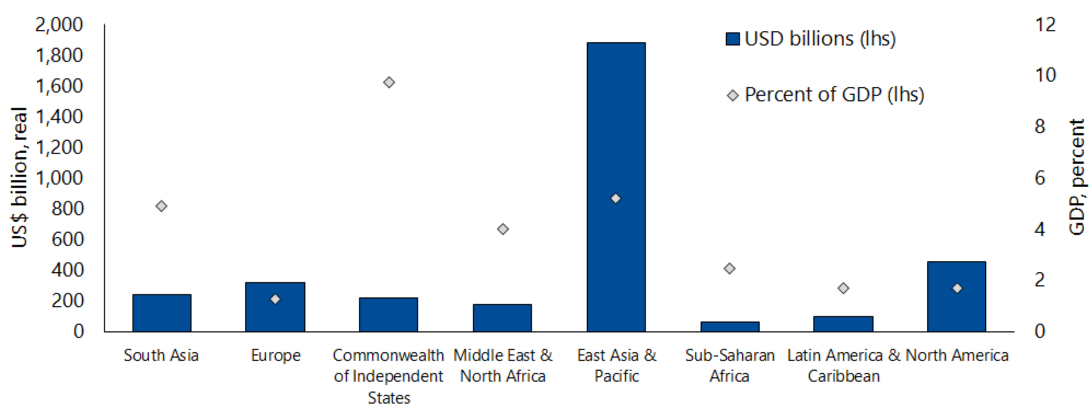
much larger proportionate increase in coal prices from fuel price reform compared with petroleum and natural gas (see Figure 1) and the larger shares of coal and petroleum in global CO_2.[41] The regional CO_2 reductions vary from 21 percent below BAU levels 2025 in Europe to around 40 percent in the CIS and EAP, with much of the differences reflecting differences in the share of coal in regional CO_2 BAU emissions. In contrast, if explicit subsidies only are removed global CO_2 are reduced by only 3 percent below 2025 BAU levels.

Full fuel price reform also reduces global air pollution deaths from fossil fuel combustion by 32 percent below BAU levels in 2025, or 0.9 million a year in absolute terms. Again, the reduction is dominated by coal (at about 75 percent) because of both the disproportionately large reduction in coal consumption and an assumed reduction in local air emissions rates[42] (hence the reduction here is proportionately larger than in the case of CO_2 emissions where CO_2 emissions factors for coal are taken as fixed). The proportionate reduction in mortality ranges from 19 percent in SSA to 63 percent in the EAP region again with the differences explained in part by differences in the BAU intensity of coal use.

(ii) Fiscal and Economic Welfare Impacts

Full price reform (see Figure 9) raises revenues of $4.2 trillion, 3.8 percent of global GDP, in 2025 (relative to BAU levels and accounting for revenue losses due to erosion of pre-existing fuel tax bases). Revenue gains vary substantially across regions, largely mirroring the distribution of (explicit and implicit) subsidies. The revenues generated by full price reform in 121 EME and developing countries in 2025 would amount to $3 trillion, which is broadly in line with their additional spending needs for Sustainable Development Goals.[43]

