Special Feature: Commodity Market Developments and Forecasts

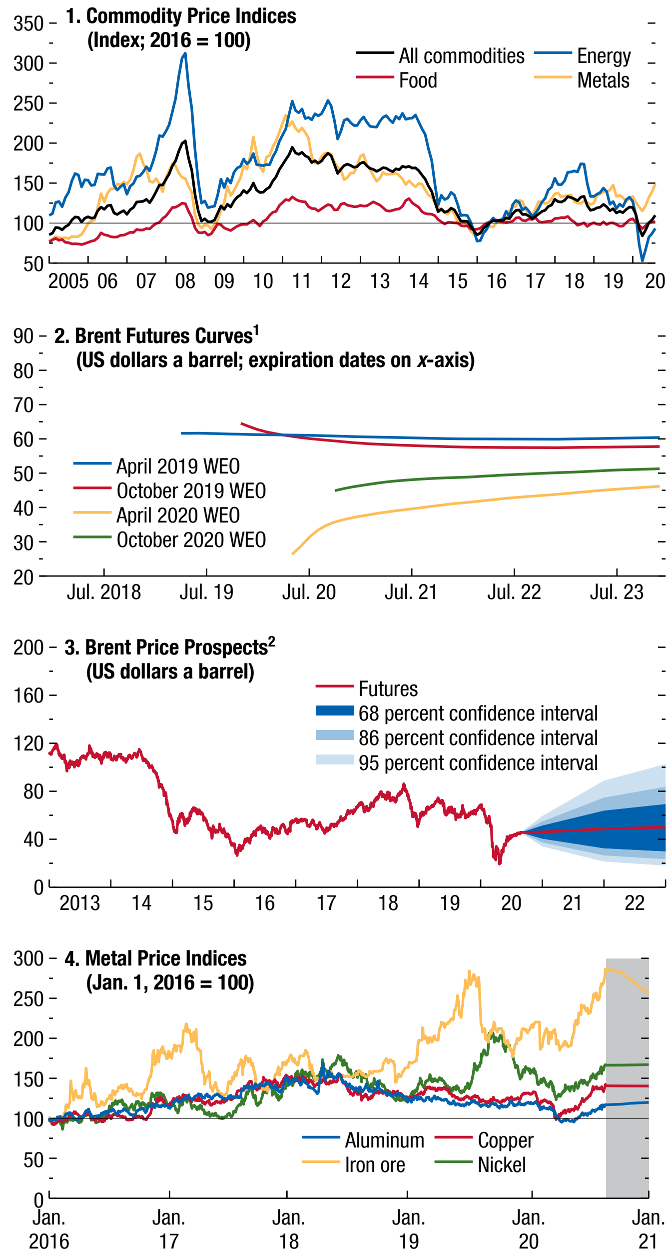
Despite heightened volatility, the IMF's primary commodity price index remained broadly stable between February and August 2020, the respective reference periods for the April 2020 and October 2020 WEOs (Figure 1.SF.1, panel 1). This reflects two distinct phases: between February and April the index fell by 24 percent as the COVID-19 pandemic intensified; between April and August the index recovered by about 31 percent, as many countries eased lockdown measures and economic activity resumed. The rebound, however, has varied across commodities, depending on conditions in end-use sectors and regions affected by the outbreak and on the storability and supply elasticity of a commodity. Prices of energy and some agricultural raw materials rebounded later than metals' prices. Food prices were less affected, even though changes were widely dispersed across agricultural commodities. This special feature also includes an in-depth analysis of coal.

Energy Prices Recovered after April

Oil prices declined by 60 percent between February and April 2020 as the pandemic led to a collapse in global oil demand and concerns about storage capacity (see Figure 1.SF.2). In March OPEC+ (Organization of the Petroleum Exporting Countries, including Russia and other non-OPEC oil exporters) could not agree on supply cuts to restore order to the market, but as the oil price fall intensified, in mid-April the cartel decided to curb production by 9.7 million barrels a day in May and June (later extended until July) by 7.7 million barrels a day until December 2020 and by 5.8 million barrels a day until April 2022. US crude oil producers were also hurt as the front-month futures price for the West Texas Intermediate blend briefly went to –$37 in April. Protracted low oil prices led to shut-ins, sharply reduced drilling activity, and a surge in US shale producer bankruptcy filings. This resulted in an unprecedented 2 million barrel a day decrease in US crude oil production in May 2020.

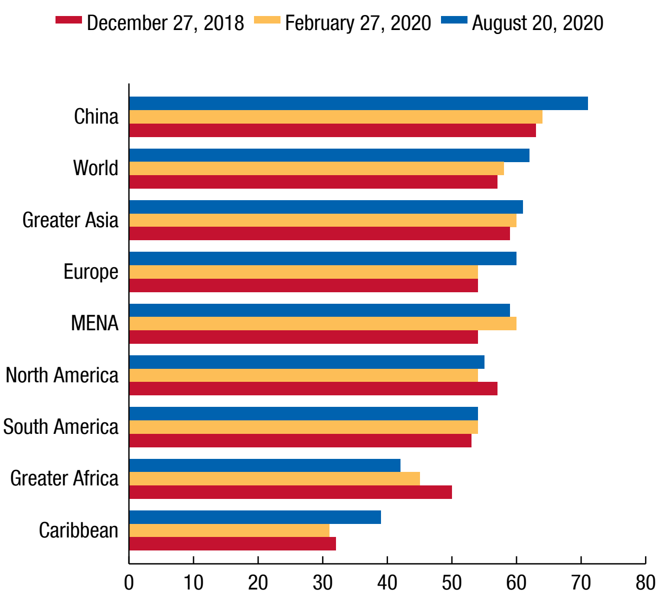
Thanks to supply reductions, from late April onward, oil prices recovered from the mid-$10s to more than $40 a barrel by early June, but into August they remained about $25 below early January prices. As a result, many oil firms have suffered large losses,

Figure 1.SF.1. Commodity Market Developments



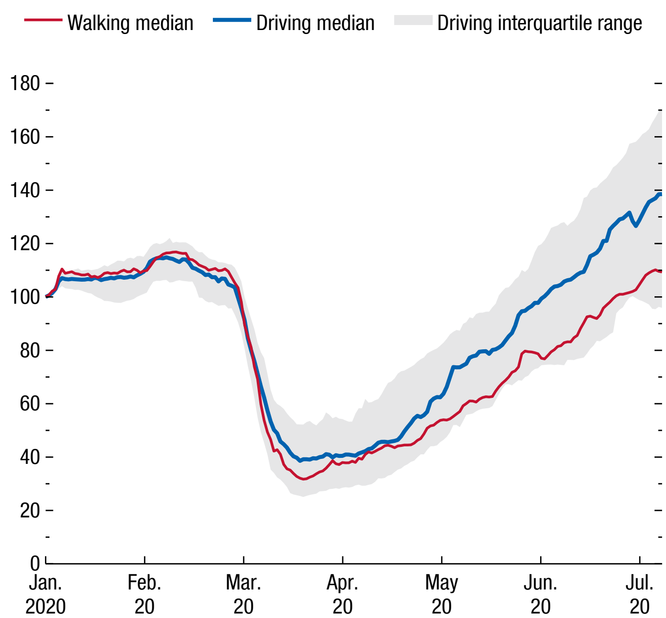
Sources: Bloomberg Finance L.P.; IMF, Primary Commodity Price System; Refinitiv Datastream; and IMF staff estimates.
Note: WEO = *World Economic Outlook.*
[1]WEO futures prices are baseline assumptions for each WEO and are derived from futures prices. October 2020 WEO prices are based on August 21, 2020, closing.
[2]Derived from prices of futures options on August 27, 2020.

Figure 1.SF.2. Oil Storage Capacity Utilization Rates
(Percent)



Sources: URSA Space Systems; and IMF staff calculations.
Note: MENA = Middle East and North Africa. Countries and regions as defined by URSA.

Figure 1.SF.3. Global Driving and Walking Mobility Indices
(Index; Jan. 13, 2020 = 100)



Sources: Apple; and IMF staff calculations.
Note: Data are the seven-day moving average of Apple Mobility Indices.

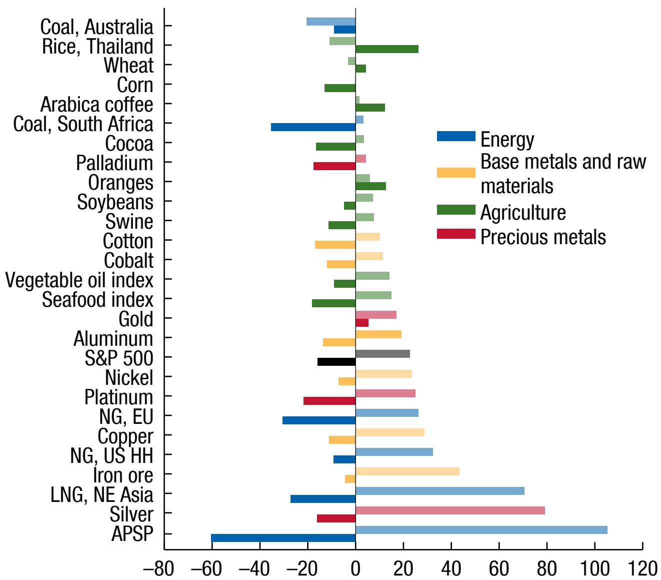
massive layoffs, and asset write-downs as they reassess price outlooks and investments.

