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The energy transition and its macroeconomic effects[1]

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Abstract

The energy transition will have profound and varying effects across the globe. We assess how clean technologies are evolving – mainly wind, solar and electric vehicles – and the challenges and opportunities the transition poses for fossil fuel and metals and minerals producers in the short and long term. We describe the likely macroeconomic consequences of the energy transition and identify the countries that are most positively and negatively exposed. A small number of fossil fuel-producing countries are likely to be severely hit. Meanwhile, a concentrated group of minerals producers should experience large net benefits. Fuel importers – that is, most of the world – should benefit to varying degrees.

Keywords: Energy transition, transition risks, macroeconomics.

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1. Introduction

The energy transition is well under way and accelerating. Wind and solar energy are the cheapest sources of electricity in most of the world, renewable energy accounts for nearly all global electrical capacity growth, electric vehicle (EV) adoption is rapidly increasing and auto manufacturers are moving towards fully electric fleets (International Energy Agency (IEA) (2023), International Renewable Energy Association (IRENA) (2021)). These trends will be reinforced as technology improves and the impacts of measures such as the US Inflation Reduction Act, the European REPowerEU plan and China's latest Five-Year Plan for Renewable Energy Development begin to be felt. The increase in fossil energy prices after the Russian invasion of Ukraine has likewise added a further impulse to the transition.

This paper seeks to provide a broad, qualitative overview of the energy transition by bringing together research from a variety of disciplines – economics, finance, energy systems and environmental science – to give a directional view of how the transition may evolve in future. That is, it aims both to complement quantitative macroeconomic scenarios, such as those outlined by the Network for Greening the Financial System (NGFS), and to give a more targeted, sector-specific description than is plausible in such large-scale macroeconomic models (NGFS (2022)). We hope this paper can also serve as a launch point for future research that more narrowly focuses on the specific aspects of the energy transition which researchers, policymakers and investors typically focus on (eg quantifying its effects on inflation, trade flows and financial flows).

When exploring the macroeconomic implications of the energy transition, we find it convenient to focus on three types of country: (i) fossil fuel exporters, who will see their main source of export and fiscal revenues severely eroded, forcing a shift to a new growth model; (ii) fossil fuel importers, who will spend less on importing fuel due to the abundance and geographical dispersion of clean energy resources; and (iii) exporters of key metals and minerals, who are likely to benefit from a structurally higher demand for their products and possibly from a new metals and minerals supercycle. Of course, these groups are conceptual and actual countries may fall into more than one of these buckets. Moreover, countries could have some regions falling into one category and others falling into a different one. Still, we find this distinction is a good starting point for an exploration of the macroeconomic effects of the energy transition.

The transition may follow a variety of paths in the near-term. Constrained fossil fuel investment could push up energy prices sharply for an extended period and bottlenecks in metals and minerals markets could slow or raise the costs of the transition. But the opposite scenario is equally conceivable; rapid adoption or faster than expected improvement of clean technologies could push energy costs and fossil fuel demand down faster than anticipated. Metals and minerals production constraints could create a new commodity supercycle for the handful of countries where accessible reserves and refining capacity are concentrated (eg Argentina, Australia, Bolivia, Chile and Peru for reserves and China for refining).

The long-term picture may be as follows. Most of the world, particularly East and South Asia, should benefit from replacing expensive, polluting, imported fossil fuel with cheaper, cleaner, locally sourced energy. For major fossil fuel producers, especially those in the Middle East and North Africa, the economic benefits of clean energy will probably be overshadowed by the decline of existing energy sources.

Producers of key metals and minerals (eg copper, lithium, rare earths) should see amplified benefits, but the value of these exports will be substantially smaller than for fossil fuels. Overall, economic activity should shift from fossil fuel producers and towards energy importers and metals/minerals producers.

The next section surveys the evolution of and the outlook for clean technology and fossil fuel markets. Section 3 discusses how the transition may manifest itself macroeconomically (eg in growth, inflation, exchange rates and capital flows). Section 4 looks at how exposed different countries are to the transition. We conclude with a discussion on the policy implications of the energy transition.