Figure 9. Revenue Gain from Reform

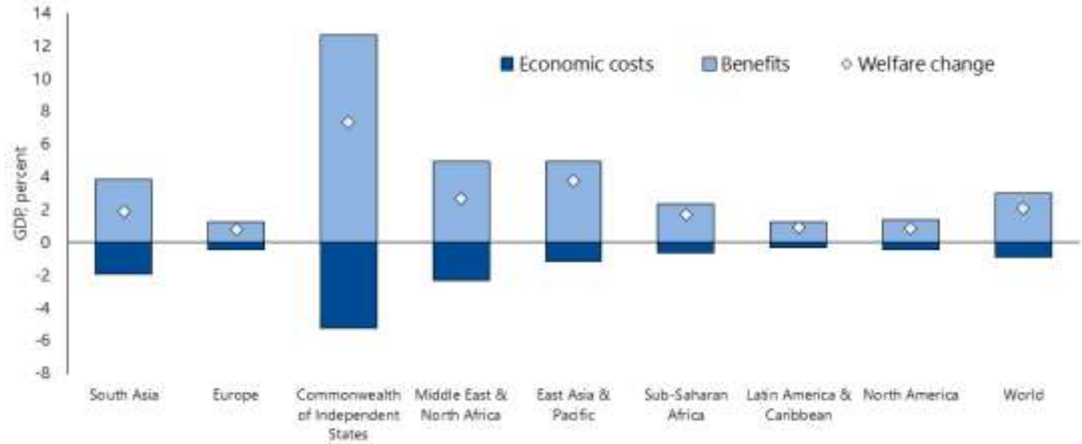


[41] Around 40 percent each in the 2025 BAU and 20 percent for natural gas.

[42] Large increases in coal taxes to reflect local air pollution costs would likely create strong incentives to rebate firms that adopted abatement technologies. The calculations therefore assume emission rates (averaged over all firms) fall to those of the cleanest firms (see above).

[43] Gaspar and others (2019).

Figure 10. Economic Welfare Impact of Reform



At the global level, full fuel price reform would generate net economic efficiency costs of 1 percent of global GDP,[44] but environmental benefits are 3.1 percent of GDP, leaving a net economic efficiency gain of 2.1 percent of GDP (Figure 10). Again, the pattern of efficiency gains by region and by fuel products is like that for total subsidies and fiscal gains.

D. Sensitivity of Results

A formal sensitivity analysis is not provided as the implications of alternative values for key parameters is often transparent, and the results would resemble the sensitivity analysis in Coady and others (2019). For example, given that global warming is $1.7 trillion (27 percent of the total global subsidy) in 2020, increasing or decreasing the value of CO_2 emissions by 50 percent would increase or decrease the global subsidy by $0.85 trillion. Similarly, since local air pollution is $2.4 trillion (38 percent of the global subsidy), increasing and decreasing the mortality risk value by 50 percent would increase and decrease the global subsidy by $1.2 trillion. And as noted by Coady and others (2019), increasing and decreasing fuel price elasticities by 50 percent would increase and decrease the CO_2, air pollution mortality, and economic efficiency benefits from fuel price reform by approximately one third (this reflects the constant elasticity specification for fuel demand curves—see Annex A).

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[44] These costs are measured by the value of forgone benefits to fossil fuel consumers less savings in supply costs (i.e., the area between the fuel demand and supply curves integrated over the fuel reduction). Equivalently, they are measured by reductions in consumer and producer surplus, less government revenue gains. A more comprehensive measure of efficiency cost would capture the net effect of interactions between fuel tax increases and distortions in the economy from the broader fiscal system—the magnitude and sign of these interactions is however sensitive to how revenues are used (e.g., Goulder and Parry 2008) and a consistent cross-country database of parameters needed for estimating them is not currently available.

V. Conclusion

It is rare to find near universal support among economists for a major policy action, but reforming fossil fuel prices is one such policy. The conceptual case for pricing externalities is clear, country-level assessments suggest mispricing of energy is pervasive, and the potential benefits from reform are substantial. Analytical frameworks like those presented here provide guidance on the direction and magnitude of needed reforms. The hard part is getting it done in practice, given opposition from impacted groups and powerful interests.

Nonetheless, a comprehensive approach incorporating a variety of supportive measures (productive use of new revenues, complementary public investments, just transition measures, etc.) can increase the acceptability, effectiveness, and credibility of reform. And success in one region or country provides a prototype that can catalyze action elsewhere. But time is of the essence—in the absence of a drastic cut in fossil fuel use over the next decade the planet will become locked into risks of dangerous and irreversible instabilities in the global climate system. Given these ubiquitous and potentially existential risks, policymakers should urgently seek to design and implement reforms which finally get energy prices right.