On the demand side, the COVID-19 outbreak drove oil prices sharply down as travel restrictions strongly reduced global demand for liquid fuels in the first half of 2020. On one hand, road traffic has recovered in many countries (see Figure 1.SF.3); on the other hand, air traffic volume—especially international flights—remains subdued. As a result, the International Energy Agency expects oil demand for this year to be down by 8.1 million barrels a day, to 91.9 million barrels a day, and to rebound by 5.2 million barrels a day in 2021—a significant revision up from –9.3 million barrels a day for 2020 in its April forecast.

In the natural gas market, spot prices have hovered around record lows in recent months amid large inventories left in place after a mild winter, weak demand, and subdued oil prices. This led oil producers to burn off large amounts of unwanted natural gas as a byproduct of oil extraction—equivalent to 400 metric tons of carbon dioxide (CO_2) in 2019, the most since 2009, according to the World Bank. In late August natural gas prices increased due to an expected rise in winter demand, supply uncertainty in Asia, and technical trading patterns. Competing with natural gas for electricity generation, coal has also experienced significant downward price pressure, although supply disruptions in South Africa and strong demand from Indian industrial buyers supported South African coal prices, while Australian prices have been depressed by China's apparent tightening of import restrictions and by Japan's intention to phase out inefficient coal-fired power plants by 2030 (see the section on coal).

As of early September, oil futures contracts indicate that Brent prices will increase to $50 by the end of 2023, highlighting near-term demand concerns (Figure 1.SF.1, panel 2). Baseline assumptions, also based on futures prices, suggest average annual prices of $41.7 a barrel in 2020—a decrease of 32 percent from the 2019 average—and $46.7 a barrel in 2021 for the IMF's average petroleum spot prices. Currently, the oil market is characterized by elevated uncertainty as the COVID-19 pandemic is not yet under control (Figure 1.SF.1, panels 2 and 3). Risks, however, are broadly balanced. Upside risks to prices include escalating geopolitical events in the Middle East and faster containment of the pandemic as well as excessive cuts in oil and gas upstream investments and further bankruptcies in the energy sector. The biggest downside risk is a renewed slowdown in global economic

Figure 1.SF.4. Commodity Prices during the COVID-19 Pandemic
(Percent)



Sources: Argus; Bloomberg L.P.; IMF, Primary Commodity Price System; Thomson Reuters Datastream; and IMF staff calculations.
Note: Dark fill sections represent the percent change in commodity prices for February–April 2020, while light fill sections represent the percent change for April–August 2020. APSP = Average petroleum spot price; AU = Australia; EU = Europe; HH = Henry Hub; LNG = liquefied natural gas; NE = northeast; SA = South Africa; US = United States.

activity as large inventories remain a concern. Other downside risks for oil prices include stronger oil production growth in several non-OPEC+ countries, a faster normalization of Libya's oil production, and a breakdown of the OPEC+ agreement. In the medium and long term, global policy actions to lower CO_2 emissions present a further downside risk to oil demand (see Box 1.SF.1).

Metal Prices Recovered amid an Uncertain Economic Outlook

Base metal prices increased by 18.2 percent between February and August 2020. Slow global industrial activity weighed heavily on prices in the first quarter of 2020 (see Figure 1.SF.4). Since then, supply disruptions in mining related to COVID-19 and a resurgence in industrial activity in China—which accounts for half of base metal demand—have helped metal prices return to pre-pandemic levels. Unprecedented stimulus measures and a stock market surge also boosted sentiment toward metals. Precious metal prices continued to rise due to increasing demand for safe-haven assets amid concerns that a second wave of COVID-19 infections would cause protracted monetary policy stimulus.

Among base metals, iron ore prices increased the most between February and August, by 37.0 percent, reaching a year high, while copper prices increased by 14.4 percent amid growing optimism over China's economic recovery, falling inventories, and supply disruptions in key producing countries (Chile and Peru). Aluminum (+3.0 percent), whose supply has been more insulated from the pandemic as it is mostly sourced domestically, did not rally as global automotive sales slumped. The price of nickel and cobalt, key inputs for stainless steel and batteries in electric vehicles, increased by 14.6 percent and fell by 1.9 percent, respectively.

The IMF annual base metal price index is projected to increase by 0.8 percent on an annual average basis in 2020 and by a further 3.0 percent in 2021 on concerns surrounding the long-term impact of the pandemic. The possibility of a second wave of COVID-19, the sustainability of strong China demand, and tensions between China and the United States are the major risks to metal prices falling. These more than offset the risk of supply disruptions in major metal-producing countries. The precious metals index is expected to increase by 28.4 percent in 2020 and by 10.4 percent in 2021 due to the effects of heightened global uncertainty and continued accommodative monetary policies.

Food Prices Declined amid Ample Global Supplies

The IMF's food and beverage price index increased by 0.7 percent, reflecting pandemic-induced changes in demand and supply conditions, with different effects on food prices depending on the region and the agricultural commodity. As COVID-19 slowed economic activity, demand for agricultural raw materials and animal feed initially declined. Prices of most staple crops, including wheat, maize, soybeans, and palm oil, have been stable or have declined since the beginning of the pandemic due to large global supplies and the initial collapse of crude oil prices (see Figure 1.SF.4).

Led by pork, the meat price index fell by 7.1 percent from the April baseline. Amplified by large seasonal farm supply, wholesale pork prices declined by 4.5 percent as several meat processing facilities in the United States closed after employees were infected by the coronavirus. The resulting drop in processing capacity reduced supply to retail channels and drove a wedge between wholesale and retail prices, which generally increased.[1] The wholesale price decline spilled over to other meats and seafood, which saw similar downward trends.

Staple food prices, such as for wheat and rice rallied, initially driven by consumer stockpiling, but, given ample supply, as the initial surge in demand passed, prices retrenched. Overall, though, the price of rice is still up by 12.6 percent. Corn prices plummeted by 13.0 percent on ethanol demand destruction, with prices reaching a 10-year low in May. Soybean prices declined by 13.0 percent beginning in February on account of ample global supplies, nothwithstanding the fact that China ramped up buying in June as part of the 2020 US-China trade deal.

Food prices are projected to increase slightly, by 0.4 percent year over year in 2020 and then increase 4.3 percent in the year thereafter on tighter supply conditions (meats, for example), in part related to expected delays in the supply chain. Further supply chain disruptions and export restrictions in large food exporters are a significant source of upside risk. Renewed tensions between the United States and China could disrupt food trade and lower US food prices while increasing them in competing exporters.

Coal: Past, Present, and Future

Many countries are taking steps to reduce their dependence on fossil fuels, especially coal, as they seek to pursue a more sustainable future. Because of its high carbon intensity, coal accounts for just under half of global CO_2 emissions and nearly three-quarters of all power sector CO_2 emissions. In the absence of pollution mitigation systems, it contributes to local air pollution, with potentially severe damaging effects on human health (Smith, Mehta, and Maeusezahl-Feuz 2004). The unprecedented drop in electricity demand in 2020 favored renewables over traditional fossil fuel sources, such as coal and natural gas. In Europe, where electricity consumption fell by more than 10 percent in April, the share of coal (fossil fuels) in power generation declined to below 8 (30) percent—a historical low. As electricity demand recovered, use of coal resumed globally.

So why is coal still popular if it has large negative externalities? Which economies and economic sectors are most dependent on coal? Some countries moved away from coal in the past. How did they do it, and is this replicable? Will the pandemic speed or slow the demise of coal? These questions are explored by looking at the use of coal throughout history, until the recent pandemic, and its trends in production and consumption across countries.

Coal Usage, Industrialization, and Energy Transition to Fossil Fuels

The Heydays

The use of coal took off during the industrial revolution in 18th century England and then spread to continental Europe and the United States during the 19th and 20th centuries. A series of technological innovations (including the steam engine and coal-fueled furnaces for steel production) radically transformed manufacturing, coal mining, and transportation (for example, steam locomotives and steamships). This spurred rapid economic growth, industrialization, and urbanization, which drastically increased demand. The transition to coal in Europe also helped reverse a pattern of excessive deforestation from centuries of intensive wood harvesting—a major energy transition that saw industrial economies moving away from biomass (that is, wood fuel).[2,3] Hence, until the early interwar period, coal consumption and its share in the energy mix grew unabated in almost every country.

