INTERNATIONAL MONETARY FUND

IMF Fossil Fuel Subsidies Data: 2023 Update

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WP/23/169

2023
AUG

WORKING PAPER

WP/23/169

IMF Working Paper
Fiscal Affairs Department

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Authorized for distribution by James Roaf
August 2023

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. Globally, fossil fuel subsidies were $7 trillion in 2022 or 7.1 percent of GDP. Explicit subsidies (undercharging for supply costs) have more than doubled since 2020 but are still only 18 percent of the total subsidy, while nearly 60 percent is due to undercharging for global warming and local air pollution. Differences between efficient prices and retail fuel prices remain large and pervasive. For example, 80 percent of global coal consumption was priced at below half of its efficient level in 2022. Full fossil fuel price reform would reduce global carbon dioxide emissions to an estimated 43 percent below baseline levels in 2030 (in line with keeping global warming to 1.5-2ºC), raise revenues worth 3.6 percent of global GDP, and prevent 1.6 million local air pollution deaths per year. Accompanying spreadsheets provide detailed results for 170 countries.*

RECOMMENDED CITATION: Black, Simon, Antung Liu, Ian Parry, and Nate Vernon, 2023. “IMF Fossil Fuel Subsidies Data: 2023 Update.” Working paper, IMF, Washington, DC.

JEL Classification Numbers:	Q31; Q35; Q38; Q48; H23
Keywords:	Fossil fuel subsidies; efficient fuel prices; supply costs; climate change; local air polution mortality; revenue gains; energy price surge; non-pricng reform, spreadsheet tools
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* A spreadsheet with results for all countries can be found here. In addition, the data can be found on the IMF’s Climate Indicators Dashboard here. The authors would like to thank James Roaf for helpful comments and suggestions.

WORKING PAPERS

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Executive Summary

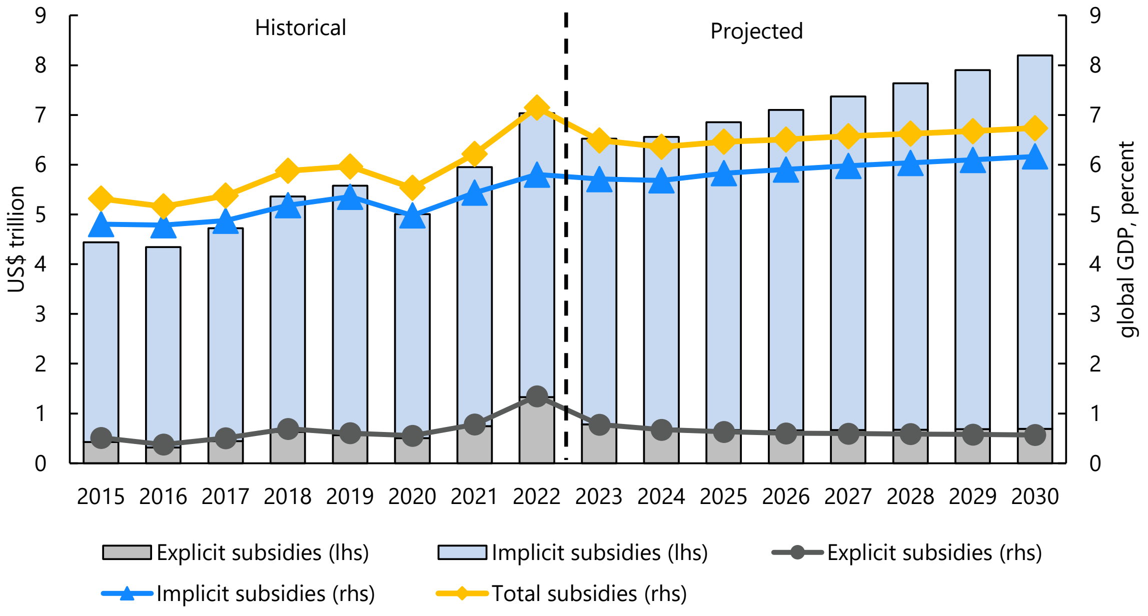
This paper provides an updated assessment of fossil fuel subsidies at a country, regional, and global level. It builds on a series of previous IMF reports, quantifying both explicit subsidies (undercharging for the supply costs of fossil fuels) and implicit subsidies (undercharging for environmental costs and forgone consumption tax revenues). The full gap between efficient prices (the sum of supply, environmental, and other costs) and retail prices multiplied by consumption equals the total fossil fuel subsidy.

Indeed, the gap between efficient and current fuel prices is often substantial given, not least, the damages from climate change and the large number of people dying prematurely from fossil fuel air pollution exposure (4.5 million a year). Underpricing fossil fuels implies that governments forgo a valuable source of much-needed revenue and undermines distributional and poverty reduction objectives since most of the benefits from undercharging accrue to wealthier households.

Results for 170 individual countries are available online.[1] The main findings of the analysis include:

- Globally, total fossil fuel subsidies amounted to $7 trillion in 2022, equivalent to nearly 7.1 percent of global GDP. Explicit subsidies (undercharging for supply costs) account for 18 percent of the total while implicit subsidies (undercharging for environmental costs and forgone consumption taxes) account for 82 percent.
- Explicit subsidies have more than doubled since the previous IMF assessment, from $0.5 trillion in 2020 to $1.3 trillion in 2022, with sharply higher international fossil fuel prices. However, much of the increase is due to temporary price support measures, and hence explicit subsidies are expected to decline if international prices continue receding from their peak levels.
- Implicit subsidies are projected to rise in the baseline (see Figure ES1) as the share of fuel consumption in emerging markets (where local environmental costs are generally larger) continues to climb.

Figure ES1. Global Fossil Fuel Subsidies



Source. IMF staff calculations. Note. 2019 and 2022 onwards use projections of fuel use and fuel prices, respectively.

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[1] See https://www.imf.org/-/media/Files/Topics/energy-subsidies/EXTERNALfuelsubsidiestemplate2023new.ashx

- Differences between efficient prices and retail prices for fossil fuels are large and pervasive across fuels, but especially for coal. Globally, 80 percent of coal consumption was priced at below half of its efficient level in 2022.

- Underpricing for local air pollution and global warming account for nearly 60 percent of global fossil fuel subsidies and underpricing for supply costs and transportation externalities (such as congestion) explain another 35 percent (the remainder is accounted for by forgone consumption tax revenue).

- By fuel product, undercharging for oil products accounts for nearly half the subsidy, coal another 30 percent, and natural gas nearly 20 percent (underpricing for electricity accounts for the remainder).

- By region, East Asia and the Pacific accounts for nearly half of the global subsidy. By country, in absolute terms China remains the biggest subsidizer of fuels, followed by the US, Russia, EU, and India.

- Fully reforming fossil fuel prices by removing explicit fuel subsidies and imposing corrective taxes such as a carbon tax would reduce global carbon dioxide (CO_2) emissions by 43 percent below 'business as usual' levels in 2030 (34 percent below 2019 levels). This would be in line with keeping global warming to 'well below' 2^oC and towards 1.5^oC.

- Full fuel price reform would also raise substantial revenues, worth about 3.6 percent of global GDP. These revenues could be used to cut more burdensome taxes such as on those labor, help with debt sustainability, or fund productive investments. Indeed, for developing countries as a whole, revenue gains from full price reform exceed the estimated extra spending needed to achieve the Sustainable Development Goals.

- Fuel price reform would avert about 1.6 million premature deaths per year from local air pollution by 2030.

- Reforming fossil fuel subsidies is in countries' own interest, even when excluding climate benefits. For the average country, reforming fuel subsidies to the extent that they reduce CO_2 by about 25 percent below baseline levels in 2030 would raise net welfare (due to local environmental benefits and removing price distortions), before even counting global climate benefits.

- Globally, full price reform would generate net welfare benefits of about 3.6 percent of GDP.

- Second-best efficient combinations of (tradable) CO_2 and local air emission rate standards (or their feebate equivalents) across sectors would reduce CO_2 emissions by around 20 percent in 2030 relative to baseline levels and avert 1.2 million air pollution deaths a year, while largely avoiding (politically difficult) increases in energy prices.

Introduction

Fossil fuels in most countries are priced incorrectly. The optimal price would reflect the full societal costs of fuel use—their supply costs (e.g., labor, capital, raw materials); environmental costs, including carbon dioxide (CO_2) emissions, local air pollution, and broader externalities associated with fuel use like road congestion; and general taxes applied to consumer goods. Unfortunately, current prices are routinely set at levels that do not adequately reflect environmental damages and, in some cases, not even supply costs. Consequently:

- Environmental damages like global warming costs and local air pollution deaths are far too large;
- Governments rely extensively on more distortive taxes like taxes on work effort and investment and too little on more efficient ones like taxes on fossil fuels, or they do not adequately fund public investments, for example for Sustainable Development Goals (SDGs); and
- Distributional objectives and poverty reduction objectives are undermined, as most of the benefits from inefficiently low fossil fuel prices accrue to better off households (e.g., Coady, Flamini, others 2015).[2]

This paper presents an updated assessment of efficient prices by fossil fuel product and country and, at the global, regional, and country level. It builds on a series of previous IMF reports (Parry and others 2014, 2021; Coady and others 2017, 2019) and quantifies both the *explicit* and *implicit* subsidies from undercharging for supply costs and environmental costs/general consumer taxes respectively. It also assesses the environmental, fiscal, and economic benefits from reforms to address the mispricing of energy. And it discusses the implications for policymakers, including those who are implementing non-pricing reforms and wish to avoid additional burdens on low-income households. The full set of results, including time series data on subsidies and efficient fuel prices at the country-level, is available online.[3]

Fossil fuel price reform is especially timely. If global CO_2 and other greenhouse gas emissions are not reduced by 25-50 percent below 2019 levels by 2030 this will likely put the goal of containing global warming to 1.5 to 2°C beyond reach[4]—policies to increase the relative price of fossil to clean fuel technologies must play a pivotal role in achieving these reductions. While the energy price surge of 2021-22 promoted energy conservation, the relative price of coal compared to natural gas reduced in a way that is harmful from a climate perspective. As energy prices recede from their elevated levels, governments have an opportunity to phase in robust carbon pricing or equivalent measures. Furthermore, relief measures for the price surge, following on from the COVID-19 pandemic, have heightened the attraction of policy reforms that raise new revenues to address limited fiscal space. At the same time, 99 percent of the global population remain exposed to local air pollution levels that exceed World Health Organization guidelines.[5]

The principle that energy prices should be set efficiently to appropriately allocate an economy's scarce resources across sectors while levelling the playing field for clean technologies is both well established in economic theory (e.g., Baumol and Oates 2012, Parry and others 2014, Pigou 1920) and increasingly reflected in practice.[6] A transparent methodology indicating how current fuel prices compare with efficient levels, and the environmental, fiscal, and economic benefits from fuel price reform, is critical for guiding such policy reforms.