Annex A. Carbon Pricing Assessment Tool (CPAT)

The basic data on country level fuel consumption by sector, and fuel prices and taxes, is taken from CPAT, with updated data on prices and supply costs as described below. CPAT provides, on a country-by-country basis for 191 countries, projections of fuel use and CO_2 emissions by major energy sector.[45] This tool starts with use of fossil fuels and other fuels by the power, industrial, transport, and residential sectors[46] and then projects fuel use forward in a baseline case using:

- GDP projections;
- Assumptions about the income elasticity of demand 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
- Future international energy prices.

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

The impacts of carbon pricing on fuel use and emissions depend on: (i) their proportionate impact on future fuel prices in different sectors; (ii) a simplified model of fuel switching within the power generation sector; and (iii) various own-price elasticities for electricity use and fuel use in other sectors. For the most part, fuel demand curves are based on a constant elasticity specification.

The basic model is parameterized using data compiled from the International Energy Agency (IEA) on recent fuel use by country and sector.[47] GDP projections are from the latest IMF forecasts.[48] Data on energy taxes, subsidies, and prices by energy product and country is compiled from publicly available and IMF sources, with inputs from proprietary and third-party sources (see below). International energy prices are projected forward using an average of IEA (which are rising) and IMF (which are flat) projections for coal, oil, and natural gas prices. Assumptions for fuel price responsiveness are chosen to be broadly consistent with empirical

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[45] CPAT was developed by IMF and World Bank staff and evolved from an earlier IMF tool used, for example, in IMF (2019a and b). For descriptions of the model and its parameterization, see IMF (2019b Appendix III, and Parry and others (2021), and for further underlying rationale see Heine and Black (2019).

[46] International aviation and maritime fuels are excluded from the model and from computations of fossil fuel subsidies.

[47] IEA (2021). Any fuel consumption that could not be explicitly allocated to a specific sector was allocated apportioned based on the relative consumption by sector in a given country.

[48] A modest adjustment in emissions projections is made to account for partially permanent structural shifts in the economy caused by the pandemic.

evidence and results from energy models (fuel price elasticities are typically between about -0.5 and -0.8).

Carbon emissions factors by fuel product are from IEA. Non-carbon externalities per unit of fuel use in different sectors are based on methodologies described above and in Annex B.

One caveat is that the model abstracts from the possibility of mitigation actions (beyond those implicit in recently observed fuel use and price data) in the baseline, which provides a clean comparison of policy reforms to the baseline. 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. In addition, fuel price responsiveness is approximately similar across countries—in practice, price responsiveness may differ across countries with the structure of the energy system and regulations on energy prices or emission rates. The model also does not explicitly 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 climate or energy price reform in large countries. Parameter values in the spreadsheet are, however, chosen such that the results from the model are broadly consistent with those from far more detailed energy models that, to varying degrees, account for these sorts of factors.

Annex B. Further Details on Data and Parameters

A new approach was adopted for collecting or calculating retail prices and supply costs which is somewhat more accurate as it accounts for potential variation in prices and supply costs across different sectors.

Retail Prices

Retail fuel prices are expressed as annual averages. Prices for coal, natural gas, and electricity were disaggregated by end-user—industrial, residential, and power generation. The top two panels in Figure 1 in the main text show weighted average fuel prices (i.e., averaging over sector prices weighted by the sectoral fuel share), while the accompanying spreadsheet provides end-user specific prices.

For all fuels, retail prices are taken from IMF and World Bank country desk datasets as the prioritized source. For cases where such data was not available, a simple average across various third-party sources were used including Eurostat, the IEA, the World Bank, Global Petrol Prices, and Enerdata.[49]

[49] Eurostat Energy Statistics, 2021; International Energy Agency Energy Prices, 2020; World Bank Doing Business Indicators, 2021; Global Petrol Prices Retail Energy Price Data, 2021; Enerdata Global Energy & CO2 Data, 2021.

Still, there remained missing price data, especially for natural gas and coal, and the following steps were taken to fill in gaps. For natural gas and coal, if price data was not available for the power generation sector but available for the industrial sector, then the industrial price was used, and vice versa. If price data was still missing the retail price was assumed equal to the supply cost plus any known taxes, including import duties (weighted by the portion of fuel that is imported) and pre-retail taxes (such as an ETS).