Decline and Renaissance

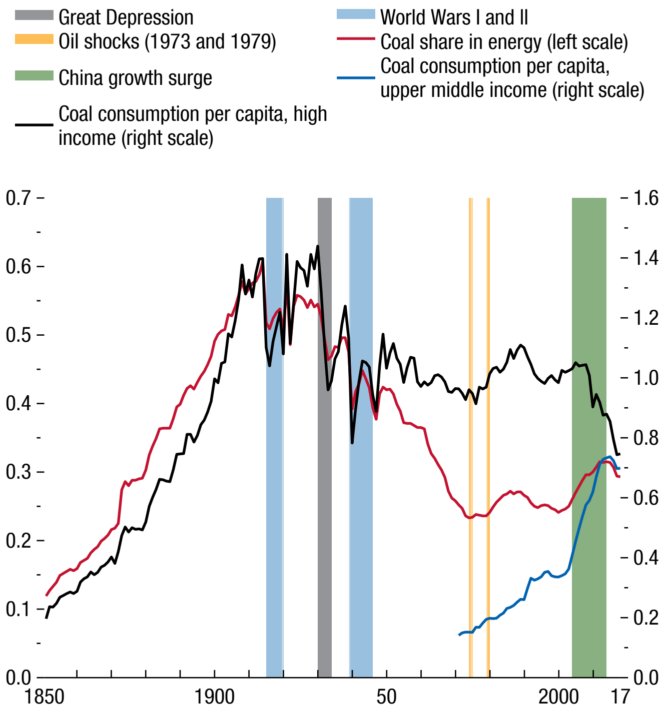
During the 1930s and especially after World War II cleaner fossil fuel alternatives—such as oil and, later, natural gas—increasingly displaced coal in the transportation, residential, and commercial sectors and even in power generation (Figure 1.SF.5). Coal, especially the low-grade sulfurous variety, was cheap but a major

[1]The harmonized consumer price subindex for food and nonalcoholic beverages, for instance, increased by 4.5 percent between February and June in the United States and by 1.3 percent in the euro area. In China, on the other hand, the food consumer price subindex fell by 9.7 percent.

[2]Indeed, forest cover in Europe today is higher than it has been in a century (Fuchs and others 2015). Afforestation notwithstanding, primeval forests in western Europe are extremely rare. For a vivid depiction of a preindustrial Italian forest, see "Hunting in the Pontine Marshes" by Horace Vernet (1833).

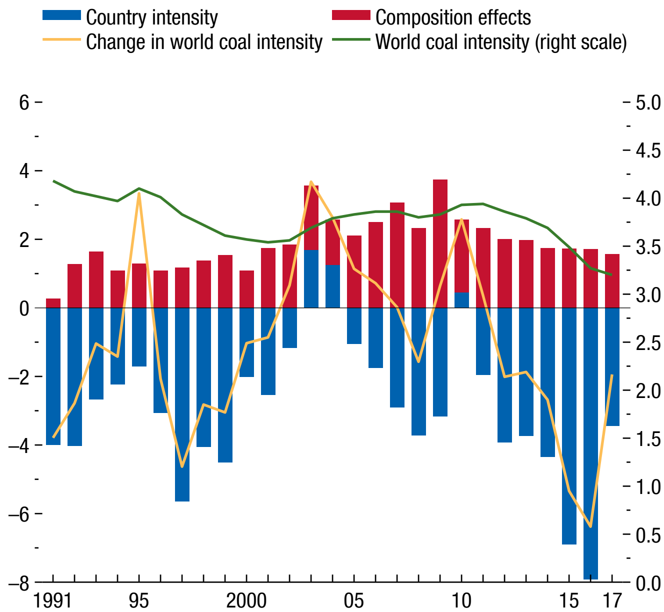
[3]Similarly, the rise of the American oil industry in the 19th century helped save several whale species from extinction as kerosene lamps quickly displaced whale oil lamps and candles in the 19th century.

Figure 1.SF.5. Coal, 1850–2017



Sources: B.R. Mitchell; Maddison Project Database (2018); United Nations; and IMF staff calculations.
Note: China growth surge is defined as the years between 2003 and 2011, when annual GDP growth exceeded 12 percent, except in 2009. Income categories are as defined by the World Bank.

Figure 1.SF.6. Decomposition of Change in World Coal Intensity
(Percent)



Sources: International Energy Agency; World Bank, *World Development Indicators*; and IMF staff calculations.

cause of air pollution and environmental damage.[4] Hence, per capita coal consumption, and especially the coal share in the energy mix, declined rapidly—and was further pushed down by the expanding motor vehicle industry's thirst for gasoline.

That coal decline was surprisingly interrupted in the 1970s and then partially reversed by three significant factors (Figure 1.SF.5): (1) energy security concerns (because of the twin oil shocks of the 1970s), (2) the growing electrification of energy end-uses, and (3) fast economic growth in emerging markets. The combination of (1) and (2) contributed to increased demand for coal for power generation in many advanced economies that wanted to reduce dependence on oil because of energy security concerns.[5] Later, at the turn of the century, as economic growth shifted to markets with higher coal intensity (that is, coal consumption per unit of GDP) and income elasticity of coal demand (such as China and India), coal demand in emerging markets surged, more than offsetting declining coal usage in advanced economies.[6] As a result, global per capita coal consumption, its energy share, and even coal intensity increased again: the coal renaissance (Figure 1.SF.6).

Today, the top five coal-consuming countries (China, India, United States, Russia, Japan) account for 76.7 percent of global coal consumption (Figure 1.SF.7). China accounts for about half of global coal consumption after industrial and power generation coal demand grew particularly fast in the mid-2000s following an infrastructure boom. In fact, today, driven by China, emerging markets, where industry coal demand is still important, account for the lion's share—76.8 percent—of coal consumption. Globally, industry takes about 20 percent of total coal consumption (Table 1.SF.1).

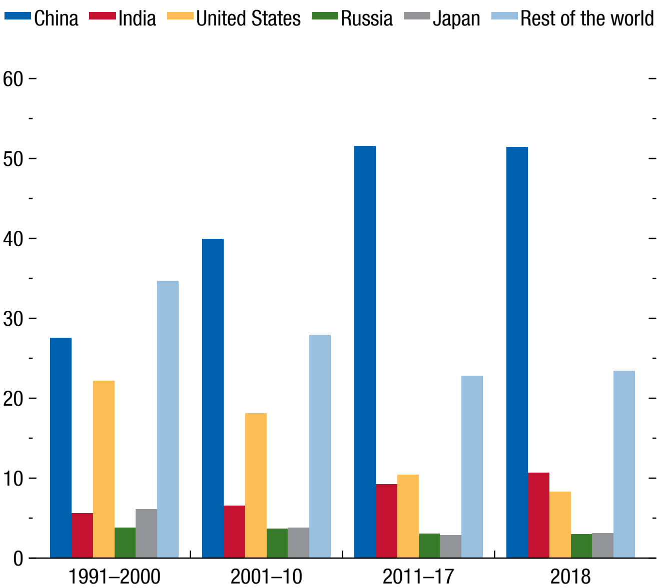
In advanced economies, coal demand is predominantly associated with power generation because of the decline of

[4]During the Great Smog of London (December 5–9, 1952), due to weather conditions, air pollutants from the combustion of coal and diesel-powered buses for public transportation covered the city in a blanket of smog. UK government medical reports estimate that 4,000 people died as a direct result of the smog and 100,000 more were made ill.

[5]The share of coal in energy troughed in 1973, globally.

[6]China and India increasingly relied on coal to satisfy their rising energy needs as economic activity accelerated (Steckel, Edenhofer, and Jakob 2015).

Figure 1.SF.7. Coal Consumption, by Country
(Percent)



Sources: International Energy Agency, *World Energy Balances*; and IMF staff calculations.

Table 1.SF.1. Coal Consumption, by Sector
(Percent)

	OECD	Non-OECD	Total
Power Generation	20.1	50.7	70.8
Industry	2.2	19.4	21.6
Others	0.9	6.7	7.6
Total	23.2	76.8	100.0

Sources: International Energy Agency; and IMF staff calculations.
Note: "Others" consist of residential and commercial and nonenergy use. OECD = Organisation for Economic Co-operation and Development.

coal-intensive industries, such as steel and cement. Given that the electrification of economic systems is ongoing, energy demand from power generation is expected to increase in advanced economies, where total energy demand is flattening.[7] Whereas no significant economical alternatives to coking coal exist in the industrial sector (for example, in making steel and cement), low-carbon alternatives compete with coal for investment in new power plants. This is more relevant in emerging markets, where power generation capacity is expected to grow the most.

Coal's Negative Externalities: Health, Environment, and Carbon Emissions

Coal-fired thermal power plants release several substances—including sulfur dioxide, nitrogen oxide, particulate matter, and mercury—into the air and rivers, streams, and lakes. These emissions are hazardous to human health (toxins) and degrade the environment (pollutants).[8] Air pollution from the combustion of coal and other fossil fuels was long considered the most serious environmental problem in advanced economies.[9] In Europe and the United States, for example, regulations were rolled out beginning in the 1980s and 1990s to incentivize the adoption of environmental pollution mitigation technologies, such as scrubbers, thereby curtailing emissions from coal plants.[10] Other countries decided to (slowly) steer away from the use of coal altogether, with nuclear, hydropower, natural gas, and—more recently—renewable energy slowly displacing coal.