Raising energy prices can be politically challenging. A portion of savings from subsidy reform can, however, finance targeted, income-based transfers to vulnerable households and increased access to low

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[2] In absolute terms, most benefits of failing to tax fuels tend to accrue to wealthier households. When expressed as a share of income the distribution of these benefits can vary (being regressive, neutral, or progressive depending on the country).

[3] See www.imf.org/en/Topics/climate-change/energy-subsidies and https://www.imf.org/-/media/Files/Topics/energy-subsidies/fuel-subsidies-template-2023.ashx.

[4] Black and others (2022).

[5] See www.who.int/publications/i/item/9789240034228.

[6] For example, carbon pricing schemes are now operating in nearly 50 countries (WBG 2023).

carbon alternatives.[7] Alternatively, governments often use non-pricing instruments, like emission rate standards, feebates, and clean technology subsidies, because they avoid significant increases in energy prices though these are less efficient.[8] Nonetheless, the methodology developed here can also guide design of non-pricing reforms by indicating price signals that ideally would be implicit in regulations or other policies. It also provides a benchmark for assessing the trade-offs involved in pricing and non-pricing measures in terms of their environmental, health, and economic impacts. In other cases, there are more fine-tuned instruments, for example direct fees on local air pollution emissions or kilometer (km)-based charges for road congestion. The discussion below also provides guidance on the efficient levels of such instruments and explains why—in their absence—it is still appropriate to reflect the full range of environmental costs in fuel prices.

One caveat concerns uncertainties on parameter values—for example, on the valuation of CO_2 emissions, or the link between pollution exposure and elevated mortality risks and their monetization. The results below however are based on central case assumptions for parameter values and to a large degree the implications of alternative assumptions are transparent. Another caveat is that the assessment of efficient fuel prices does not consider broader market failures like, for example, spillovers associated with learning-by-doing at firms adopting new, clean technologies—these considerations usually warrant more targeted measures however (like temporary technology deployment subsidies) rather than further increases in fossil fuel prices.

The paper continues a series of IMF reports on efficient fuel prices and energy subsidies.[9] For example, the last assessment in Parry and others (2021) put global fossil fuel subsidies at $5.9 trillion[10] in 2020 or 6.8 percent of GDP, with only 8 percent of the 2020 subsidy reflecting undercharging for supply costs (explicit subsidies) and 92 percent undercharging for environmental costs and forgone consumption taxes (implicit subsidies). Besides providing a thorough update of all data, parameters, and results, this paper also builds on earlier work by: assessing how the energy price surge of 2021/22 has affected energy subsidies; improving the methodology for parameter assessment (e.g., congestion externalities); and presenting some new analyses on the portion of climate mitigation that is in countries' own national interests, comparisons between pricing and non-pricing reforms, and efficient fees on local air pollution.

The paper is divided in two sections, the first covers methodology and the second presents main findings.

Methodological Issues

This section provides conceptual background on efficient fuel prices and energy subsidies and discusses the nature and measurement of environmental costs.

Conceptual Background

Efficient Fuel Prices

The economically efficient price for a fossil fuel product is given by:

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

The discussion below elaborates on components of this expression and their rationale.

Environmental costs

Global warming. The environmental costs of all fossil fuel products include global warming. The climate damage is the fuel's CO_2 emissions factor times the value per tonne of CO_2 emissions. Emissions factors per

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[7] To do so, some countries may need to expand and redesign social protection systems. Such a reform package would more efficiently protect poorer households as most benefits from fossil fuel subsidies go to the wealthy.

[8] See Black, Minnett, and others (2022) for a stocktaking of mitigation policy instruments employed by G20 countries.

[9] These include Coady, Parry and others (2015, 2019), Parry, Heine, and others (2014), and Parry, Black and Vernon (2021).

[10] Henceforth, all monetary figures in the paper are expressed in year 2021 US$.

unit of energy vary very little across countries but are about 25 and 45 percent lower for oil products and gas respectively than for coal.[11] For road fuels, CO_2 emissions per liter are about 16 percent higher for diesel than for gasoline (our data accounts for the moderately lower emissions from biofuel blending but not for the partially offsetting land use emissions).

The rationale for reflecting CO_2 emissions in fuel prices is clear, given that emissions are currently proportional to fuel use—directly pricing emissions downstream at the point of fuel combustion for power plants and industrial firms therefore has equivalent effects to pricing the carbon content of fuels used as inputs by these firms. Upfront carbon charges will however need to be combined with rebates for downstream carbon capture and storage as these technologies become viable in future.

Local air pollution. Combustion of all fossil fuel products also generates local outdoor ('ambient') air pollution damages. The major local air pollutants from coal include: (i) directly emitted fine particulates, which are 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 fine particulates; and (iii) (low-lying) ozone formed, for example, from volatile organic compounds (VOCs) like benzene. 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 vary substantially across countries depending on the use of end-of-pipe control technologies (like flue gas desulphurization systems) and fuel quality (e.g., bituminous coal has higher sulfur content than lignite and anthracite).

Natural gas combustion primarily produces only NO_x and in relatively moderate amounts. Combusting gasoline and diesel can also produce SO_2, NO_x, VOCs, and direct fine particulates, though emission rates are generally much lower for gasoline than diesel and vary across countries with emission rate regulations (for new and used vehicles) and fuel quality.

For large stationary emission sources, local air pollution is most efficiently addressed by a fee on smokestack emissions that promotes both switching away from pollution-intensive fuels and adoption of end-of-pipe abatement technologies.[12] Such fees may be impractical for some countries however due to constraints on the ability of governments to continuously monitor smokestack emissions. Until such fine-tuned fees are implemented, imposing taxes upfront on fuel inputs to reflect air pollution damages is a second-best policy (i.e., that promotes some but not all the needed responses). Fuel taxes however might be combined with rebates for downstream firms that demonstrate (through installing their own metering systems) their emission rates are lower than assumed in the fuel tax assessment. Regarding local air emissions from road fuels, these are commonly addressed through vehicle emission rate standards which progressively lower emissions factors over time and the local pollution component of road fuel taxes.

Congestion, accidents, and road damage. Use of road fuels in vehicles is also associated with broader externalities like traffic congestion and accidents and (less importantly and mainly for heavy vehicles) wear and tear on the road network (see below). All three externalities would be most efficiently addressed through various km-based charging systems including per km fees varying over space and time with prevailing congestion levels, with driver/vehicle accident risk, or (for heavy vehicles) with axle weight. Until such systems are comprehensively implemented however (which no country has done to date) fuel taxes remain a valid (albeit blunt) second-best instrument.[13] Indeed, excluding congestion, accident, and road damage externalities from assessments of efficient road fuel taxes can lead to perverse policy implications (like European countries

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[11] EIA (2021). The analysis does not account for upstream emissions leakage (e.g., venting and flaring of methane at coal mines and oil wells) given the focus on fuel consumption rather than production (which might be in another country).

[12] Ideally the fee would also vary spatially within a country with the local population to the emissions source (as, for example, is the case with air emissions fees in Chile).

[13] Parry and Small (2005).

lowering their fuel taxes toward US levels). 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.[14]

Environmental costs of other fuel products. Environmental costs of non-road petroleum products (e.g., for home heating, off-road vehicles) are limited to CO_2 and local air 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, liquified petroleum gas (LPG), and kerosene—the local air pollution and climate externalities are assumed to be equal to the average of the four oil products.

Environmental costs from electricity consumption are taken to be zero—global and local pollution are attributed to the fuel inputs, while only a negligible share of electricity consumption is presently used for road vehicles (i.e., congestion and accident externalities from EVs are small when expressed relative to total electricity consumption).

General consumption taxes

In principle, all products consumed at the household level should be subject to same value added tax (VAT), or general consumption tax, and these taxes should be applied to the full social cost (supply and environmental cost) of products with rates aligned with revenue targets. 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]

Alternative Notions of Fossil Fuel Subsidies

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

$$[\text{sectoral unit supply cost} - \text{fuel user price}] \times [\text{sectoral fuel consumption}]$$

And the *total explicit and implicit subsidy* is defined by:

$$[\text{sectoral efficient fuel price} - \text{fuel user price}] \times [\text{sectoral fuel consumption}]$$

Explicit subsidies are more commonly discussed among policymakers and in the literature[16] as they reflect fiscal costs—either directly in the government budget (e.g., rebates to households for energy purchases) or indirectly as losses/reduced profits at state-owned enterprises. But the total (explicit plus implicit) subsidy is what matters from the perspective of getting fossil fuel prices right—environmental costs are just as real as supply costs (even if they are more uncertain). Under the above definition, undercharging for VAT is counted as an implicit subsidy. Producer subsidies (e.g., favorable tax treatment for fossil fuel extraction, such as accelerated depreciation) are included in explicit subsidies, though they play a relatively small role at the global level.

If a fuel 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 buildings), fuels (coal, natural gas, gasoline, diesel, kerosene, LPG, and other oil products), and countries.

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[14] Indeed, if all the tax-induced reduction in fuel use came from improved fuel economy, and none from reduced driving, raising fuel taxes would have no congestion, accident, and road damage benefits.

[15] Crawford and others (2010). A theoretical literature in public finance demonstrates that higher taxes can be warranted (from a revenue-raising perspective) on products that are relatively weak substitutes for leisure (the more so, the more inelastic the own-price elasticity of the product). These adjustments are difficult to operationalize however due to difficulties in accurately estimating cross-price elasticities with leisure and, moreover, the optimal tax adjustment is more complex when other distortions from the broader tax system (e.g., biases towards informality and tax-preferred goods) are considered.

[16] For example, the 2009 Group of Twenty meeting in Pittsburg called for phasing out explicit fossil fuel subsidies. See also IEA (2022).

Measurement Issues

Global Warming

The illustrated values per tonne of CO_2 emissions are based on assessments of the least-cost global carbon price trajectory that would be consistent with limiting global warming to 2°C. There is a large modelling literature on price trajectories with differences reflecting different assumptions about baseline emissions trends and the responsiveness of fuel use in different sectors to carbon pricing. Based on recent modelling, the carbon price is assumed to rise by $1.5 per tonne each year from a starting value of $60 per tonne in 2020.[17] This is a conservative price trajectory, given the Paris Agreement seeks to limit warming to 1.5-2°C and in reality countries rely, at least to some degree, on less efficient non-pricing strategies which involve higher implicit carbon prices for a given emissions reduction. Moreover, a recent assessment of the discounted global (economic and environmental) damages from current CO_2 emissions suggest a (dramatically larger) value of $185 per tonne[18]—if this figure was used our total global subsidy estimates would be about 50 percent larger, at around 11 percent of global GDP!