Prices were then projected for future years using a pass-through method. The pass-through was determined using a regression with the historical retail prices on the left-side variable and historical spot prices as the right variable. The regression was restricted in the following ways: (i) historical data limited to years 2010 to 2019 to avoid the impact of COVID and potential changes to pricing policies pre-2010; (ii) countries with fewer than 5 observations for 2010-2019 were excluded; and (iii) the coefficient on spot prices were limited to between 0 and 1, and the constant term from the regression was re-estimated given this constant. For countries with fewer than 5 observations, the supply cost plus tax was used as the retail price if there was no spot price data for any year from 2010 to 2019 or a pass-through equal to the regional average was assumed if there was data for 1 to 4 years from 2010 to 2019. Pass through rates average around 50 to 60 percent.

Supply Costs

For finished petroleum products, supply costs consist of the port (or hub) prices from the IEA, with countries mapped (based on region) to either the United States, NW Europe, or Singapore. LPG is priced at a 30 percent discount to gasoline, as this is the difference between gasoline and LPG pre-tax prices for unsubsidized European markets. A shipping and distribution margin of \$0.15-\$0.22 per liter—the average of unsubsidized OECD countries—is added for all countries, and an additional \$0.10 per liter is added to land-locked and small island developing countries—roughly the average transportation cost to select landlocked poor countries.

For natural gas, supply costs are based on hub, import or net-back export prices with upward adjustments for transportation and distribution. For large natural gas consuming countries (e.g., most European and South and East Asian countries) domestic natural gas prices were available through Argus, the IEA, or Enerdata. For LNG exporters, without a well-functioning domestic natural gas market, a country-specific liquefaction and shipping fee was deducted to net-back prices from delivery abroad.[50] Countries that do not have available domestic prices were mapped to a specific regional hub price (either the US, Netherlands TTF, or Northeast Asian LNG). Mark-ups for within-country transportation, distribution, marketing, and margins were applied, with higher margins for residential users than for industrial power generation (as per the US EIA, 2021 and European Commission, 2018). These mark-ups were \$3 per GJ for power generation and

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[50] Liquefaction fees larger came from Claudio Steuer of the Oxford Institute of Energy Studies (2019), Outlook for Competitive LNG Supply. The delivery point for LNG was assumed to be Europe for West and Northern Africa, East Asia for the Middle East, Asia-Pacific, and Western Latin America, and the US for Trinidad and Tobago.

industrial users and $10 per GJ for residential users, with a slightly lower assumption for the Russia and the US due to the availability of country-specific data.

For coal, the export or import-parity price were inferred using one of three methods with prioritization given in the following order: supply costs equal to (i) the country-specific export or import prices; (ii) the pre-tax end-user price; or (iii) the price at the nearest hub. Again, mark-ups were applied for transportation, processing, and distribution, with higher mark-ups for residential coal use (mark-ups of $1, $5, and $10 for power generation, industrial, and residential users). Supply costs for countries with significant domestic production were adjusted downwards to reflect the large transportation costs associated with coal.

For electricity, supply costs were provided by IMF country desks or calculated using CPAT.

The constructed supply costs may differ from the actual supply costs, as country specific conditions vary and coal, natural gas, and electricity do not trade on global markets (to the extent that liquid fuels do). This is expected to have minimal impacts on the subsidy estimates where retail price information is not available (about 150 countries for coal and 120 for natural gas) since the supply cost and retail price are assumed to be equal and taxes are generally not applied to coal or natural gas. The only other channel that the supply costs matter is through the revenue components of the efficient prices (calculated as the consumption tax rate multiplied by the sum of supply costs and environmental externalities) and this effect tends to be small, especially since coal is not commonly used in the residential sector.

Miscellaneous data

The consumption tax component of efficient energy prices is computed by the standard VAT (or general sales tax) in each country (from IMF sources) and applied to the sum of supply and environmental cost and for final consumption only (not intermediate use). Additional data on income used for projection purposes are from IMF (2021).