Though steps have been taken to mitigate coal's direct environmental impact, the combustion of coal also emits CO_2. Coal is more carbon intense than any other primary energy fuel. This means that replacing coal with other energy sources decarbonizes the energy system, and the degree to which that happens depends on the substitute. To rank energy sources by carbon intensity, their emission factors can be compared, expressed in tons of CO_2 per unit of electricity generated, which considers both the intrinsic carbon intensity of the fuel per unit of energy and the average efficiency of the generation technology. When burned to generate both heat and electricity, coal is 2.2 times as carbon intense as natural gas—the only realistic fossil fuel alternative in the power sector (Figure 1.SF.8). With its high emission factor and large share in world energy consumption, coal contributes about 44 percent of all CO_2 emissions and 72 percent of all power sector emissions (Figure 1.SF.9).[11]

[7]There has been a steady increase in the role of electricity as energy service provider. In 2017 power generation accounted for about 41 percent of total energy demand, up from 26 percent in 1971.

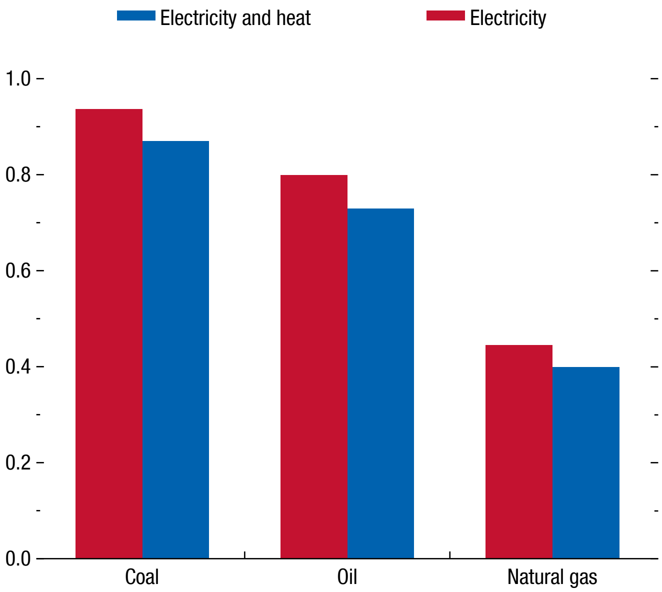
[8]Emissions from coal combustion can damage the respiratory, cardiovascular, and nervous systems of the human body (Smith, Mehta, and Maeusezahl-Feuz 2004).

[9]According to Fouquet (2011), by 1880 the mining, transportation, and combustion of coal in the British economy had imposed external damages close to 20 percent of GDP.

[10]An important milestone in this context has been the United Nations Convention on Long-Range Transboundary Air Pollution, the first treaty to deal with air pollution on a regional basis, which entered into force in 1983.

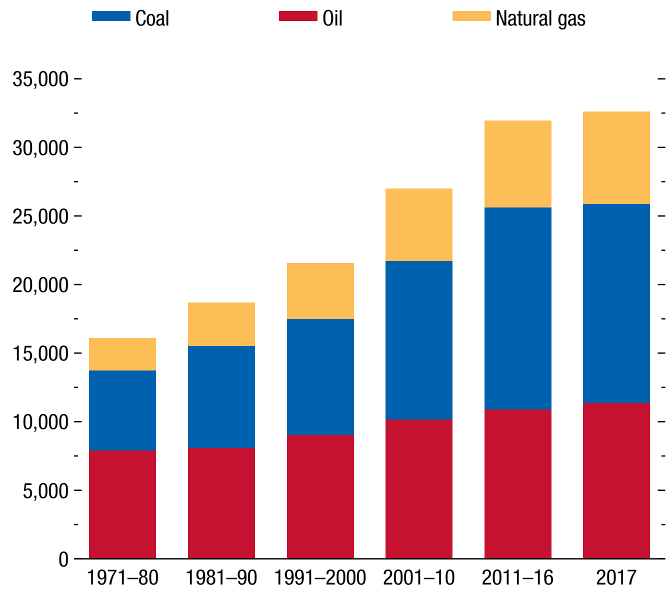
[11]According to the International Energy Agency, the share of energy in total greenhouse gas emissions was 74.2 percent in 2015. The remainder constitutes greenhouse gas emissions from agriculture, deforestation, and land conversion more broadly.

Figure 1.SF.8. Emission Factors
(Metric tons of carbon dioxide a megawatt-hour)



Sources: International Energy Agency; and IMF staff calculations.

Figure 1.SF.9. Average Annual Carbon Dioxide Emissions
(Metric tons of carbon dioxide)



Sources: International Energy Agency; and IMF staff calculations.

How Fast and When Do Countries Lessen Their Dependence on Coal?

With the introduction and rise of new energy sources, especially after World War II, the energy mix in many countries broadened and they became less dependent on coal. Currently, per capita coal consumption has already peaked in 73 out of the 84 countries whose share of coal in total energy consumption at some point crossed 5 percent. Irrespective of their absolute dependence reached at peak consumption, the average annual decline across these countries was 2.3 percent between 1971 and 2017 (Figure 1.SF.10). This implies that it takes, on average, 43 years to phase out coal after the peak in coal consumption per capita has been reached.

Contrasting the energy mix of countries across income groups reveals stark differences (Table 1.SF.2). Poor countries rely primarily on biomass for their energy needs, while middle-income countries have a strong dependence on coal.[12] At high incomes, the coal share in energy decreases as nuclear and natural gas options grow.

The quality ladder hypothesis may help explain the observed relationship between income and the energy mix. The hypothesis states that as income rises, energy sources are chosen not just for affordability and availability but increasingly for their efficiency, convenience, low environmental impact, and safety.[13] Biofuels occupy the low rungs of that ladder; coal, oil, and hydro the middle rungs; and capital-intensive sources, such as nuclear, natural gas, and renewables, the upper rungs. The low price of coal-fired power generation (Figure 1.SF.11) is consistent with the notion that coal plays an important role in the energy mix of lower-middle- and upper-middle-income countries as an affordable and often abundant energy source (Table 1.SF.2).[14,15] Country-specific endowments of competing energy sources, such as hydropower potential, could also influence the attractiveness of coal during different stages of development.

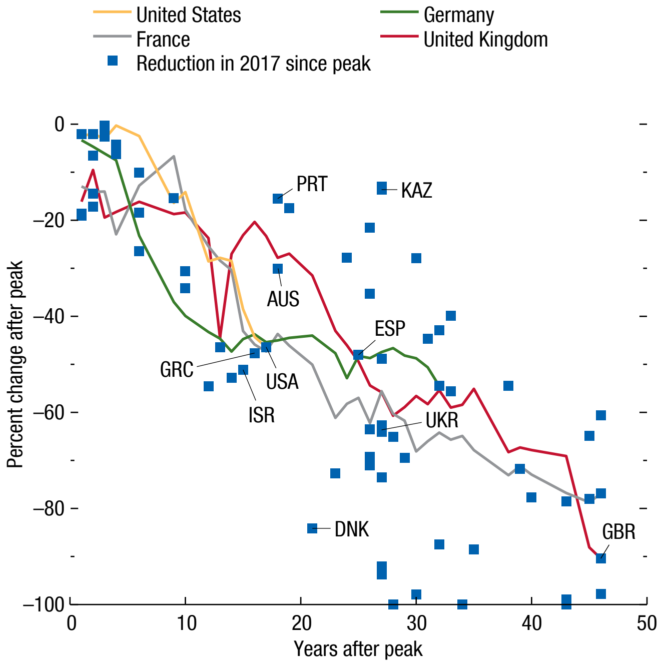
[12]See the relationship between income level and biomass consumption in Chapter 1 of the October 2018 WEO.

[13]See Stokey (1998) for a theory model on demand for environmental quality.

[14]Even today, the marginal cost of operating a coal-fired power plant is one of the lowest. The cost of wind and solar has substantially declined at the plant level, but a full ramp-up of renewables in the electricity grid faces decreasing returns due to their intermittency.

[15]A common way to compare alternative options for electrical energy production is the levelized cost of electricity, which is defined as the present value of the price of the produced electrical energy (usually expressed in units of cents per kilowatt-hour), considering the economic life of the plant and the costs incurred in the construction, operation and maintenance, and fuel costs.

Figure 1.SF.10. Coal Phaseouts



Sources: International Energy Agency; and IMF staff calculations.
Note: For each country, coal peak is defined as the year with the highest coal consumption per capita. Blue square = coal consumption per capita reduction in 2017 since peak. Coal phaseout paths for selected countries are shown in the figure. Data labels use International Organization for Standardization (ISO) country codes.