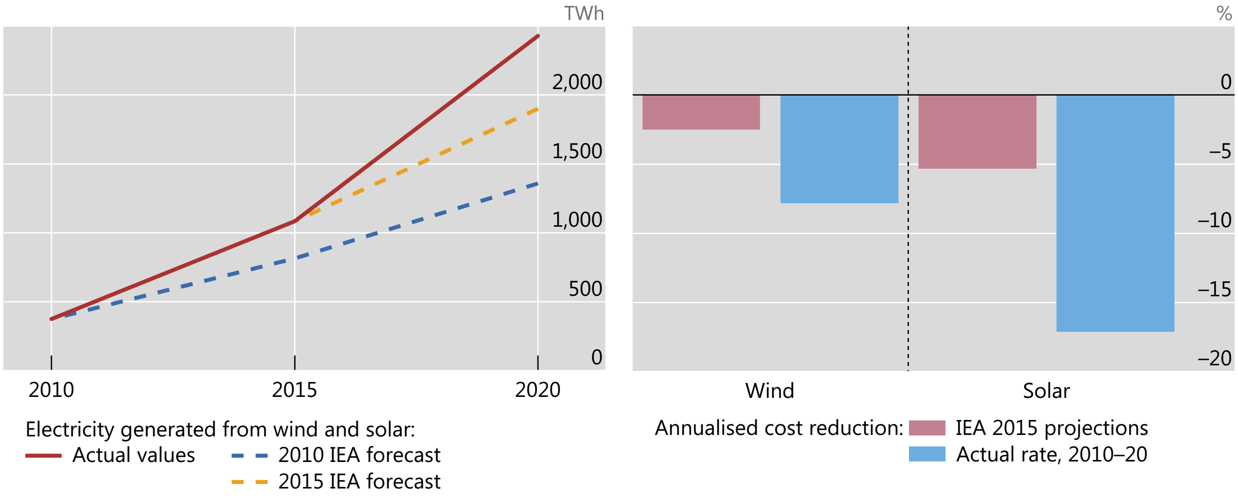
2. Evolution and outlook for energy markets

Renewables are cheap and usage is growing fast

Price declines and the adoption of wind and solar energy have far surpassed expectations over the past decade (Graph 1).[2] Measures of learning rates – the rate at which technology costs decline for every doubling of capacity – cluster around 15% for wind energy and 25% for solar energy.[3] The advantages of renewables should thus only grow over the coming decades; applying the International Energy Agency's (IEA) projections for electricity capacity in its three principal scenarios – the Stated Policies Scenario (SPS), Sustainable Development Scenario (SDS) and Net Zero Scenario – wind energy costs could fall by a further 17–29% by 2030 as compared with 2020, while solar costs could fall by another 40–60%.

Clean energy is growing and improving far faster than expected | Graph 1

Projected versus realised wind/solar generation | Projected versus realised wind and solar cost declines



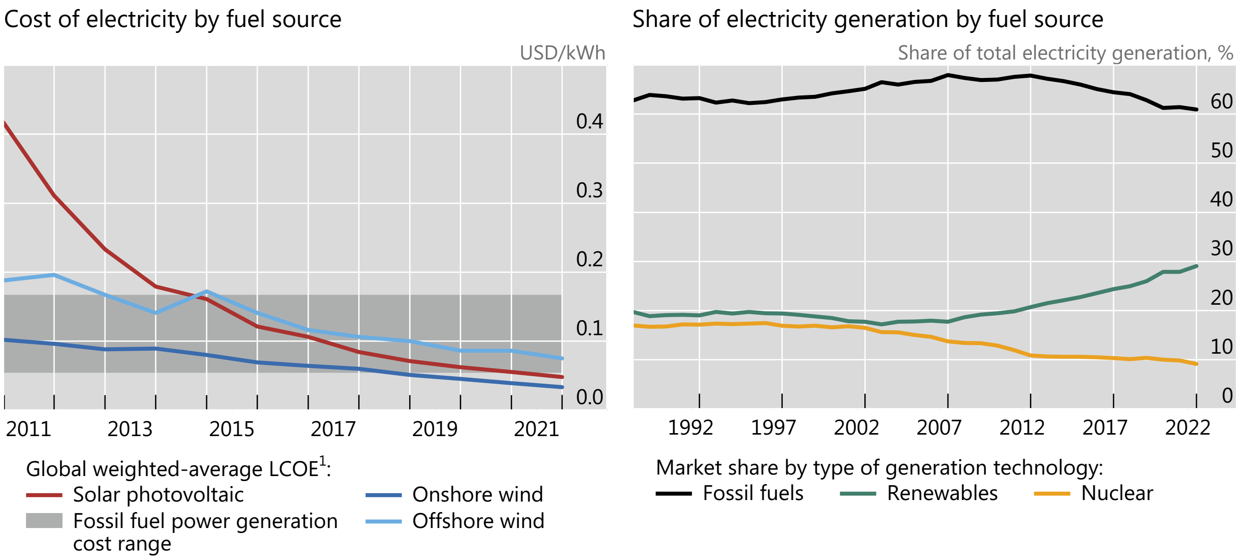
Source: IEA.