Estimates of producer subsidies for fossil fuels by country are from the OECD and major energy producers (IEAa, 2021) and then projected forward using expected production from Rystad.[51]

Annex C. Comparison with Other Fossil Fuel Subsidy Methodologies

This annex compares the IMF subsidies methodology to that of the IEA and OECD and the relevant SDG indicator (12.c.1). It compliments more comprehensive comparisons, such as those in the IISD-OECD fossil fuel subsidy tracker (IISD, OECD, 2021) and UNEP guidance on measuring SDG target 12.c (UNEP, 2019), and largely focuses on technical aspects of the IMF and IEA-OECD methodologies and how the IMF estimates relate to the relevant SDG.

[51] Rystad U-Cube, 2021. https://www.rystadenergy.com/energy-themes/oil--gas/upstream/u-cube/

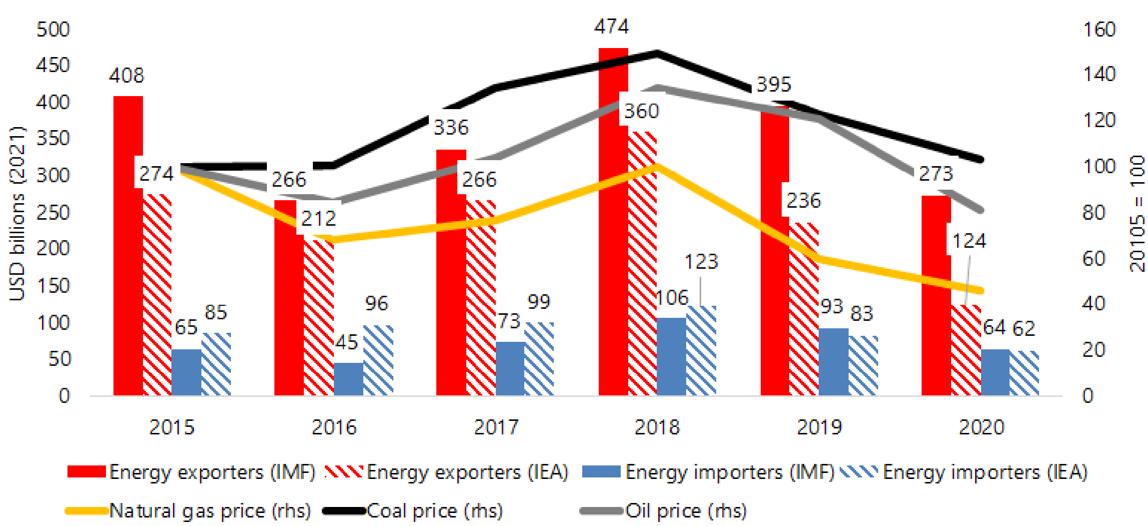
Price Gap versus the Inventory Approach

There are two general approaches to measuring fossil fuel subsidies: the price-gap and the inventory approach. The price-gap approach, which is used by the IMF and IEA (IEAb, 2021), measures a subsidy as the difference between the retail price and a calculated supply cost / reference price (i.e., the price of a fuel without any government intervention)—there is a subsidy if the retail price is less than the supply cost. The inventory approach, which is used by the OECD (OECD, 2021), measures the nominal value of individual subsidy measures (i.e., accelerated depreciation for producers, loan guarantees, and direct financial support).[52]

IEA and IMF Subsidy Estimates

The IEA subsidy estimates cover 42 non-OECD countries (compared to over 190 for the IMF) and uses a price-gap approach (IEAb, 2021). The IEA total subsidies can be directly compared to the IMF's explicit subsidy estimate as these indicators use a similar methodology, with a small discrepancy—the IEA includes VAT in the supply cost while the IMF includes VAT when calculating the implicit subsidy but not the explicit.[53] The disaggregation across fuel sources is more nuanced as the IEA accounts for underpricing of natural gas and coal for electricity generators as an electricity subsidy, while the IMF accounts for it as natural gas and coal subsidies, respectively. The IMF's implicit subsidies include the cost of externalities and, therefore, is not comparable to those of the IEA.