Empirical Analysis

A panel regression is used to test for the relationship between income per capita and coal dependence, which is defined as the share of coal in total primary energy supply (*relative* coal dependence) or as coal consumption per capita (*absolute* coal dependence). The analysis controls for country-specific factors, including the share of manufacturing in nominal value added, coal reserves per capita, and hydropower potential (see Online Annex I, available at www.imf.org/en/Publications/WEO, for a more detailed discussion).

Results strongly support the presence of an inverse U-shaped relationship between income and the share of coal in the energy mix, with coal attaining its maximum share at an income level of $9,600 per capita—that is, when a country reaches upper-middle-income status. For example, our main specification predicts that, between 1971 and 2017, income per capita contributed to reductions in the coal share of 6.4 percentage points in the United States and 5.2 percentage points in Japan and to increases of 12.2 percentage points in India and 11.3 percentage points in China.

Results also show that energy endowments, such as hydropower and coal reserves, play a quantitatively important role—more so than manufacturing and environmental regulation, for which modest effects are found. Harsher winters are also associated with higher use of coal.

Like the relationship between the coal share and income, the relationship between coal consumption per capita and income is highly nonlinear. The preferred specification shows an S-shape relationship with income per capita: at low income levels, coal consumption growth accelerates, reaches its maximum at the middle income level, and then levels off. The turning point of absolute coal dependence, after which coal consumption declines, ranges from $35,000 to $39,000.

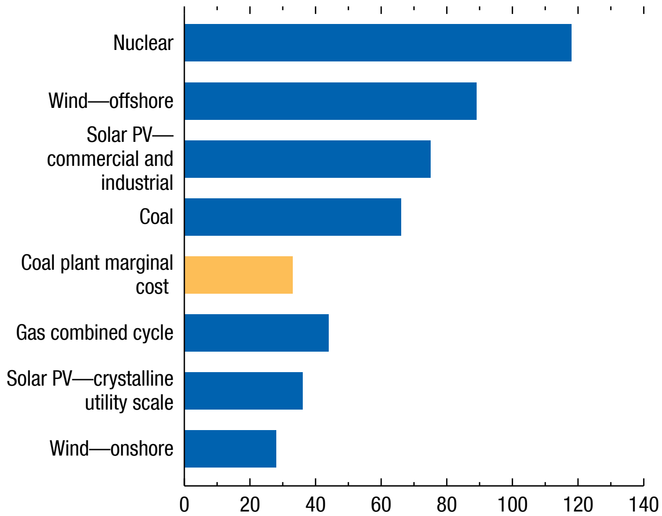
Contrasting the turning points of the two different measures of coal dependence leads to the finding that the "share (or relative) turning point" occurs before the "per capita (or absolute) turning point." At middle and high income levels coal is indeed increasingly succeeded by faster-growing and higher-quality fuels, such as oil, nuclear, and natural gas, *causing* its share in the energy mix to decline. However, coal consumption per capita continues to grow after that (albeit at a slower pace than some other energy sources) to satisfy fast-growing energy demand. Assuming income per capita growth of 4 percent a year, it takes another 33 years to get from the share turning point to the

Table 1.SF.2. Energy Mix, by Income Groups, 2017
(Percent)

Primary Energy Share from:	Biomass	Coal	Crude Oil	Natural Gas	Hydropower	Renewables	Nuclear
Low-Income Countries	80.8	2.3	13.3	0.9	2.8	1.6	0.0
Lower-Middle-Income Countries	26.2	26.9	26.6	14.4	1.8	2.3	1.8
Upper-Middle-Income Countries	5.2	40.9	25.0	21.5	3.4	1.4	2.5
High-Income Countries	5.7	15.8	36.6	29.0	2.1	1.6	9.2
World	12.9	28.0	29.9	23.3	2.6	1.6	1.6

Sources: International Energy Agency; World Bank; and IMF staff calculations.
Note: Income groups as defined by the World Bank.

Figure 1.SF.11. Levelized Cost of Electricity for New Investment, 2019
(US dollars a megawatt-hour)



Source: Lazard 2019.
Note: Based on lower range of Lazard *Levelized Cost of Energy Comparison—Unsubsidized Analysis* estimates. Yellow bar represents the midpoint of the marginal cost of operating an existing coal power plant. PV = photovoltaic.

per capita turning point. These findings are consistent with the idea that new energy fuels only slowly displace old energy fuels.

Combining estimates of the average speed of decline and the estimated time interval between the peaks in relative and absolute coal dependence, it takes, on average, 76 years to phase out coal once it reaches its largest share in the energy mix. For the United Kingdom, which is on the verge of eliminating coal, it took almost 100 years to accomplish that feat (Figure 1.SF.10). For China, whose coal share peaked in 2013, it implies at least another 38 years of coal consumption under business-as-usual conditions. Still, the United Kingdom shows the relevance of policy actions, stimulated by the introduction of carbon pricing at the utility level; the United Kingdom experienced one of the fastest declines in coal usage between 2013 and 2018 as coal was replaced by natural gas (Table 1.SF.3).[16] In the United States, instead,

[16]In 2013 the United Kingdom became the first country in the European Union to introduce a carbon price support—a tax paid by companies that generate electricity from fossil fuels that tops Europe's emissions trading system, through which energy companies buy permits to emit carbon dioxide. The tax was initially set at £9 a metric ton of CO_2 and gradually doubled to £18.

Table 1.SF.3. Selected Recent Fast Coal Phaseouts

Country	Year	Five-Year Reduction (Percent)	Starting Share (Percent)	Mostly Replaced by
United Kingdom	2018	–12.4	17.0	Natural Gas
Israel	2018	–9.4	29.8	Natural Gas
Greece	2018	–8.9	29.9	Natural Gas
Kazakhstan	2016	–8.1	51.3	Natural Gas
Spain	2010	–6.8	12.8	Mixed
Australia	2014	–6.5	39.7	Natural Gas
Portugal	2010	–6.3	13.5	Natural Gas
China	2017	–6.2	69.7	Mixed
Denmark	2018	–5.9	15.7	Biofuel
Ukraine	2017	–5.8	35.8	Nuclear
United States	2018	–5.3	19.6	Natural Gas

Sources: International Energy Agency; and IMF staff calculations.
Note: "Mixed" is natural gas, nuclear, and renewables.

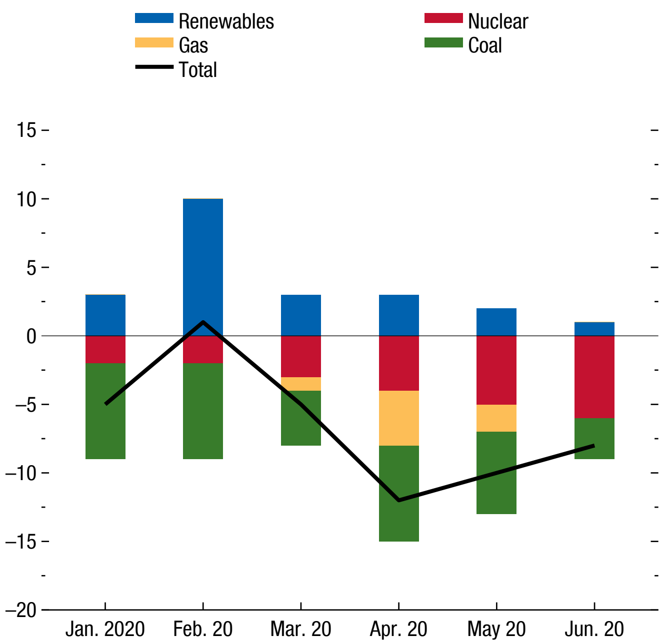
a similar, but more modest, decline was driven by market forces as the shale gas revolution pushed down natural gas prices. The fastest recent transitions away from coal have been driven by natural gas, at times helped by renewables (Table 1.SF.3).

Unsurprisingly, the COVID-19 pandemic has led to a sharp reduction in coal consumption in many coal consumer countries (see Chapter 3). Given that renewables' marginal costs are extremely low, natural gas and coal accounted for most of the decline in electricity generation leading, in some regions, to record-high renewables shares in electricity production (Figure 1.SF.12). However, it is too early to declare "mission accomplished." First, the downward pressure on natural gas prices was even stronger than on coal, in part because of lack of storage for natural gas (Figure 1.SF.13). Second, where electricity demand recovered, coal usage resumed.

These considerations and the previous examples and econometric analysis suggest that a full coal phaseout will occur long after low-carbon energy sources start to gain importance in the energy mix. There are two main reasons for this persistence. First, industrial use of coal is hard to replace with other energy sources and still represents 33 percent of coal consumption in emerging markets, where most industrial sector coal usage is concentrated. Second, and most important, coal-fired power plants are long-lived assets with a minimum design lifespan of 30–40 years. This makes the obsolescence rate of a recently built coal-fired power plant very low without either large changes in the levelized cost of electricity for renewables or policy intervention.