An alternative approach would be to use estimates of the carbon prices implicit in countries' own mitigation pledges, which tend to be much higher for advanced countries than developing countries.[19] One problem however is that, even if achieved, emissions reductions in current pledges fall far short of the emissions reductions consistent with warming goals (so the implied prices would be much too low on average). In addition, given its extremely long atmospheric lifespan (hundreds of years or more) CO_2 emissions become fully assimilated in the global atmosphere, so the contribution to future global warming from a tonne of CO_2 is the same regardless of where it was released—from this global perspective it makes sense to use a common value for CO_2 emissions across all countries. In any case, the implications of alternative CO_2 values at the global or country level are easily inferred from the discussion below.

Local Pollution

The main component of local air pollution costs, and therefore the focus here, is increased mortality and morbidity risk for people exposed to outdoor, fine particulate concentrations.[20] According to the last assessment of the Global Burden of Disease (GBD), outdoor air pollution resulted in 4.5 million premature fatalities in 2019.[21] 92 percent of deaths were due to fine particulates (and 8 percent ozone), two-thirds were among people aged 65 and over (who have higher prevalence of pre-existing conditions), and 60 percent were attributed to fossil fuels (as opposed to other sources like burning crop residue and natural dust). GBD also reports deaths at the country level, but (unlike the approach below) these are not decomposed by the contribution from individual fuels, which can also include cross-border effects for emissions released from tall smokestacks, which could have long-range atmospheric transport. Estimates of air pollution costs by fuel product used here combine several sources of information.

First is the baseline rates of mortality (taken from GBD) for illnesses whose prevalence is increased by local air pollution exposure, where the main illnesses include: ischemic heart disease (28 percent of the global total in 2019), stroke (26 percent), chronic obstructive pulmonary disease (20 percent), lower respiratory infections (11 percent), and trachea/bronchitis/lung cancers (6 percent). GBD provides mortality rates by illness, age class (25-64 and 65 and above), and sub-region (urban/rural) for 204 countries. There is significant

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[17] A widely cited and extensive literature review by an expert panel put the value of CO2 emissions consistent with a 2°C warming target at $40-80 per tonne in 2020 (in 2017$), rising to $50-100 per ton by 2030 (Stern and Stiglitz 2017). Updated estimates in Black and others (2022) suggested little overall change on net in the needed global prices for 2030.

[18] Rennert and others (2022).

[19] Black and others (2022).

[20] See Parry et al. (2014), pp. 20. Other damages include impaired visibility, crop, and ecosystem damage, and building corrosion..

[21] IHME (2020). Indoor air pollution caused a further 2.3 million deaths, but the externality is less well defined in this case (as those causing the pollution are the ones affected by it) and some of the outdoor deaths are from burning other fuels (like crop waste and dung) rather than fossil fuels.

cross-country variability in mortality rates which, for example, can be relatively high in countries with high rates of pre-existing heart and lung disease (e.g., from alcohol and cigarette abuse) and low in countries with low life expectancy (where people are less likely to live long enough to be at risk from pollution-related illness).

Second is local air emissions factors for fossil fuels in different sectors, which are taken from projections for 2020 onwards in Wagner and others (2020). This cross-country data is more extensive for the power and transport sectors (any data gaps are filled using comparable countries)—for the industrial and building sectors, data gaps are more common and are filled using power sector emission rates (this gives conservative estimates as abatement technologies are more common in the power sector). The emissions factors represent an average over newer sources (that may have advanced emissions control technologies) and older sources (that do not) and therefore tend to decline over time as capital stocks turn over—an exception is diesel vehicles where emission rate estimates were revised upwards following evidence (in the Volkswagen case) that on-road emission rates exceeded new vehicle standards.

Third is country-level estimates of population exposure to air pollution, which average across two different modelling approaches—see Box 1.

Box 1. Estimating Local Population Exposure to Air Pollution

Country-level estimates of population exposure to air pollution average across two modelling approaches.

One approach is based on intake fractions, which measure the fraction of fine particulate emissions that are ultimately inhaled (or ingested) by exposed populations—estimates here (see Black and others 2023) are based on an extensive update (with more recent data and more extensive country coverage) of an earlier approach developed in Parry and others (2014). For coal and gas plants which have tall smokestacks, intake fractions are calculated by: (i) mapping geographical data on the location of the individual plants in different countries to very granular data (each grid cell is 1 km square or less) on population density at different distance classifications from each plant (up to 2,000 km away, within and across borders); (ii) regression coefficients indicating how intake fractions (for given population size) decline at greater distances from the emissions source; and (iii) averaging over plants within each country. For vehicle and building emissions (which tend to stay close to ground level rather than being transported through the atmosphere), intake fractions are extrapolated nationwide from an international 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 for coastally located sources where a large portion of emissions dissipate without harming local populations. Fixed coefficients are used to translate intake fractions into increased rates of relative mortality risks from pollution-related illness based on local linearization of concentration response functions[22] from the epidemiological literature.

The other approach is computational modelling of how emissions released from one location affect air quality and mortality risk in that and other locations. The results here are based on TM5-FASST, a downscaled 'source-receptor' model applied at the country level.[23] 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 (less significantly) (ii) possible non-linearities in concentration response functions over the relevant range of pollution reductions from fuel price reform. On the other hand, air quality modelling is less granular than the intake fraction approach, implying less precision in measuring population sizes potentially exposed to fossil fuel-related pollution.

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[22] These functions indicate how relative mortality rates for individual illnesses increase with higher pollution exposure.

[23] 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 from transport, atmospheric chemistry, and 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.

Fourth is assumptions about peoples' willingness to pay for mortality risk reductions in different countries (which are contentious but required to quantify efficient fossil fuel prices). The estimates use OECD's (2012) meta-analysis of several hundred stated preference studies on health risk valuations in different countries which (after updating for inflation and real per capita income) implies a value of around $5.2 million per death avoided for 2022 for the average advanced country. This figure is extrapolated to other countries based on their per capita income relative to the advanced country average and an assumed elasticity for the mortality value with respect to per capita income that declines from 1.2 to 0.8 as per capita income increases.[24]

Broader Externalities for Transportation

Regarding traffic congestion, motorists should factor average delays into their driving decisions but not marginal delays, that is, their impact on adding to road congestion, slowing speeds, and increasing delays for other road users. Assessing how much fuel taxation is warranted by congestion requires a nationwide measure of marginal congestion costs. The starting point is the average delay per vehicle km in different countries—Box 2 explains how these estimates were obtained.

Box 2. Estimating Average Delays from Road Congestion

Estimates for the average delay per vehicle kilometer are compiled with two approaches: direct measurement using Global Positioning System (GPS) data from TomTom and extrapolation for countries which did not have TomTom data using Least Absolute Shrinkage and Selection Operator (LASSO).

TomTom uses anonymized GPS data collected via navigation devices, in-dashboard systems and smartphones, to assemble indices of congestion in 400 cities across 54 countries. As a first step, TomTom establishes baseline of travel times during uncongested, free flow conditions across each road segment in each city. They then analyze actual travel across the year for each city, weighted by the number of drivers on road segments. The resulting TomTom Traffic Index represents the ratio between observed travel times and free flow travel time. For example, an overall congestion level of 36 percent means that the average driver spends 36 percent more time than they would during uncongested conditions. Congestion indices for all cities in a country are averaged to obtain that country's urban congestion index.

While direct measurements are the best way to calculate congestion, they are only available for 54 countries. To estimate congestion for other countries, the LASSO was used to extrapolate congestion based on externally visible characteristics. A dataset of country-level characteristics was compiled using IRF (2022), OECD (2023), and the World Bank's World Development Indicators. A penalized maximum likelihood estimator was used to fit a generalized linear model connecting the TomTom Traffic Index for 54 countries to the other characteristics of those countries. Under the assumption that the same relationships hold for countries where TomTom had no data, congestion indices were estimated for these other countries.

Average delays are then multiplied by: (i) the relationship between marginal and average delays, which is estimated to be 400 percent (based on a review of the literature); (ii) vehicle occupancy (averaging over cars and buses); (iii) people's value of travel time (VOT) which is assumed to be 60 percent of the nationwide

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[24] The income elasticity declines with declining marginal utility of consumption, which is consistent with households gaining less utility from consumption over and above subsistence levels—see Robinson and others (2019). Mortality valuations may also differ across countries with differences in life expectancy, health, religion, culture, economic and social support and so on, however the quantitative implications of these factors are not well established. The extrapolations use purchasing power parity (PPP) income per capita, which accounts for local price levels and more accurately reflects people's willingness to pay for risk reductions out of their own income (Robinson and others 2019, Masterman and Viscusi 2018). Externalities that incorporate monetary valuations in PPP are compared to fuel prices converted at market exchange rates since the fuel price is observed at the country-level, reflecting the actual cost borne to consume a unit of the fuel in the economy, and supply costs are dominated by internationally traded commodities and capital equipment that are not impacted by local price levels, whereas PPP accounts for the average price level in the economy relative to the US (after incorporating for exchange rate differences).

average market wage in 2022;[25] (iv) fuel economy (to express costs per liter rather than per km); 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).[26]

Regarding traffic accidents, some of the associated costs are commonly viewed as internal to drivers (e.g., injury risks to drivers in single vehicle collisions) while other costs are external (e.g., injury risks to pedestrians, increased injury risks to other vehicle occupants in multi-vehicle collisions and third-party property costs). Externalities per vehicle km are measured by apportioning country-level data on traffic fatalities from IRF (2022), OECD (2023), and WHO (2023) into external versus internal risks, monetizing them using the above approach to mortality valuation, and obtaining non-fatality external costs (from non-fatal injuries, third-party costs) via extrapolations from several country case studies.[27] The result is then converted into costs per unit of fuel use and adjustments are made for the distance-based fraction of fuel price elasticities.

Externalities from wear and tear on the road network imposed by high axle-weight vehicles are based on highway maintenance expenditures by country (from IRF 2022 and OECD 2023) per unit of road diesel fuel use, an assumption that half of the expenditures are attributed to vehicle use as opposed to other factors (weather and natural deterioration) and scaled by the driving portion of the fuel price elasticity.

Where data is unavailable, values are inferred by averaging countries with similar per capita incomes in the same region.

Fuel Use, Supply Costs, and Prices

Annex 1 provides details on data collection procedures for fuel use, prices, and supply costs. Fuel use data by sector and country is obtained from IEA (2023a) and supplemented by Enerdata (2023). Data is available to 2019 after which baseline fuel consumption is projected using the IMF-World Bank's Climate Policy Assessment Tool (CPAT).[28]

For fuel products traded in well-integrated international markets such as oil, supply costs—the opportunity cost of consuming the product domestically rather than selling it abroad—are measured by the import or export price (for fuel importing and exporting countries, respectively), with adjustments for margins for transportation, processing, and distribution. For a (largely) non-tradable product like electricity, the supply cost is the domestic production cost, inclusive of margins. For coal and natural gas, where global markets are partially integrated, supply costs are measured by the weighted sum of domestic and international (margin-inclusive) prices where weights are the shares of domestic consumption from domestic and foreign producers, respectively.