[2] At a 16% annual price decline, solar energy costs fell by substantially more than assumed in several thousand integrated assessment model (IAMs) projections (Way et al (2022)). The mean projection was for a 2.6% annual decline and the highest forecast was 6%.

[3] From 2010 to 2020, learning rates were much faster; 32% for wind energy and 39% for solar energy (IRENA (2021)). Applying the IEA's scenarios to these data implies that wind energy costs will fall by 35% to 65% by 2030 vis-à-vis 2020, while solar costs will fall by 59% to 79%.

Declines in realised prices have already made renewable energy the cheapest source of electricity in most of the world and thus the preferred choice for new capacity (Graph 2, left-hand panel). Renewables' share of newly added capacity increased from just under 40% in 2010 to nearly 90% (IRENA (2022)). This share is expected to increase to 95% of new investment by mid-decade (IEA (2021a)). This rapid growth has pushed the share of renewables in global electricity generation from around 20% in 2010 to almost 30% in 2022 (Graph 2, right-hand panel).

Renewables' cheapness and abundance is increasing their usage — Graph 2



[1] Levelised cost of energy.

Sources: IRENA; BP; EMBER; authors' calculations.

A lack of transmission capacity could, however, impede the adoption of wind and solar. Intermittency – because of a lack of local wind or sunshine that cannot be offset by sunny or windy conditions elsewhere – may become a more binding constraint. Yet if these issues are resolved, renewables could supply a large share of many countries' electricity demand; wind and solar could theoretically provide 72% to 91% of major countries' electricity needs (Tong et al (2021)).[4] Transmission and distribution also create a floor on how low retail electricity costs can go; such costs account for around a respective 13% and 31% of electricity costs in the United States (US Energy Information Administration (EIA) (2021)),

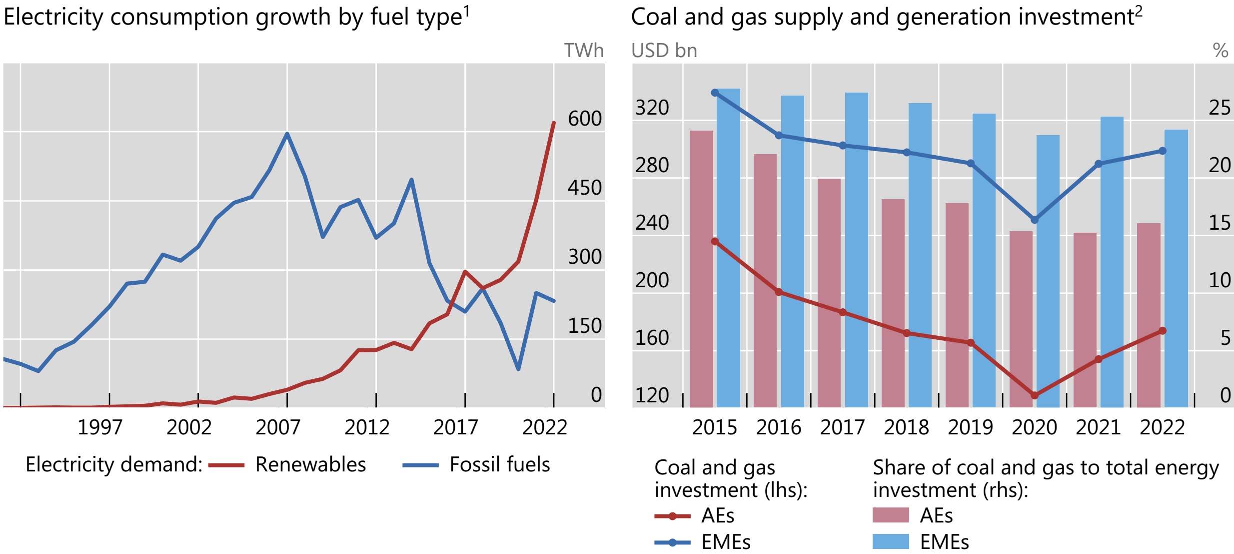
Beyond transmission, other technologies (eg hydroelectricity, geothermal, nuclear, batteries, hydrogen) and strategies (eg demand reduction and shifting) will be needed to support variable sources of energy to ensure around-the-clock reliability. In any case, as wind and solar power are still far from hitting even their near-term saturation points, their rapid growth should increasingly eat away at fossil fuel demand in the power sector.

[4] It should be noted that, as these figures do not reflect siting constraints, nor do they necessarily reflect the lowest-cost zero emissions grid, actual usage is likely to be lower. Nevertheless, these issues highlight that a lack of sun or wind in a given country are not the main constraints facing the adoption of wind and solar.