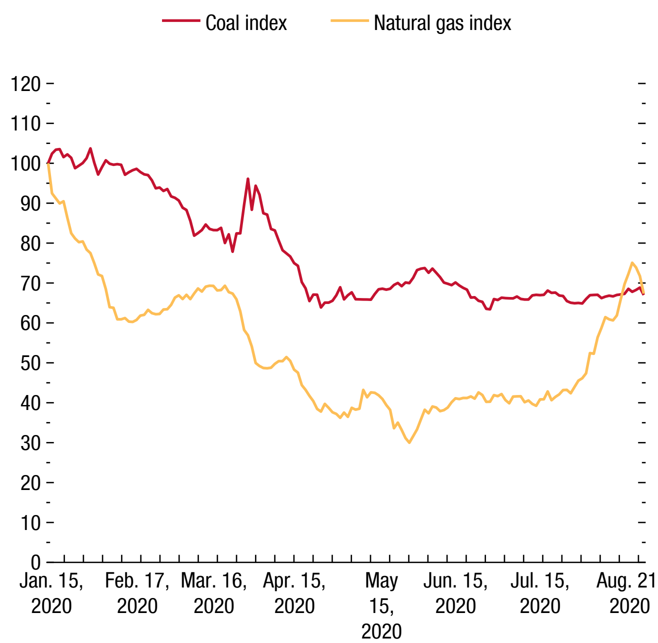
The pandemic and its effects on economic activity are changing the medium-term outlook for coal and coal-fired power plants in various ways but, overall,

Figure 1.SF.12. Contribution to European Electricity Generation Growth
(Year over year, percent)



Source: EMBER.
Note: Data represent the 27 member countries of the European Union.

Figure 1.SF.13. Coal and Natural Gas Prices in 2020
(January 2–15 = 100)



Sources: IMF, Primary Commodity Price System; and IMF staff calculations.
Note: Coal index is the simple average of Australian and South African coal prices. Natural gas index is the simple average of Netherlands Title Transfer Facility and Asian liquefied natural gas prices.

the impact is unclear. On one hand, if the reduction in electricity demand turns out to be more permanent, this would likely reduce the utilization of existing coal-fired power plants, encouraging their closure, especially in advanced economies. On the other hand, in emerging markets, even if electricity demand does not fully recover to trends before the pandemic, it is still expected to grow strongly. A possible reduction in coal prices, coupled with lower wholesale electricity prices, may slow investment in renewables, to the benefit of coal, in the absence of policy intervention.

Finally, it is worth noting that, in contrast to studies examining total energy consumption, a large part of the variation in coal dependence is unexplained.[17] In part, this may reflect political economy factors leading to cross-country differences in energy policies. In some countries the value of coal reserves is multiples of GDP, raising the risk of stranded coal assets. Strong domestic mining interests in large coal consumer and producer countries, especially in Asia, including China and India, may further complicate and delay the phaseout of coal in major coal consumer-producer countries (see Online Annex II for more detailed discussion).

[17]See the Commodity Special Feature of the October 2018 WEO for an analysis of energy demand.

Conclusions

Reducing carbon emissions from coal would go a long way toward fighting climate change. Furthermore, decarbonization of the power generation sector would amplify the benefits of a global transition to electric vehicles and electric mobility more broadly—given that electric vehicles would be charged with low-carbon electricity.

Moving away from coal usually starts in high-income nations and takes decades to complete. The pandemic may have dented coal consumption but, probably, only temporarily. Moreover, countries that have recently, or not yet, seen per capita coal consumption peak (including China, India, and Indonesia) account for the lion's share of global coal consumption, which will therefore take years to decline in the absence of significant policy actions. Further significant reductions in prices of low-carbon alternatives such as solar and wind may help, but to avoid the intermittency problem associated with renewables, natural gas (the closest substitute for coal) is probably needed even if electricity demand does not fully recover to its pre-pandemic trend.

Although carbon-capture and storage technology may be a viable solution, in the absence of substantial carbon pricing, it is currently expensive to retrofit existing plants or build new coal plants with such technology (see IMF 2019 for a detailed analysis of the benefits of carbon pricing). Furthermore, some claim that the CO_2 emission opportunity costs of further investment in carbon capture and storage may be large, as proven technologies, such as wind and solar, can already be used to lower carbon emissions (see, for example, Jacobson 2020). It may be wise, however, to diversify and invest in multiple mitigation strategies, as the intermittency problem of renewables, especially for a high degree of grid penetration, remains unsolved and may still require coal for power generation in some locations.

The decline in coal could be accelerated if governments were willing to compensate the losers from a coal phaseout and see the COVID-19 pandemic as an opportunity to accelerate it. In emerging markets, the degree to which coal is locked in can be minimized if capital constraints are reduced to favor investment in renewables. The international community can provide financial and technical assistance (on how to build grids with the intermittent electricity generated by renewables) and limit funding of new coal plants, at least where alternatives are available.

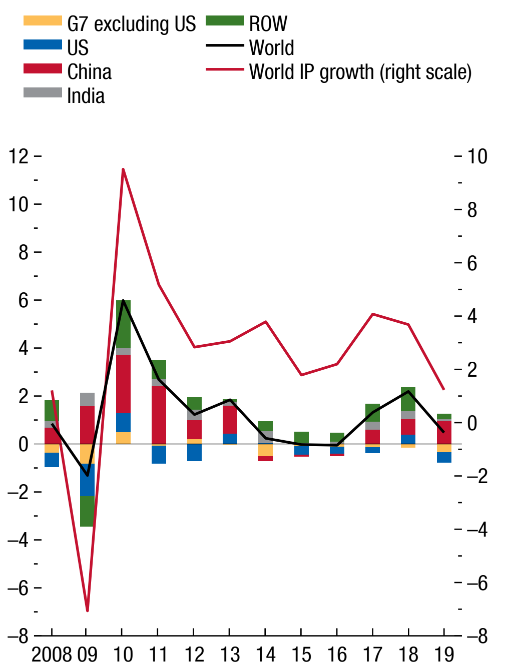
Box 1.SF.1. What Happened with Global Carbon Emissions in 2019?

This box updates the assessment of global carbon emissions from the October 2019 *World Economic Outlook*. Latest data for the end of 2019 show that the growth in global carbon emissions fell to below 0.5 percent, after an alarming rebound in 2017 and 2018 of more than 2 percent (Figure 1.SF.1.1).

China remains a key driver of emission growth, and its impact picked up again in 2019, after a period of gradual regression. India and other emerging markets' contribution in 2019 fell substantially, and emissions decreased in all Group of Seven economies.

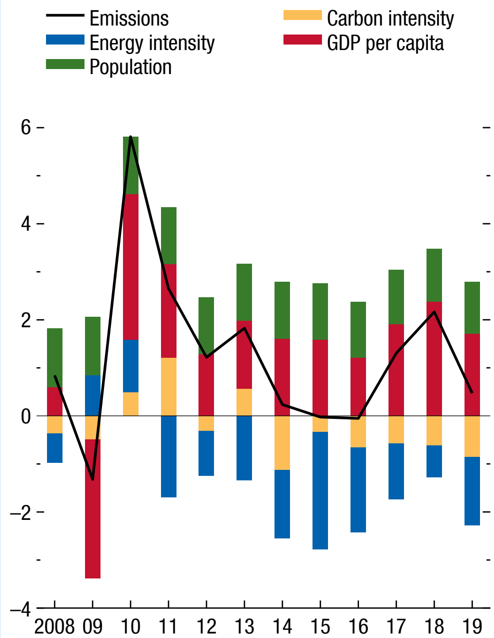
The decline in global emissions in 2019 can be attributed mainly to a fall in energy intensity and

Figure 1.SF.1.1. Contribution to World Emissions, by Country/Region
(Percent change)



Sources: British Petroleum; International Energy Agency; and IMF staff calculations.
Note: G7 = Group of Seven (Canada, France, Germany, Italy, Japan, United Kingdom, United States); IP = industrial production; ROW = rest of the world; US = United States.

Figure 1.SF.1.2. Contribution to World Emissions, by Source
(Percent change)



Sources: British Petroleum; International Energy Agency; World Bank, *World Development Indicators*; and IMF staff calculations.

lower income growth (Figure 1.SF.1.2).[1] This is consistent with previous years and likely reflects the cyclical slowdown in global industrial production in 2019. Decarbonization remained an important mitigation force in 2019 as wind, solar, and natural gas continued to replace coal as the energy source of choice in the power sectors of all major emitters.

In 2020 the COVID-19 pandemic and associated lockdowns will likely lead emissions to fall, although most of the reduction will likely be short-lived when normal economic growth returns. Policymakers should thus seize the crisis as an opportunity to invest in greener growth that permanently lowers emissions (Georgieva 2020).

The authors of this box are Claire Li and Nico Valckx.

[1]The October 2019 *World Economic Outlook* shows that total emissions can be expressed as a product of carbon intensity (carbon emissions per unit of energy), energy intensity (energy per unit of GDP), GDP per capita, and human population.