Retail prices are based on averaging over a range of sources. Fuel taxes (or subsidies) are computed as the difference between retail prices and supply costs and implicitly include excises, carbon taxes, emissions trading systems (ETSs), and VAT. Future fuel prices are given by current prices plus the product of changes in future international prices and (historically estimated) pass through rates to domestic prices, which are typically 60-100 percent. International energy price projections (in 2021$), shown in Figure 1, are based on averaging over IMF and World Bank projections and differentiated by region in the case of natural gas. International coal and oil prices increased about 400 and 110 percent, respectively, between mid-2020 and mid-2022, while gas prices increased 200 percent in North America, 750 percent in East Asian markets, and 1,100 percent in

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[25] See Parry et al. (2014), pp. 106-7 for a summary of the evidence.

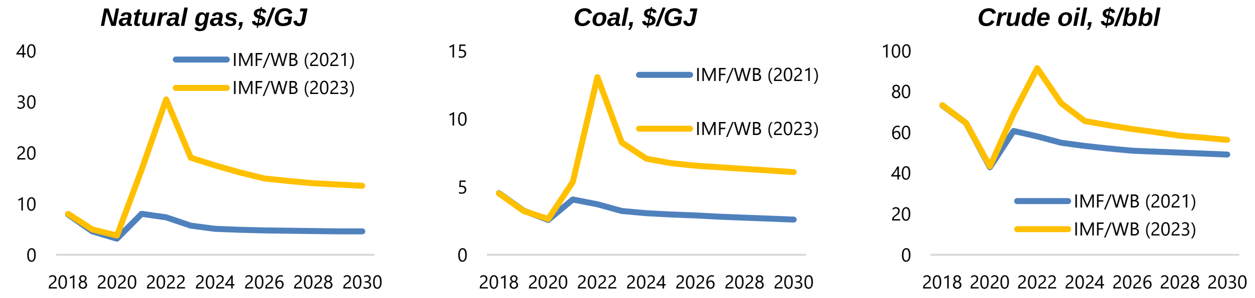
[26] Further adjustments are made to account for the relatively weaker responsiveness of driving on congested roads (which is dominated by commuting) to fuel taxes than driving on free flowing roads and the share of buses and trucks in the vehicle fleet (larger vehicles contribute more to congestion per vehicle km). See Parry and others (2014), Ch. 5, and Black and others (2023) for details on these adjustments and data sources (which were updated for this study as needed).

[27] For details on the approach see Parry and others (2014), Ch 5. Non-fatality costs tend to be relatively more important in countries where a larger share of external fatalities is to vehicle occupants rather than pedestrians.

[28] See Black and others (2023). Baseline projections assume no changes in current fuel taxes/subsidies or current carbon mitigation policies, except for a reversion to pre-COVID policies if subsidies were introduced in response to COVID and the 2021/22 energy price surge.

Europe, due to a recovery in global energy demand, weak fossil fuel investment, and supply disruptions following the Russian invasion of Ukraine. Prices are projected to steadily decline in the medium-term but remain substantially above previously predicted levels—for example, the forecasted 2030 prices for oil, natural gas, and coal price are now 15, 200, and 130 percent above those forecasted by the IMF and WB in 2021 (Figure 1) though considerable uncertainty surrounds future price projections.

Figure 1. Trends in International Fuel Prices



Natural gas, $/GJ ***Coal, $/GJ*** ***Crude oil, $/bbl***

Source: IMF staff calculations, the IMF WEO, and WB CMO. Note: the above figure reflects European, the average of South African and Australian, and average of Brent, North American, and Middle Eastern prices for natural gas, coal, and crude oil, respectively.

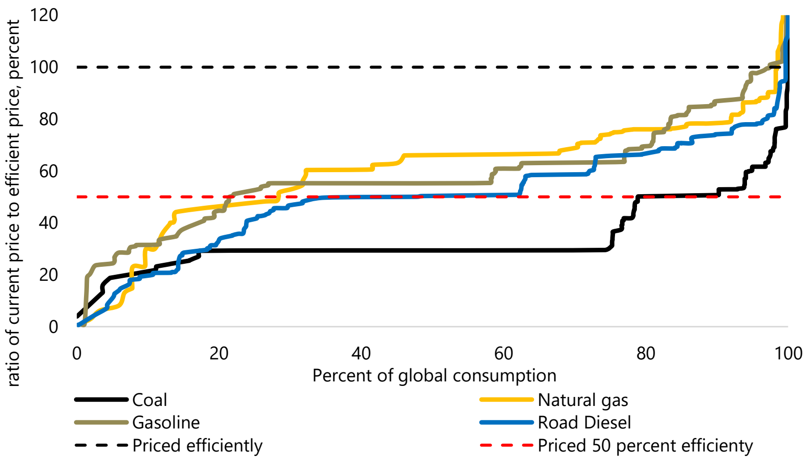
Results

Four sets of results are presented: a comparison of current and efficient fuel prices by product and selected countries; the size of global fossil fuel subsidies and their decomposition by product, component, and region; the environmental, fiscal, and net economic benefits from price reform; and additional findings on efficient air emission fees, the net domestic benefits of climate mitigation, and the benefits of non-pricing reform. Detailed results for 170 countries are available in the accompanying spreadsheet.

Comparing Current and Efficient Fossil Fuel Prices

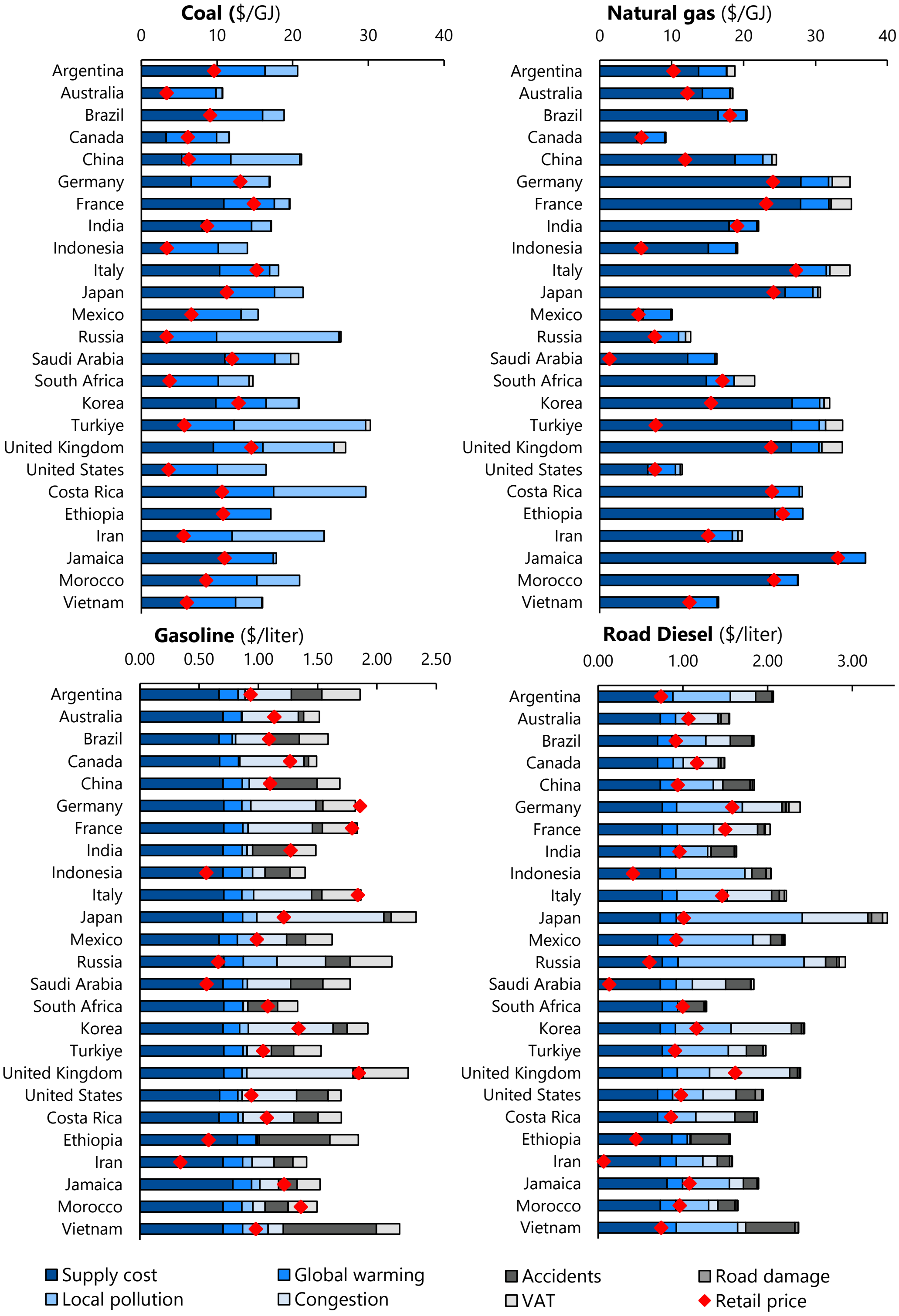
Figure 2 shows the cumulative share of global fuel consumption (from 170 countries) priced at a given ratio of the current price to the efficient price. Figure 3 shows estimates of current and efficient fuel prices for coal and natural gas (averaged over the power, industry, and building sectors), as well as gasoline and (road) diesel (averaged over light- and heavy-duty vehicles) for Group of Twenty (G20) and selected other countries. Results are for the average of 2021-22.

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



Source: IMF staff calculations. Note: the flat portions of the gasoline and diesel curve are consumption for China and the US, and the flat portion for coal is China.

Figure 3. Current and Efficient Fuel Prices, 2021-2022



Source: IMF staff calculations. Note: prices for coal and natural gas are average over fuel consumption in the power generation, industrial, and building sectors and weighted by consumption, while prices for gasoline and diesel are for road fuel consumption only. Congestion, accident, and road-damage externalities are scaled by the fraction of fuel price elasticities reflecting changes in driving distances, rather than improvements in fuel efficiency.

Coal and Natural Gas

Supply costs for coal vary significantly across countries (e.g., with local productivity, labor costs, accessibility of extraction sites, coal quality) from around \$3 per gigajoule (GJ) to \$11 per GJ in 2021-22. Fuel user prices are generally as large as supply costs aside from Brazil and Indonesia where prices are slightly below supply costs. Undercharging for supply costs coal was largely not impacted by the recent energy price surge.