Figure A1. IEA and IMF Subsidy Estimates over Time



Source. IEA (2021) and IMF staff estimates.

[52] More information on the two approaches is provided in UNEP (2019) while Koplow (2009) provides an overview of specific types of subsidies that are potentially omitted when using the price-gap approach.

[53] This is likely to cause a larger difference for gasoline as other fossil fuels are generally used as an intermediate input and, thus, not subject to VAT.

A comparison of subsidies between the IEA and IMF is shown in Figure A1 and Table A1. Differences may arise for several reasons,[54] but it is difficult to disentangle the contribution of different factors. However, there are two main takeaways: (i) the changes in subsidy estimates over time are strongly correlated between the IMF and IEA; and (ii) the underlying energy price and subsidies for energy exporters are consistently higher for the IMF estimates, while there is no clear pattern for energy importers.

Table A1. Comparison of IEA and IMF Subsidy Estimates for 2018, Selected Countries , $billion

	Data source	Oil	Coal	Natural gas	Electricity	Total
All countries	IMF	105.1	5.6	78.5	148.0	337.2
All countries	IEA	92.4	1.8	37.8	53.7	185.6
Energy exporters	IMF	102.1	5.5	62.0	103.3	272.9
Energy exporters	IEA	48.4	1.4	35.2	38.9	123.9
Energy importers	IMF	3.0	0.1	16.5	44.8	64.3
Energy importers	IEA	44.0	0.4	2.6	14.8	61.7
Algeria	IMF	6.2	0.0	3.1	2.2	11.5
Algeria	IEA	5.9	0.0	1.3	1.4	8.6
China	IMF	0.0	0.0	0.2	13.7	13.9
China	IEA	22.2	0.0	0.0	3.9	26.1
Mexico	IMF	0.0	0.0	2.0	3.2	5.1
Mexico	IEA	0.0	0.0	0.0	1.7	1.7
Nigeria	IMF	0.2	0.0	0.0	1.1	1.3
Nigeria	IEA	0.4	0.0	0.0	0.0	0.4
Russia	IMF	0.1	0.0	42.1	25.1	67.4
Russia	IEA	0.0	0.0	7.0	8.0	15.0
South Africa	IMF	0.1	0.0	0.0	5.6	5.7
South Africa	IEA	0.0	0.0	0.0	0.0	0.0
Taiwan Province of China	IMF	0.0	0.0	0.9	1.7	2.6
Taiwan Province of China	IEA	0.2	0.0	0.0	0.0	0.2

Source. IEA (2021) and above estimates.

Comparison with SDG target 12.c

The SDG target 12.c states that fossil fuel subsidies should be rationalized by "removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts"

[54] Deviation could arise from: (i) different retail prices, (ii) the IMF calculating natural gas and coal subsidies for power generation, industry, and households separately (it is not clear if the IEA does this), (iii) different reference prices, and (iv) different levels of consumption.

(UNEP, 2019). The corresponding SDG indicator disaggregates subsidies into: (i) direct transfers of funds measures; (ii) tax revenue foregone and underpricing of goods and services; (iii) induced transfers; and (iv) transfer of risk to the government.

There are two key points on the relationship between the IMF subsidy calculations and UNEP definition. First, the UNEP definition states that taxation should "reflect their environmental impacts". One could interpret this as similar to the IMF's definition of explicit plus implicit subsidy where a fuel is subsidized if its tax-inclusive price is less than the supply cost plus all environmental externalities. The IMF definition also includes additional transportation externalities for gasoline and diesel. Second, there are some country-specific considerations related to what an un-subsidized fuel prices should be as implied by "in accordance with national circumstances", whereas the IMF's subsidy calculations use the same methodology across all countries.