Annex 1.SF.1. Coal Dependence: Econometric Analysis and Energy Transition Risks for Coal Producers

A panel regression is used to test for the relationship between income per capita and coal dependence. Time fixed effects are used to capture changes in relative energy prices common to all countries, among other factors. Specifically, the following specification is estimated, relating energy dependence to a third order polynomial in (log) income per capita (gdp):[1]

$$coal\_dep_{it} = \beta_0 + \beta_1 gdp_{it} + \beta_2 (gdp_{it})^2 + \beta_3 (gdp_{it})^3 + \beta_4 X_i + \lambda_t + \varepsilon_{it}$$

where X_i is a vector of control variables, including the share of manufacturing in nominal value added (in deviation from global average), coal reserves per capita (in logs), and hydropower potential (in logs), and λ_t represent time fixed effects, and the indexes *i* and *t* refer to countries and years, respectively.

Two measures of coal dependence are used: (1) the share of coal in total primary energy supply (*relative* coal dependence), and (2) (the log of) coal consumption per capita (*absolute* coal dependence). For the coal share in the energy mix and coal consumption per capita, the conjecture is that of an inverse U-shaped relationship between coal share income and an S-shaped relationship between coal consumption and income.

Results strongly support the presence of an inverse U-shaped relationship between income and the share of coal in the energy mix, with coal attaining its maximum share at an income level of $9600 per capita—that is, when a country reaches upper-middle level income status (Annex Table 1.SF.1.1). For example, specification (1) predicts that, between 1971 and 2017, income per capita contributed to *reductions* in the coal share of 6.4 percentage points in the United States and 5.2 percentage points in Japan, and to *increases* of 12.2 percentage points in India and 11.3 percentage points in China.

Having a larger manufacturing sector modestly increases coal consumption, since manufacturing is coal intensive. However, the decline (rise) of US (China) manufacturing between 1971 and 2018 contributed only to a modest reduction (increase) in the US (China) coal share by 1.2 (2.1) percentage points. Similarly, electricity market deregulation and limits on pollution have had minor effects on coal dependence. A one standard deviation increase in

[1] Coal share (in percentage of total primary energy supply) and coal consumption per capita (in thousands tons of oil equivalent per capita) are from the International Energy Agency; data on real GDP per capita (in 2011 USD) is from the recently revised Maddison Project Database (see Inklaar and others 2018); manufacturing share (as percentage of total value added) is from the UN national accounts database. Hydropower potential, as measured by freshwater resources in billion cubic meters per capita is from the World Bank's Development Indicators. The electricity market regulation index and environmental policy stringency (EPS) indicators are from the Organization for Economic Co-operation and Development, while the average summer and winter temperature are based on data from the World Bank's Climate Change Knowledge Portal.

Annex Table 1.SF.1.1. Determinants of Coal Share and Coal Consumption per Capita

1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Coal Share	**Coal Share**	**Coal Share**	**Coal Share**	**Coal Consumption per Capita**	**Coal Consumption per Capita**	**Coal Consumption per Capita**
Real GDP p.c. (log)	0.556***	0.325***	-0.592	0.311***	-28.600*	-20.160*	-21.860*
	(-0.110)	(-0.083)	(-0.404)	(-0.083)	(-11.160)	(-9.696)	(-9.618)
Real GDP p.c. (log) Square	-0.030***	-0.019***	0.025	-0.018***	3.430**	2.475*	2.656*
	(-0.007)	(-0.005)	(-0.020)	(-0.005)	(-1.290)	(-1.112)	(-1.105)
Real GDP p.c. (log) Cubic					-0.131**	-0.096*	-0.102*
					(-0.049)	(-0.042)	(-0.042)
Manufacturing Share	0.002*	0.002*	0.003	0.002*	0.055*	0.065**	0.065**
	(-0.001)	(-0.001)	(-0.002)	(-0.001)	(-0.021)	(-0.022)	(-0.022)
Freshwater Resources p.c. (log)		-0.184**	-0.284	-0.148*		-0.459	-0.364
		(-0.066)	(-0.303)	(-0.063)		(-0.727)	(-0.704)
Freshwater Resources p.c. (log) Square		-0.007**	-0.011	-0.005*		-0.018	-0.010
		(-0.003)	(-0.013)	(-0.002)		(-0.027)	(-0.027)
Coal Reserves p.c. (log)		0.041***	0.040***	0.041***		0.368***	0.317***
		(-0.007)	(-0.009)	(-0.007)		(-0.053)	(-0.051)
EPS Market			0.003				
			(-0.006)				
EPS Pollution Limits			-0.009**				
			(-0.003)				
Electricity Market Regulation (log)			0.029*				
			(-0.014)				
Average Summer Temperature (log)				-0.145			-2.591*
				(-0.105)			(-1.098)
Average Winter Temperature (log)				-0.024*			-0.396***
				(-0.012)			(-0.108)
Constant	-2.268***	-1.991**	2.269	-1.029	79.700*	56.990*	74.050*
	(-0.427)	(-0.629)	(-2.748)	(-0.783)	(-31.930)	(-29.080)	(-29.280)
Model	wls fe	ols	ols	ols	wls fe	ols	ols
R^2	0.963	0.45	0.627	0.491	0.375	0.621	0.661
Observations	4729	3119	572	2958	4118	3004	2845
# of countries	114	74	29	72	113	74	72
Coal share maximum	9582.4	6448.1		6357.6			
Static saturation point					34972.2	38665.4	38881.9

Sources: International Energy Agency, World Energy Balances; Maddison Project Database (2018); Organisation for Economic Co-operation and Development, Environmental Policy Strigency Index; Organisation for Economic Co-operation and Development, Indicators of Product Market Regulation; World Bank, Climate Change Knowledge Portal; World Bank, World Development Indicators database; and IMF staff calculations.

Note: Standard errors are in parentheses. Coal consumption per capita is the log of coal consumption per 1 million people. Manufacturing share is in deviation from its global average. All specifications include year fixed effects. EPS = Environmental Policy Stringency; ols = ordinary least squares; wls fe = weighted least squares and country fixed effects.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

electricity market deregulation lowers the coal share by 0.59 percentage point, while the same for limits on pollution lower the coal share by 0.65 percentage point.

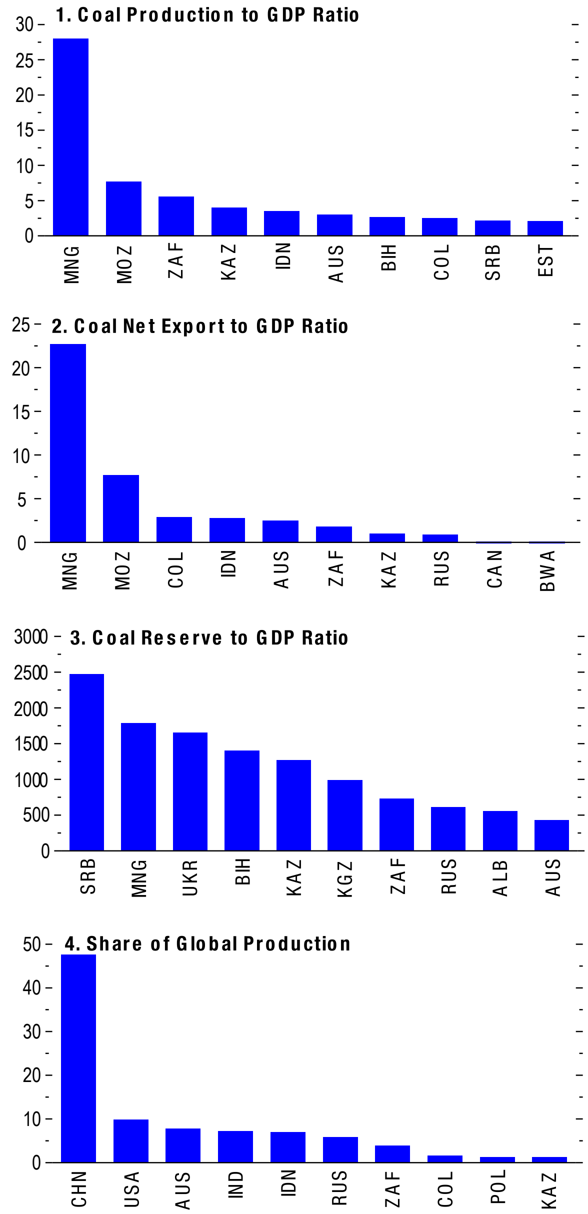
Energy endowments play a quantitatively more important role than manufacturing, however. An increase of hydropower potential of one standard deviation from the mean reduces the share of coal by 4.4 percent while a one standard deviation increases in coal reserves per capita increases the coal share by as much as 11.1 percentage points. For example, all else equal, Norway would increase its coal share by 11.3 percentage points if it had an average hydropower potential, while reductions in coal share of 3.5 percentage points in India, 7.0 percentage points in China, and 15.5 percentage points in the United States would be achieved if they had an average coal reserve per capita.

Weather also plays a large role in the use of coal. A country in the sample experiencing the lowest instead of the highest possible average annual winter temperature since 1971 will see its share of coal increase by 5 percentage points.