Pricing of the environmental costs for coal use is generally limited, as indicated by the modest or zero gaps between coal prices and supply costs in Figure 3, reflecting little use of coal excises[29] and carbon pricing (exceptions include Canada, the EU and UK, and Korea).

Climate change damages from coal are quite large—equivalent to \$6.8 per GJ or around 60-200 percent of supply costs, even when considering the high international prices of 2021/22. Local air pollution damages can also be large, but these costs vary widely across countries (e.g., with local emission rates, population exposure, health risk valuation)—local air pollution damages exceed 40 percent of climate of damages in six cases in Figure 3 (e.g., China, Russia) but are less than 50 percent of climate damages in ten cases (e.g., Australia, Canada, Mexico).[30]

Supply costs for natural gas also vary significantly by country (given the fragmentation of international markets and costs to ship/process liquified natural gas (LNG)), from around \$7 per GJ in North American to around \$25 per GJ in (gas-importing) East Asia and Europe (up from \$7-9 per GJ in 2019). Prices undercharge for supply costs in ten out of 25 cases in Figure 3 in 2021-22, in part reflecting the large subsidies introduced in response to the energy price surge.

Carbon damages are around 15 to 60 percent of supply costs for natural gas, a much lower proportion than for coal, due to both the much higher supply costs per GJ for gas and lower CO_2 emission rates per GJ. Local air pollution damages from natural gas are typically modest (below \$1 per GJ) due to the relatively low emission rates. The VAT component of efficient natural gas prices would contribute 5-20 percent of the efficient price for household consumption alone but is much smaller in Figure 3 given averaging over buildings, electricity, and industry.

In summary, there is substantial and pervasive underpricing for the environmental costs of coal use, and to a lesser extent, natural gas. Based on a consumption-weighted average across all countries (Figure 2), 80 and 27 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 in absolute terms (given the rising implicit price on CO_2 emissions as countries progress on clean energy transitions), and as a share of efficient prices. Local air pollution damages per GJ will likely decline over time as turnover of older, emissions intensive capital lowers average emission rates, though potentially offsetting factors include growth in urban population exposure and rising mortality risk valuations from higher per capita income.

Gasoline and Diesel

There is little variation in supply costs for road fuels across countries, given integrated international markets for petroleum products—supply costs in 2021-22 were around \$0.70 per liter for both fuels (Figure 3) in 2021-22. Road fuel prices exceed supply costs in all but five countries (e.g., Iran and Saudi Arabia), as most countries (85 percent in our database) impose road fuel excises. Gasoline prices exceed supply costs by 50 percent or more in all but ten countries in Figure 3, and by over 100 percent in four countries (France, Germany, Italy, UK). Most countries, however, impose lower taxes per liter on road diesel than gasoline (to contain fuel costs for commercial users).

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[29] Only 22 out of the 170 countries in our database impose coal excises and typically at modest levels.

[30] The VAT component of the efficient coal price is typically zero as coal is rarely consumed at the household level (in countries like China district heating for buildings is often co-generated by coal-fired power plants and the coal use is an input for power generators rather than purchased directly by households).

Carbon damages are equivalent to $0.15 and $0.18 per liter for gasoline and diesel respectively, about one fifth of supply costs. Local air pollution damages are generally small relative to carbon damages for gasoline. In contrast, for diesel local air pollution damages were typically 1-3 times as large as carbon damages in 2021-22. Congestion and accident externalities combined are relatively large for gasoline, contributing around $0.3-$1.1 per liter to efficient fuel taxes—congestion tends to be the larger externality in densely populated high-income countries (with high VOTs) and accidents in developing countries (where there are high incidences of pedestrian fatalities).

For diesel, combined congestion and accident externalities per liter are smaller given the significant portion of diesel fuel used in heavy-duty vehicles with much lower km per liter of fuel (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 $0.10-0.35 per liter) but less so for road diesel (where typically 50 percent or more of consumption is an intermediate product).

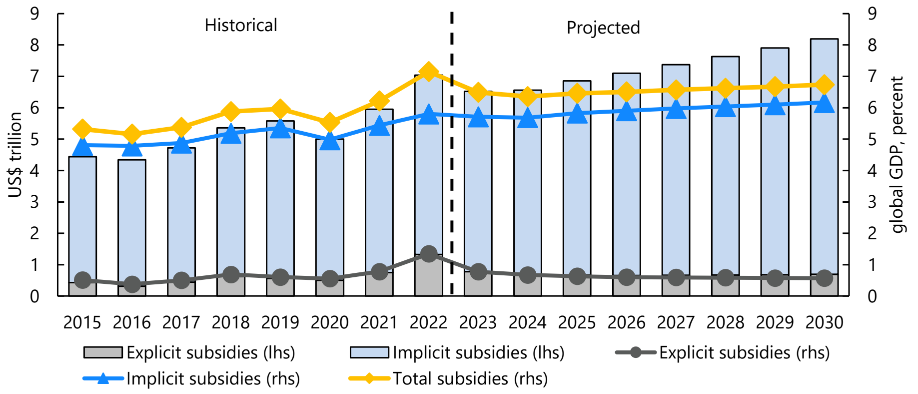
In summary, underpricing of road fuels is pervasive (Figure 2)—for example, 60 and 70 percent of global gasoline and diesel consumption, respectively, is priced at less than 60 percent of their efficient levels. Going forward, local pollution damages for diesel vehicles will likely decline as newer vehicles 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—the natural replacement is km-based tax systems which can provide a more robust revenue source and ultimately can be fine-tuned to effectively address congestion and other driving-related externalities.

Fossil Fuel Subsidies

The Global Picture

Globally, estimated fossil fuel subsidies were $7 trillion in 2022 or 7.1 percent of GDP with explicit and implicit subsidies accounting for 18 and 82 percent of the total, respectively.[31] Explicit subsidies were over twice as large in 2022 (1.3 percent of GDP) than 2020 (0.6 percent of GDP) reflecting the limited pass through of the surge in international energy prices into domestic prices.[32] Going forward however, explicit subsidies are projected to decline as international energy prices recede from their peak levels to 0.6 percent of global GDP in 2030 (Figure 4).

Figure 4. Global Fossil Fuel Subsidies



Source. IMF staff calculations. Note. Figures after 2019 and 2022 onwards use projections for fuel use and fuel prices, respectively.

Implicit subsidies rise progressively over time, from 5 percent of GDP in 2020 to 6.1 percent in 2030. Although the energy intensity of GDP is generally falling over time, emerging market economies account for a rising share of global fuel consumption and local environmental costs per unit of coal use tend to be larger in these countries.

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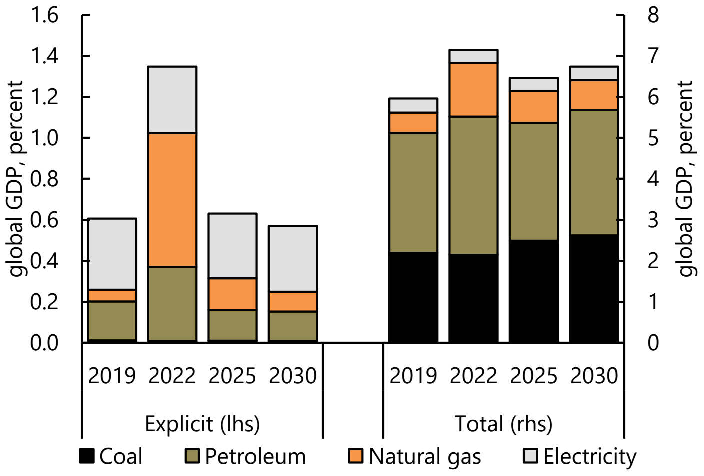
[31] For comparison, subsidies for clean technology deployment are in the order of $100 billion (Taylor 2020, pp. 26-7).

[32] For example, European governments used a variety of price suppression measures and cuts in energy taxes to limit the burden of the price surge on households (Arregui and others 2022).

Breakdown by Fuel Product

Petroleum, natural gas, and electricity accounted for 26, 48, and 25 percent of the explicit global subsidy in 2022 (Figure 5), while coal accounted for less than one percent. For petroleum and natural gas, explicit subsidies are mainly due to administered pricing keeping domestic prices below international levels in energy exporting countries (but also importing countries in response to natural gas price increases), while the subsidy for electricity largely reflects the failure to fully reflect generation, transmission, and distribution costs in domestic tariffs. Globally, 97 percent of the explicit subsidy in 2022 is consumer-side subsidies—only 3 percent reflects direct support for fossil fuel producers.

Figure 5. Global Fossil Fuel Subsidies by Fuel



Source: IMF staff calculations.

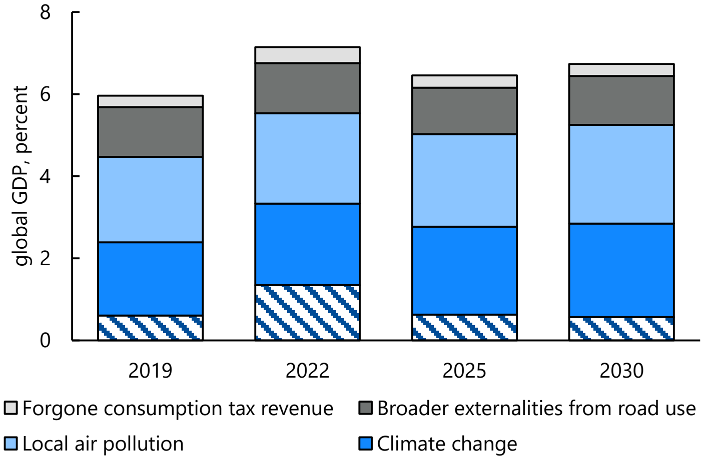
The breakdown by fuel product is quite different for total (explicit plus implicit) subsidies in 2022. In this case, coal accounts for 30 percent of the global total (nearly all due to underpricing for carbon and local air pollution damages) while petroleum accounts for 47 percent, largely because excises on petroleum products fall short of levels needed to reflect the full range of environmental costs. Natural gas (where environmental costs are more moderate) and electricity (where environmental costs are attributed to fuel inputs) account for 18 (with half being implicit) and 5 percent of the global subsidy, respectively.

Breakdown by Component

By component (see Figure 6), undercharging for local air pollution and climate change accounts for about 60 percent of total fossil fuel subsidies in 2022, undercharging for broader externalities and supply costs another 35 percent, and the remainder undercharging for general consumption taxes.[33]

For coal (not shown in the figure), local air pollution and global warming account for 53 and 45 percent of total subsidies respectively, while for petroleum underpricing for local air pollution and broader externalities account for about 30 and 40 percent of the total subsidy respectively, and global warming a smaller 15 percent. For natural gas, underpricing for global warming and supply costs accounted for 37 and 50 percent of the total subsidy for gas in 2022—by contrast, in 2019 they accounted for 71 and 11 percent of the gas subsidy respectively.