Annex D. Regional And Classification Of Countries

Commonwealth of Independent States	**Europe (continued)**	**East Asia & Pacific**	**Latin America & Caribbean**	**Middle East & North Africa**	**Sub-Saharan Africa (continued)**
Armenia	Finland	Australia	Anguilla	Algeria	Dem. Republic of the Congo
Azerbaijan	France	Brunei Darussalam	Antigua and Barbuda	Bahrain	Republic of the Congo
Belarus	Georgia	Cambodia	Argentina	Djibouti	Ghana
Kazakhstan	Germany	China	Aruba	Egypt	Guinea
Kyrgyz Republic	Greece	Fiji	Bahamas, The	Iran	Guinea-Bissau
Moldova	Hungary	Hong Kong SAR	Barbados	Iraq	Kenya
Russia	Iceland	Indonesia	Belize	Israel	Lesotho
Tajikistan	Ireland	Japan	Bolivia	Jordan	Liberia
Uzbekistan	Italy	Kiribati	Brazil	Kuwait	Madagascar
	Kosovo	Korea	Chile	Lebanon	Malawi
North America	Latvia	Lao P.D.R.	Colombia	Libya	Mali
Canada	Lithuania	Macao SAR	Costa Rica	Malta	Mauritania
United States	Luxembourg	Malaysia	Dominica	Morocco	Mauritius
	Montenegro, Rep. of	Marshall Islands	Dominican Republic	Oman	Mozambique
South Asia	Netherlands	Micronesia	Ecuador	Qatar	Namibia
Afghanistan	Macedonia, FYR	Mongolia	El Salvador	Saudi Arabia	Niger
Bangladesh	Norway	Myanmar	Grenada	Syria	Nigeria
Bhutan	Poland	Nauru	Guatemala	Tunisia	Rwanda
India	Portugal	New Zealand	Guyana	United Arab Emirates	Senegal
Maldives	Romania	Palau	Haiti	West Bank and Gaza	Seychelles
Nepal	San Marino	Papua New Guinea	Honduras	Yemen	Sierra Leone
Pakistan	Serbia	Philippines	Jamaica		Somalia
Sri Lanka	Slovak Republic	Samoa	Mexico	**Sub-Saharan Africa**	South Africa
	Slovenia	Singapore	Montserrat	Angola	South Sudan
Europe	Spain	Solomon Islands	Nicaragua	Benin	Sudan
Albania	Sweden	Taiwan Province of China	Panama	Botswana	São Tomé and Príncipe
Austria	Switzerland	Thailand	Paraguay	Burkina Faso	Tanzania
Belgium	Turkey	Timor-Leste	Peru	Burundi	Togo
Bosnia and Herzegovina	Turkmenistan	Tonga	Puerto Rico	Cabo Verde	Uganda
Bulgaria	Ukraine	Tuvalu	St. Kitts and Nevis	Cameroon	Zambia
Croatia	United Kingdom	Vanuatu	St. Lucia	Central African Republic	Zimbabwe
Cyprus		Vietnam	St. Vincent and the Grenadines	Chad	
Czech Republic			Suriname	Comoros	
Denmark			Trinidad and Tobago		
Estonia			Uruguay		
			Venezuela		

Annex E. Total (Explicit and Implicit) Subsidies by Country

Country	Total subsidies, US$ billion	Total subsidies, % GDP	Total subsidies, per capita US$
Argentina	29	7.4	644
Australia	44	3.2	1,729
Brazil	43	2.9	203
Canada	64	3.8	1,686
China	2,203	14.7	1,569
Germany	72	1.9	863
France	30	1.1	457
India	247	9.0	179
Indonesia	127	11.8	470
Italy	41	2.1	676
Japan	170	3.3	1,348
Mexico	40	3.7	315
Russia	523	34.8	3,560
Saudi Arabia	158	22.1	4,548
South Africa	51	16.4	848
Korea	69	4.2	1,332
Turkey	117	15.9	1,387
United Kingdom	24	0.9	352
United States	662	3.1	2,006
Jamaica	0	1.1	57
Costa Rica	2	2.8	342
Vietnam	32	9.2	327
Ethiopia	2	1.6	16
Iran	153	23.6	1,815
Morocco	6	5.3	170

Source. See above.

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