Like the relationship between the coal share and income, the relationship between coal consumption per capita and income is highly nonlinear. The preferred specification shows an S-shape relationship with income per capita: at low-income levels, coal consumption growth accelerates, reaches its maximum at the middle-income level, and then levels off. The turning point of absolute coal dependence, after which coal consumption declines, ranges from $35000 to $39000. Furthermore, increasing the average annual winter temperature by 10 percent reduces coal consumption per capita by 4 percent. Hence, warm winters reduce both relative coal dependence and absolute coal dependence.

Annex Figure 1.SF.1.1. The Macroeconomic Relevance of Coal

(Percent)



Sources: British Petroleum, *Statistical Review of World Energy*; International Energy Agency, *World Energy Balance*; World Bank, World Development Indicators database; and IMF staff calculations.

Note: Data labels use International Organization for Standardization (ISO) country codes.

Coal Producers and Risks Associated with Energy Transition

In 2017 total coal production was about 3800 million metric tons, equivalent to $506 billion, or 0.63 percent of global GDP (for comparison the oil expenditure share is about 3 percent). A few coal-exporting countries, such as Mongolia, have a substantial exposure. In general, however, coal exports represent a somewhat modest share of GDP—about 3 percent in Mozambique and Australia and about 1 percent in South Africa, Colombia, and Indonesia (Annex Figure 1.SF.1.1). Even though production is smaller than that of other fossil fuels, the value of coal reserves is multiples of GDP in various countries, which makes the risk of stranded coal assets macro relevant, especially for some major coal-producing countries.[2]

The needs of major coal consumers are typically met domestically.[3] This can raise a political economy hurdle when countries try to introduce policies to curb domestic coal consumption. Indeed, moving away from coal typically lowers demand for the domestically mined product, which could lead to hefty losses for the local mining industry and its workers.[4] Interestingly, in many European countries coal imports have displaced domestic coal production in recent decades. Hence, a large portion of losses from a coal phaseout would not be borne by domestic citizens. This likely paved the way for the European Green Deal.[5]

Looking forward, strong domestic mining interests in large coal consumer and producer countries, especially in Asia, including China and India (Annex 1.SF.2), may complicate and delay the phase-out of coal in major coal consumer-producer countries. In recent US experience, for example, the rapid transition from coal to natural gas—driven by the shale boom—has led to a decline in coal mine employment,[6] a record number of bankruptcies among coal mining firms, and a sharp decline in the Dow Jones US Coal Index. An analog transition in some emerging market coal producers—possibly induced by the introduction of carbon pricing globally or local environmental regulations—may spark financial stability risks associated with the exposure of the banking system to power and mining sector's stranded coal assets.

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[2]While there are some infant technologies to replace coking coal with hydrogen, it is uncertain whether these technologies will mature quickly enough to become an affordable and scalable alternative.

[3]In 2017 the top three coal-producing countries (China, United States, India) accounted for about 70 percent and 78 percent of world production and consumption, respectively—with China alone responsible for [47.3] and [51.5] percent of world production and consumption, respectively.

[4]Mining is the most labor-intensive portion of the global coal supply chain, and fuel costs—not capital—accounts for the lion's share of the costs of coal-fired power generation. In fact, fuel costs and fixed capital investment account for about 50–65 percent and 25–40, respectively, of the total costs of coal-fired power generation (McNerney and others 2011).

[5]The European Green Deal is a set of policy initiatives brought forward by the European Commission with the overarching aim of making Europe climate neutral in 2050. Only Poland, the major European coal producer, expressed discontent with these initiatives.

[6]From 2012 to 2016 coal mining employment fell from almost 90,000 to about 50,000 and later stabilized (US Bureau of Labor Statistics).

Annex 1.SF.2. Coal in India

India faces the dual challenge of satisfying increasing energy needs, driven by a growing middle class and social development objectives (for example, universal electricity access), while reducing (both carbon and noncarbon) emissions. Given its size, India's energy policy choices and emissions trajectory matter for meeting global climate mitigation goals.

While India's per capita emissions are about one-tenth that of the United States, in sheer numbers, India accounted for 6.4 percent of global energy consumption and 6.8 percent of global carbon dioxide emissions in 2018. Its share of emissions is expected to exceed 10 percent by 2030 (IEA 2018). India's relatively high carbon intensity is driven by coal's significant use in power generation (see Annex Table 1.SF.2.1), a dirty and inefficient energy source that contributes not only to carbon emissions but also to local pollution. What explains such high reliance on coal? What are India's prospects of moving away from coal?

Annex Table 1.SF.2.1. Electricity Generation, 2018

	Terawatt Hour		Share	
	World	India	World	India
Total Generation	**26,603**	**1,618**	**100**	**100**
Coal	10,123	1,194	38	74
Oil	808	17	3	1
Natural Gas	6,118	71	23	4
Nuclear	2,718	40	10	2
Renewables	6,799	295	26	18
Wind	1,265	58	5	4
Solar Photovoltaic	592	44	2	3
Hydro	4,203	146	16	9
Other Renewables	739	47	3	3

Sources: International Energy Agency, *World Energy Outlook*; and IMF staff calculations.

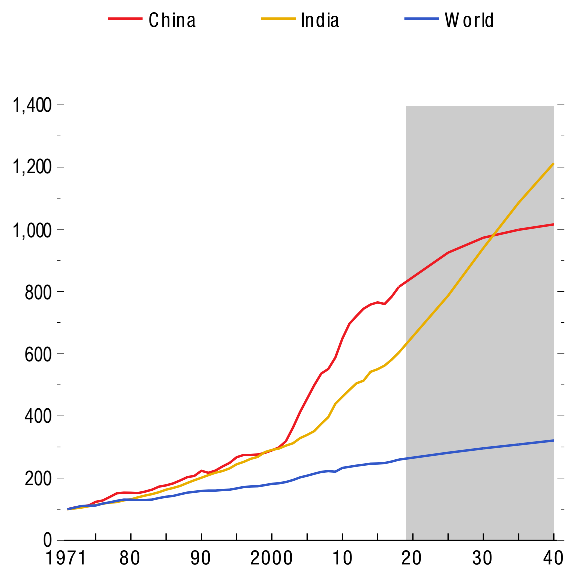
Coal has had such a dominant role in India because it is affordable, available, and reliable, and because the political economy supports the coal sector.

About 70 percent of the coal consumed in India is produced domestically, making India the second-largest hard coal producer after China. Coal is more affordable and reliable than other fuels—such as natural gas, which would need to be imported and requires a huge infrastructure investment in gasification facilities and pipelines. Renewable energy, instead, once installed, has low operating costs and would dispel concerns about energy security. Indeed, in recent years, renewable capacity has increased rapidly, but the upfront investment (per megawatt) remains sizable and has a high import content.

Political economy considerations may also entrench coal in the current economic system (Tongia and Gross 2019). Employment in mining and its footprint on the economy is non-negligible, especially in some regions. Coal accounts for about 44 percent of Indian Railways' revenue and half of its profit, allowing the railway operator to cross-subsidize passenger fares considerably (Tongia and Gross 2018). Furthermore, some coal-producing states (such as Jharkhand, Odisha, West Bengal, Bihar, Chhattisgarh, Telangana, and Madhya Pradesh) need coal levies to partly finance their spending. In addition, further increasing the modest national coal levy may not be feasible, given that electricity prices for households are low and controlled. The direct involvement of India's central government in coal-fired power generation and mining sectors—through controlling stakes in the largest utility firms and coal producers—can also hinder change. This entanglement has encouraged utility firms to reach long-term purchasing agreements with coal producers, which may disincentivize faster expansion of green energy even as renewables' capacity grows.

In addition, the lack of natural gas infrastructure imposes a serious limitation, not only to the use of cleaner gas-fired power plants, but also to the replacement of coal with renewables, given that there would be no backup generation capacity to compensate renewables intermittency.

Annex Figure 1.SF.2.1. Total Energy Consumption and Projections
(Index, 1971 = 100)



Sources: International Energy Agency, *World Energy Outlook and World Energy Balance;* and IMF staff calculations.
Note: Consumption data after 2018 are IEA projections for the Stated Policies Scenario, reflecting the impact of existing policy frameworks and today's announced policy intentions.

Even as India's per capita energy consumption will continue to lag the world average by far, her changing coal usage will play a crucial role in achieving climate mitigation goals. To speed up the transition from coal generation to green energy, India could build on current policies, which have successfully encouraged investment in renewables, and support the development of natural gas infrastructure. Concessionary financing from advanced economies would help stimulate India's green policy adoption and its fairness. The green transition would eventually also reduce financial stability risks associated with Indian banks' exposure to coal assets in the power and mining sector, which could become stranded by the introduction of an international carbon tax or environmental regulations on local emissions. Offering compensation to the mining and power sectors (possibly paid for by raising carbon tax revenue) for the early retirement of old and inefficient coal-fired power plants would reduce the financial stability risks associated with stranded assets during a rapid transition.