Figure 6. Global Fossil Fuel Subsidies by Component



Source: IMF staff calculations.

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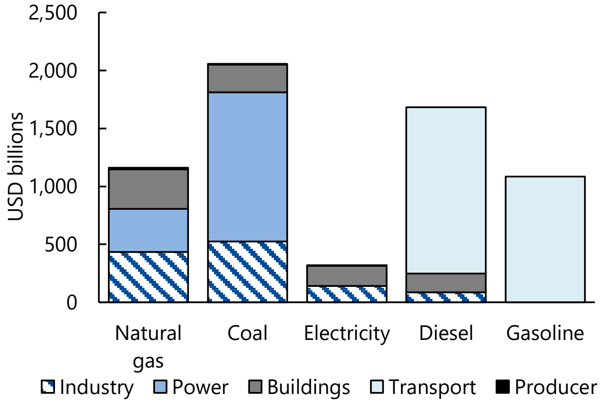
[33] Implicit subsidies are disaggregated by components by taking the proportion of the environmental cost from each externality and multiplying it by the implicit subsidy, at the fuel, country, and sectoral level.

Breakdown by End-Use Sector

Coal use in power generation (about two-thirds of total coal use) and diesel and gasoline used in transport each account for 15-20 percent of total global subsidies in 2022. Natural gas subsidies are split about equally across the power, industry and building sectors, and producer subsidies for natural gas, coal, and oil are minimal. See Figure 7.

Figure 7. Global Fossil Fuel Subsidies by End-User, 2022

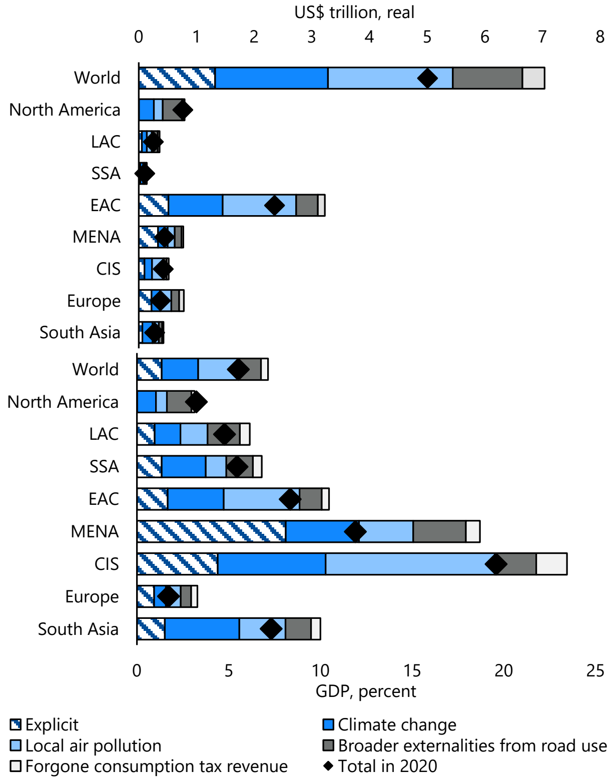


Source: IMF staff calculations.

Breakdown by Region and Country

Explicit subsidies are mostly concentrated in the East Asia and Pacific (EAP), Middle East and North Africa (MENA) region, and Europe, accounting for 38, 26, and 16 percent of this subsidy in 2022 (Figure 8), respectively. They are followed by Commonwealth of Independent States (CIS), South Asia, and Latin America and the Caribbean (LAC), ranging from 5 to 12 percent, while North America and Sub-Saharan Africa (SSA) are below 3 percent. Prior to the 2021-22 energy price surge, explicit subsidies were primarily seen in MENA and CIS, but have expanded quite significantly in Europe and EAP by 300 and 190 percent, respectively. See Annex II for a list of countries in each region.

Figure 8: Global Fossil Fuel Subsidies by Component and Region, 2022



Source: IMF staff calculations. Note: abbreviations are as follows: Commonwealth of Independent States (CIS), East Asia and Pacific (EAP), Latin America and the Caribbean (LAC), Middle East and North Africa (MENA), and Sub-Saharan Africa (SSA).

The regional breakdown is somewhat different for total (explicit plus implicit) subsidies. Here EAP accounts for 48 percent of the subsidy, MENA, Europe, and North America 11 percent each, and 5-9 percent in CIS, South Asia, and LAC. Subsidies in SSA are smallest at 2 percent of the total. Relative to regional GDP however, total subsidies for Europe and North America are smallest at about 3 percent, while these subsidies are 23 percent of regional GDP in CIS, about 18 percent in MENA, and about 10 percent in both EAP and South Asia. 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 for coal and natural gas use; and in MENA, substantial undercharging for supply and environmental costs of petroleum. Since 2020, total subsidies have increased significantly in all regions except for North America, and (nearly) doubled in Europe (due to subsidized natural gas and electricity) and MENA (due to subsidized oil products).

By country (see Annex III), China contributes by far the most to total subsidies ($2.2 trillion) in 2022, followed by the United States ($760 billion), Russia ($420 billion), India ($350 billion), and the European Union ($310 billion).

Benefits from Energy Subsidy Reform

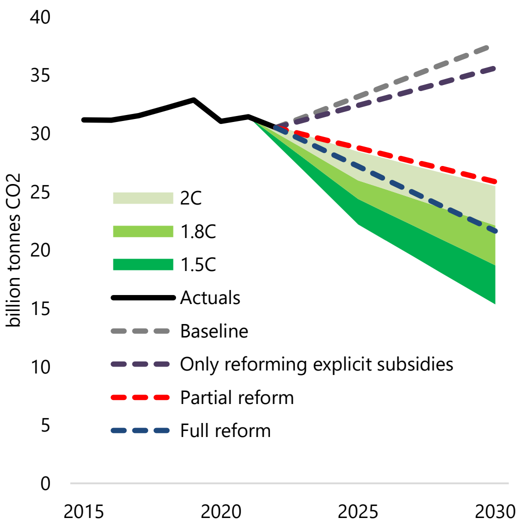
This subsection discusses the CO_2, fiscal, health, and economic welfare impacts from the policy reform scenario, comparing outcomes when all (170) countries would progressively raise fuel prices over time to reach their efficient levels (full reform) by 2030 and progressively close half the gap between pre-reform and efficient price levels (partial reform).[34] Under the baseline (no reform) scenario, it is assumed that current fuel taxes/subsidies return to 2019 levels in real terms as international prices fall or are fixed if taxes increased between 2019 and 2022, and carbon pricing is held fixed in real terms at their 2022 levels.

Climate and Other Environmental Impacts

The full reform reduces projected global fossil fuel CO_2 emissions 43 percent below baseline levels in 2030 or 34 percent below 2019 emissions (Figure 9). This reduction is in line with the 25-50 percent reduction in global greenhouse gases below 2019 levels needed by 2030 to be on track to contain global warming to 1.5-2°C.[35]

Globally, around 55 percent of the CO_2 reduction comes from reduced use of coal, while 31 and 12 percent respectively are from reductions in consumption of petroleum and natural gas—this reflects the much larger proportionate increase in coal prices from fuel price reform compared with petroleum and natural gas (see Figure 2) and the larger shares of coal and petroleum in global CO_2.[36] The regional CO_2 reductions vary from 25 percent below 2030 baseline levels in Europe to around 55 percent in the CIS, with much of the differences reflecting differences in the share of coal in regional CO_2 baseline emissions and size of existing subsidies. Under partial reform, global CO_2 emissions fall by 32 percent below 2030 baseline levels, while removing explicit subsidies reduces emissions only 5 percent.

Figure 9. Global CO_2 Pathways for Temperature Targets



Source: IMF staff calculations and IPCC (2021). Note. Warming pathways assume energy-related national CO2 emissions are reduced in proportion to total greenhouse gas emissions. Partial reform implies closing half of the gap between current and efficient fuel prices.

Full fuel price reform also reduces global air pollution deaths from fossil fuel combustion by 50 percent below baseline levels in 2030, or 1.6 million a year. Again, the reduction is dominated by coal (at about 60 percent) reflecting, in part, the disproportionately large reduction in coal consumption. In addition, local air emissions rates are assumed to decline (due to implicit rebates for downstream mitigation technologies),[37] hence the reduction here is proportionately larger than for CO_2 emissions where emissions factors are fixed. The reduction in mortality rates from fossil fuels ranges from 30 percent in SSA, North American, LAC, and Europe to 65 percent in the CIS, again with the differences explained in part by differences in the BAU intensity of coal use and baseline subsidy level.

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[34] For cases where energy prices are regulated, reform would also entail changes in institutional capacity such as liberalizing pricing, or adopting a pricing formula that fully reflects supply and environmental costs.

[35] Black and others (2022), IPCC (2018).

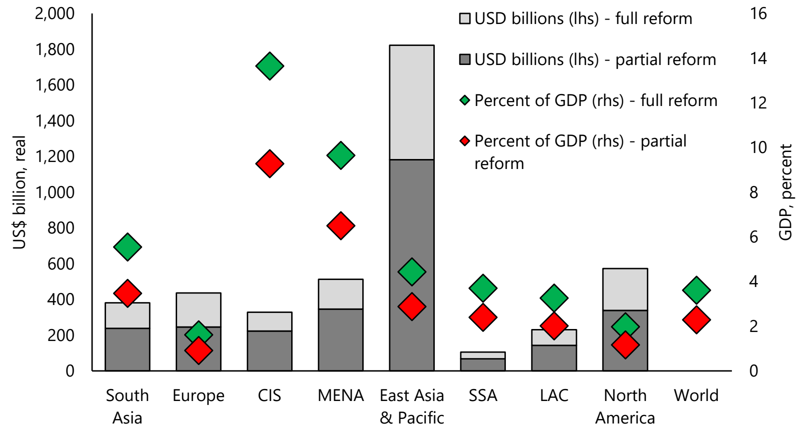
[36] Around 40 percent each in the 2030 baseline and 20 percent for natural gas.

[37] Emission rates (averaged over all firms) fall to those of the cleanest firms in response to energy price reform and tax increases are adjusted downward to reflect these falling emissions rates.

Fiscal and Economic Welfare Impacts

Full price reform (see Figure 10) raises revenues of $4.4 trillion, 3.6 percent of global GDP, in 2030 (relative to baseline levels and accounting for revenue losses due to erosion of pre-existing fuel tax bases and rebates to power generators installing local pollutant abatement equipment).

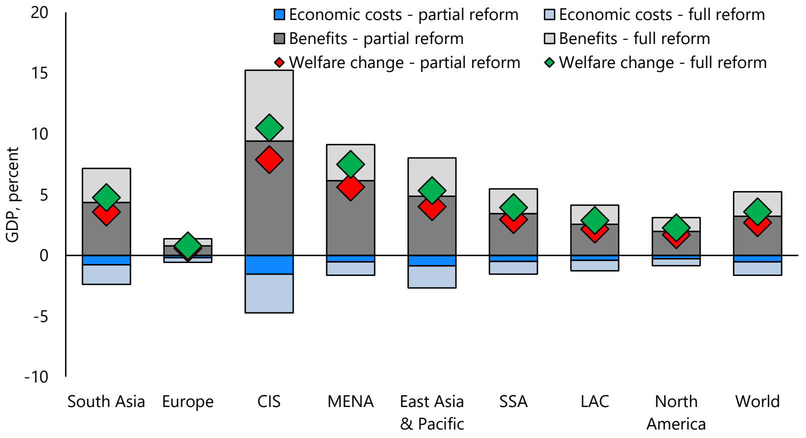
Figure 10. Revenue Gain from Reform, 2030



Source: IMF staff calculations. Note: revenue gain in $ terms for world is excluded for visualization purposes. Abbreviations are as follows: Commonwealth of Independent States (CIS), East Asia and Pacific (EAP), Latin America and the Caribbean (LAC), Middle East and North Africa (MENA), Sub-Saharan Africa (SSA) both figures in the panel.

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 2030 would amount to $3 trillion, which is broadly in line with their additional spending needs for Sustainable Development Goals.[38] Partial reform raises 64 percent of the revenue from fully reforming subsidies, amounting to about $2.8 trillion in revenue across all countries.

Figure 11. Economic Welfare Impact of Reform



Source: IMF staff calculations.

At the global level, full fuel price reform would generate net economic welfare benefits of 3.6 percent of global GDP, equal to environmental benefits of 5.2 percent of GDP less economic welfare costs of 1.6 percent of GDP (Figure 11).[39] Again, the pattern of efficiency gains by region and by fuel products is like that for total subsidies and fiscal gains. Partial reform results in higher welfare for all country groups as efficiency costs grow exponentially with taxes while gains to local health, climate and transportation co-benefits are more linear. Overall, partial reform results in environmental benefits of 3.2 percent of GDP, efficiency costs of 0.5 percent of GDP, and a net welfare benefit of 2.7 percent of GDP.

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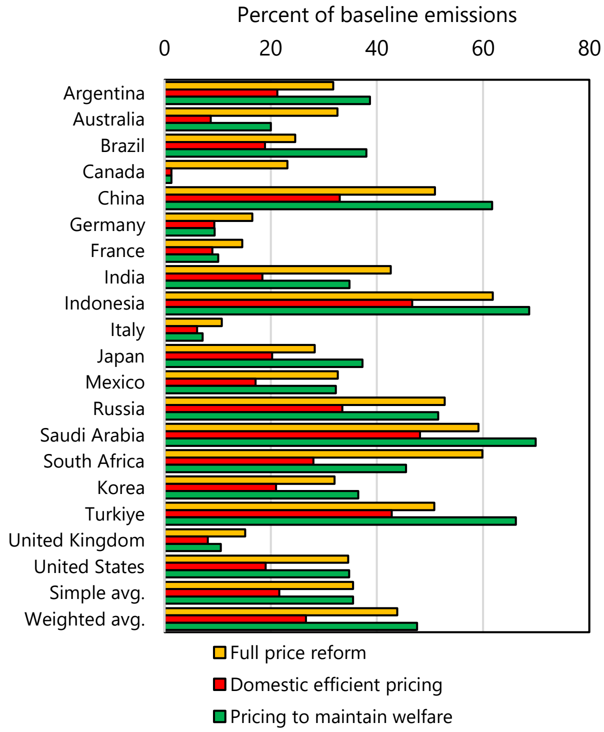
[38] Gaspar and others (2019).

[39] 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).

Further Results: Domestic Co-Benefits, Efficient Air Emission Fees, and Non-Pricing Reform

Domestic Environmental Co-Benefits from CO_2 Reductions

Figure 12: Emissions Reductions for Pricing Reform in G20 Countries



Source: IMF staff calculations. Note. Domestic efficient pricing = prices reflect supply and environmental costs, excluding climate damages. Pricing to maintain welfare = total net benefits of pricing are equal to 0.

Figure 12 presents estimates of how much CO2 reductions (below baseline levels) are in G20 countries' own domestic interests due to addressing domestic environmental co-benefits (local air pollution and vehicle-related externalities)—before even counting global climate benefits.

Calculations are presented for both: (i) CO_2 reductions that maximize domestic net benefits (where the incremental domestic environmental benefit from an additional tonne of CO_2 reduction equals the incremental abatement cost); and (ii) CO_2 reductions that leave countries no worse off from a domestic perspective (where total domestic environmental benefits equals total abatement costs). These emissions reductions are computed assuming emissions are reduced in a least-cost way through carbon pricing—smart combinations of non-pricing approaches (see below) could have similar local air pollution benefits (but would not exploit the externality benefits from reduced driving).

Aggregated across G20 countries, the CO_2 reductions that maximize domestic net benefits are substantial—27 percent below 2030 baseline levels. There is substantial cross-country variation, however—these reductions exceed 25 percent in six cases (e.g., China, Turkey) but are less than 10 percent in six other cases where local air pollution mortality is less severe and existing taxes are relatively high (e.g., Canada).[40] And in aggregate, the CO_2 reductions that leave countries no worse off reduce emissions by 48 percent on average but varying between at least 40 percent in six cases to below 10 percent in three cases.

Efficient Air Emission Fees

Figure 13 shows estimates for 2022 of the efficient fees on coal plant emissions of SO_2 (usually the most important local pollutant in terms of equivalent fine particulate emissions) if countries were pricing smokestack emissions directly (or indirectly through a coal tax/abatement refund scheme). The fee is the product of the deaths per tonne of SO_2 (also shown in Figure 13) and the mortality value per death.

Efficient fees, averaged across G20 countries with significant use of coal-fired generation, are $15,000 per tonne (simple average), but vary from above $40,000 per tonne in two cases (China and Russia) to below

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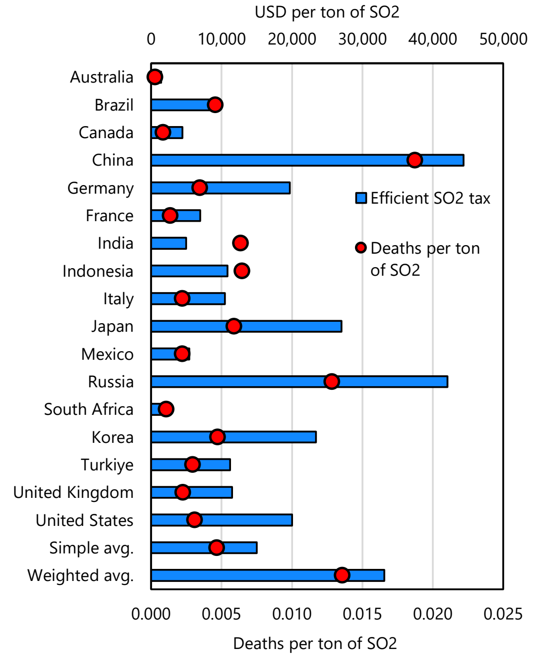
[40] Co-benefits are large due to substantial air pollution reductions, exceeding 2.5 percent of GDP in countries with high coal use (e.g., Indonesia, China, and Russia). Reduced driving externalities range from 0.1 (mostly in European countries with relatively low accident rates and congestion) to 1.5 percent of GDP.

$10,000 in seven others (e.g., Australia, Canada, and South Africa).[41] Part of the difference reflects differences in mortality risk valuations across countries (e.g., $0.8, $2.4, and $6.5 million in India, China and the US respectively). In addition, deaths averaged 5 per thousand tonnes of SO_2 (simple average) but vary from 1 in Australia, France, and South Africa to 20 in China.

Figure 13: Efficient Fees on Coal Plant SO2 Emissions, 2022



Source: IMF staff calculations. Note. Weighted average accounts for differences in coal used for power generation. Argentina and Saudi Arabia are excluded due to minimal coal use in the power sector.

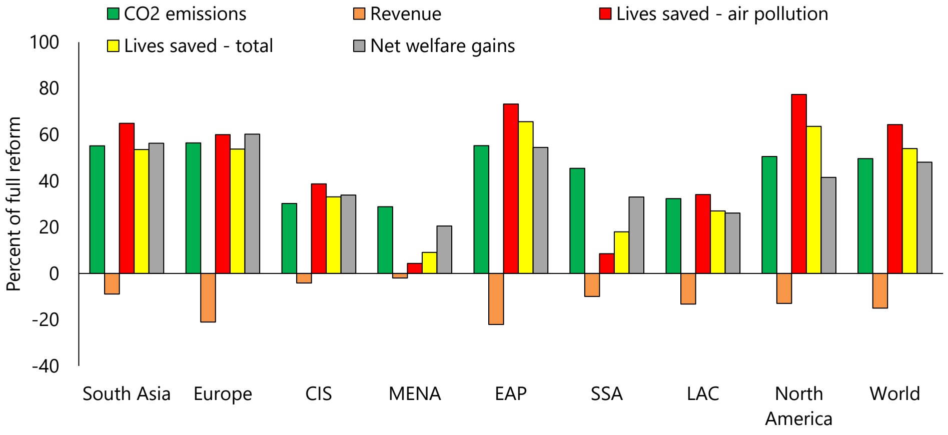
Non-Pricing Reform

Here, a least-cost combination of non-pricing reforms is considered which reduce the CO_2 and local pollution intensity of the power, industry, transport, and building sectors. This could represent a combination tradeable emission rate standards or feebates across different sectors. The prices implicit in these policies reflect the global CO_2 price assumption and country, fuel, and sector level local emissions damages. Unlike the energy pricing reform, the non-pricing combination does not exploit demand reductions (e.g., reductions in vehicle use) as it does not involve the pass through of tax revenues into fuel prices, nor does it phase out explicit subsidies but rather introduces non-pricing measures equivalent to doing so in addition to similar policies for pricing emissions.

The smart non-pricing combination achieves 50 percent of the CO_2 reductions from full fuel price reform and 65 percent of the reductions in local air pollution deaths. On the other hand, it does not raise revenues—indeed there is a revenue loss of 0.5 percent of GDP due to the erosion of fuel tax bases and the net welfare gains are 50 percent of those from full fuel price reform, partly because the non-pricing reform does not exploit reductions in driving related transportation externalities.[42]

These results show that smart non-pricing policies can have significant health and climate benefits but are significantly less effective than pricing policies. See Figure 14.

Figure 14. Impacts of Non-Pricing Policy



Source: IMF staff calculations.

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[41] There are few countries with pricing policies for sulfur dioxide, such as Chile and Sweden.

[42] While it is not modelled, non-pricing policies could moderately increase driving as they lower fuel costs per km (the so-called rebound effect).

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 about $2 trillion in 2022, increasing or decreasing the value of CO_2 emissions by 50 percent would increase or decrease the global subsidy by about $1 trillion.[43] 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 (reflecting the constant elasticity specification for fuel demand curves).

Conclusion

Fossil fuel subsidy estimates provide a summary statistic of prevailing underpricing of fossil fuels. The above update confirms the earlier finding of substantial and pervasive underpricing of fossil fuels across countries, estimates subsidies that are of macroeconomic importance, and large economic welfare gains from energy price reform. Going forward, the composition of energy subsidies may change significantly. For example, the appropriate value on carbon emissions will likely rise as countries ramp up their mitigation efforts, while underpricing for air pollution may decline with policies to reduce local air emission rates. However, large overall fossil fuel subsidies will likely persist for the foreseeable future.

Recent surges in international fossil fuel prices reinforce the case for rapidly transitioning away from fossil fuels—not only to address the climate crisis and reduce air pollution deaths but also to reduce dependence on insecure sources of energy. The price surge is not a substitute for energy price reform as it gets the relative price of natural gas to coal wrong, and prices are receding from their peak levels—a robust and progressively rising emissions price is needed to level the playing field for long-lived, low emission technologies. Indeed, falling energy prices provide an opportune time to lock in pricing of carbon and local air pollution emissions without necessarily raising energy prices above recently experienced levels. For example, even with a carbon price of $75 per tonne, international natural gas prices in 2030 (shown in Figure 1) would be well below peak levels in 2022.

Energy price reform needs to be accompanied by robust assistance for households, but this should be both targeted at low-income households (to limit fiscal costs) and unrelated to energy consumption (to avoid undermining energy conservation incentives). Assistance might therefore take the form of means-tested transfer payments or perhaps lump-sum rebates in energy bills. Where energy price reform is still subject to political acceptability constraints, non-pricing policies such as feebates and tradable performance standards can have a reinforcing role.

At an analytical level, the first-pass nature of the above estimates should be borne in mind. Given the broad country coverage, there are necessarily simplifications in the approach and country authorities may have different perspectives on some of the assumptions and parameter values, for example the value of mortality risks. We hope the above analysis, combined with the associated online analytical tools, will encourage efforts to further refine country-level assessments of the appropriate level of fossil fuel prices, the trade-offs with alternative policy instruments, and the benefits from policy reform.

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[43] A slight relates to cases where changing the assumption would lead to no implicit subsidy. In which case, the reduction in subsidies would be less than the proportional change of the assumption. The spreadsheet provides information that always for users to do rough sensitivity analysis at the country, fuel, and sectoral level.

Annex I. Further Details on Data and Parameters

Retail Prices

Retail fuel prices are expressed as annual averages. Prices for coal, natural gas, and electricity are disaggregated by end-user—industrial, residential, and power generation. The top two panels in Figure 3 of 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 based a simple average across various third-party sources including Eurostat, the IEA, the World Bank, Global Petrol Prices, and Enerdata and information from IMF and World Bank country teams.[44] The ETS price was added on top of natural gas and coal retail prices for industry and power sectors since prices reported by generally datasets exclude ETS allowance payments from retail prices.

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), taxes (such as excises and carbon taxes), and post-retail allowances (such as ETS allowances).

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-side variable. The regression was restricted in the following ways: (i) historical data limited to years 2014 to 2019 to avoid the impact of COVID and potential changes to pricing policies pre-2014; (ii) countries with fewer than 5 observations for 2014-2019 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 2014 to 2019 or a pass-through equal to the regional average was assumed if there was data for 1 to 4 years from 2014 to 2019. Pass through rates average around 50 to 60 percent and are generally higher for oil products.

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 examples.

For coal and natural gas, supply costs are the average of export or import-parity prices and domestic post-tax production costs, weighted by the share of consumption—domestic production costs are considered since markets are less globally integrated, transportation costs are high, and some producers lack the infrastructure needed to export the commodity (e.g., natural gas producers far from liquefaction terminals). The export or import-parity price is 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

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[44] Eurostat Energy Statistics, 2023; IEA Energy Prices, 2022; WB Doing Business Indicators, 2021; GPP Retail Energy Price Data, 2023; Enerdata Global Energy & CO2 Data, 2023; CEPAL 2023; ClimateScope 2022; OECD 2023; EU Bulletin 2023; CEIC 2023.

the nearest hub less estimated transportation costs for fuel exporters. More detailed pricing data was available for natural gas—specifically, large natural gas consuming countries (e.g., most European and South and East Asian countries) domestic natural gas import or market prices were available through Argus, the IEA, or Enerdata and, 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.

For coal, domestic pre-tax production costs come from a variety of third-party sources and information gathered during the IMF's capacity development work, while natural gas production costs are sourced from Rystad. Taxes for both coal and natural gas are calculated using detailed country-specific fiscal regime calculations from the IMF's Fiscal Analysis for Resource Industries (FARI) model.[45] Mark-ups were applied for transportation, processing, and distribution, with higher mark-ups for residential use (mark-ups of $1, $3, and $6 for coal and $2, $2, and $8 GJ for natural gas used in power generation, industrial, and residential user, respectively) but adjusted downwards by 50 and 25 percent for domestically produced coal and natural gas, respectively.

For electricity, supply costs were provided by IMF country desks or calculated using CPAT (see Black and others 2023 on the CPAT methodology).

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).

Estimates of producer subsidies for fossil fuels by country are from the OECD and major energy producers (IEA, 2023b) and held constant for projections.

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[45] See here for details on the FARI model: https://www.imf.org/en/Topics/fiscal-policies/fiscal-analysis-of-resource-industries.

Annex II. Regional And Classification of Countries

Commonwealth of Independent States

Armenia
Azerbaijan
Belarus
Kazakhstan
Kyrgyz Republic
Moldova
Russia
Tajikistan
Uzbekistan

North America

Canada
United States

South Asia

Afghanistan
Bangladesh
Bhutan
India
Maldives
Nepal
Pakistan
Sri Lanka

Latin America & Caribbean

Argentina
Bahamas, The
Barbados
Belize
Bolivia
Brazil
Chile
Colombia
Costa Rica
Dominican Republic
Ecuador
El Salvador
Guatemala
Guyana
Haiti
Honduras
Jamaica
Mexico
Nicaragua
Panama
Paraguay
Peru
St. Lucia
Suriname
Trinidad and Tobago
Uruguay
Venezuela

East Asia & Pacific

Australia
Brunei Darussalam
Cambodia
China
Fiji
Indonesia
Japan
Kiribati
Korea
Lao P.D.R.
Malaysia
Mongolia
Myanmar
New Zealand
Papua New Guinea
Philippines
Singapore
Solomon Islands
Thailand
Tonga
Vietnam

Europe

Albania
Austria
Belgium
Bosnia and Herzegovina
Bulgaria
Croatia
Cyprus
Czechia
Denmark
Estonia
Finland
France
Georgia
Germany
Greece
Hungary
Iceland
Ireland
Italy
Latvia
Lithuania
Luxembourg
Netherlands
North Macedonia
Norway
Poland
Portugal
Romania
Serbia
Slovak Republic
Slovenia
Spain
Sweden
Switzerland
Turkiye
Turkmenistan
Ukraine
United Kingdom

Middle East & North Africa

Algeria
Bahrain
Djibouti
Egypt
Iran
Iraq
Israel
Jordan
Kuwait
Lebanon
Libya
Malta
Morocco
Oman
Qatar
Saudi Arabia
Tunisia
United Arab Emirates
Yemen

Sub-Saharan Africa

Angola
Benin
Botswana
Burkina Faso
Burundi
Cabo Verde
Cameroon
Central African Republic
Chad
Comoros
Congo, Democratic Republic of the
Congo, Republic of
Côte d'Ivoire
Equatorial Guinea
Ethiopia
Gabon
Gambia, The

Sub-Saharan Africa (continued)

Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mozambique
Namibia
Niger
Nigeria
Rwanda
Senegal
Seychelles
Sierra Leone
South Africa
Sudan
São Tomé and Príncipe
Tanzania
Togo
Uganda
Zambia
Zimbabwe

Annex III. Total (Explicit and Implicit) Subsidies, Selected Countries, 2022

	Explicit subsidies			**Implicit subsidies**			**Total subsidies**		
Country	*US$ billion*	*% GDP*	*capita US$*	*US$ billion*	*% GDP*	*capita US$*	*US$ billion*	*% GDP*	*capita US$*
Argentina	14	2.5	313	36	6.4	800	50	8.9	1,113
Australia	8	0.5	302	40	2.4	1,519	47	2.9	1,821
Brazil	2	0.1	11	67	3.1	310	69	3.2	321
Canada	2	0.1	47	36	1.9	953	38	2.0	1,000
China	270	1.5	189	1,966	11.0	1,379	2,235	12.5	1,568
Germany	43	1.0	520	86	2.0	1,028	129	3.0	1,548
France	18	0.6	278	46	1.5	714	64	2.1	992
India	32	1.0	23	314	9.6	223	346	10.6	245
Indonesia	78	6.2	285	116	9.2	422	194	15.4	707
Italy	10	0.4	162	54	2.4	910	63	2.8	1,072
Japan	34	0.6	274	276	5.2	2,224	310	5.8	2,498
Mexico	15	1.1	115	83	6.5	657	98	7.6	772
Russia	71	4.0	488	351	19.6	2,423	421	23.6	2,912
Saudi Arabia	129	13.8	3,579	124	13.2	3,418	253	27.0	6,996
South Africa	5	1.2	85	56	12.8	934	61	13.9	1,019
Korea	65	3.2	1,250	97	4.8	1,870	162	8.1	3,120
Turkiye	59	5.9	694	93	9.3	1,098	152	15.2	1,792
United Kingdom	19	0.6	275	55	1.7	823	74	2.3	1,098
United States	3	0.0	9	754	3.2	2,234	757	3.2	2,243
Jamaica	0	0.0	0	1	3.4	195	1	3.4	195
Costa Rica	0	0.1	19	2	2.9	415	2	3.0	435
Vietnam	7	1.7	67	50	12.6	507	56	14.3	574
Ethiopia	4	3.6	33	4	3.8	34	8	7.4	67
Iran	63	10.5	711	100	16.7	1,131	163	27.2	1,842
Morocco	1	1.0	38	13	8.9	340	14	9.9	378

Sources: IMF staff calculations. Notes: Estimates for energy subsidies in other countries are available here: https://www.imf.org/-/media/Files/Topics/energy-subsidies/EXTERNALfuelsubsidiestemplate2023new.ashx

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IMF Fossil Fuel Subsidies Data: 2023 Update

Working Paper No. WP/2023/169