Fossil fuel power is facing a massive challenge from renewables

While the use of coal and natural gas in electricity generation – still the two largest sources of electricity supply globally – each hit record levels in 2021 and 2022, the rapid advance of renewables should put huge pressure on them over the next decade and beyond. Growth in fossil fuel electricity generation is slowing while renewable generation continues to grow rapidly (Graph 3, left-hand panel). Investment in fossil production and generation capacity has likewise been in a steady decline (Graph 3, right-hand panel), implying that the existing stock of fossil fuel assets will overwhelmingly be replaced by cleaner sources. Tightening policy around fossil fuel use, strong policy support for clean technologies and the cost advantages of renewables over existing capacity mean that large downside risks to fossil fuel demand in the electricity sector cannot be discounted (IRENA (2021)).

Despite a post-pandemic rebound, the outlook for fossil fuel electricity is poor — Graph 3



[1] 2022 data are on a trailing 12-month basis. Fossil fuels data are a five-year moving average. [2] AEs = OECD regional grouping and Bulgaria, Croatia, Cyprus, Malta and Romania; EMEs = All other countries not included in the advanced economies regional grouping, China included.

Sources: IEA; BP; EMBER; Global Energy Monitor; authors' calculations.

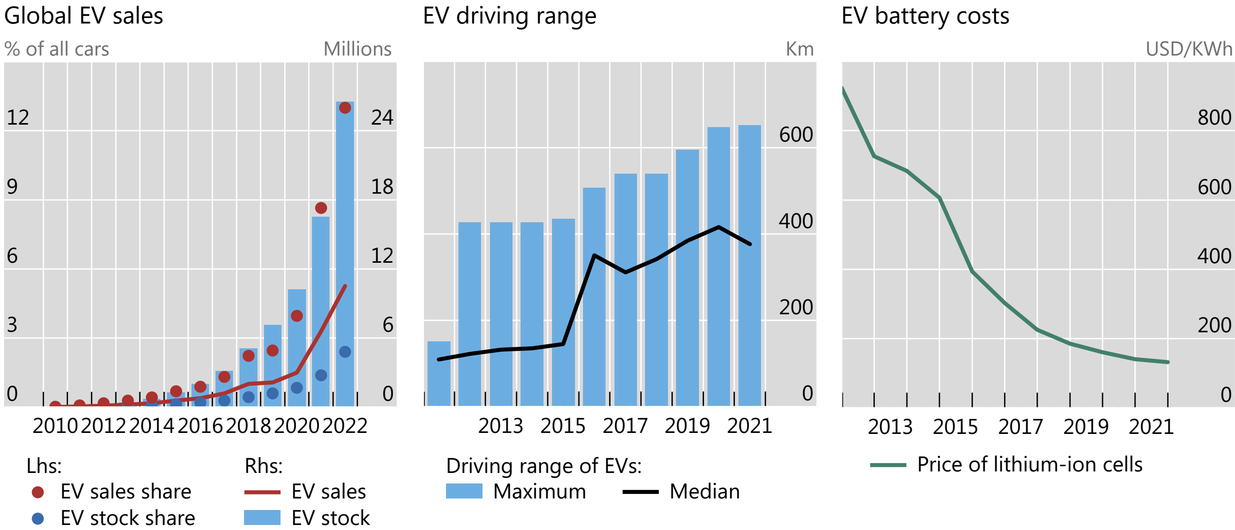
Renewables pose a more immediate threat to coal than to gas. Indeed, electricity accounts for around two thirds of global coal demand and demand challenges are already apparent. After decades of steady growth, global coal consumption has been flat since 2014. Coal's share of global electricity production has fallen from its 2011 peak of 41% to 36% in 2022 and would probably have been even lower if not for the unexpectedly strong rebound in energy demand in the aftermath of the pandemic and the effects of the war in Ukraine on energy prices (Ember (2023)). Global coal capacity additions are also on a steady downward trend (Global Energy Monitor (2022)). And coal financing costs have increased sharply, pointing to growing stigmatisation and poor growth prospects (Zhou et al (2021)).

Natural gas has more diversified range of uses, which should help to sustain demand over a longer period. For instance, electricity generation accounts for only 40% of natural gas demand, compared with 65% for coal. Moreover, gas is less polluting, its capital stock is newer and it has quicker start-up times. The latter factor makes it suitable for meeting peaks in electricity demand. It is also the largest source of heating across the world (IEA (2022)). Meanwhile, viable alternatives (eg heat pumps) are only just being rolled out at scale or are still years from being commercially competitive (eg hydrogen). Natural gas also remains a major input in some hard-to-abate industrial processes (eg production of glass, fertiliser and other petrochemicals). However, high natural gas prices and aggressive moves by European countries to wean themselves off Russian supplies could accelerate the transition.

The electrification of transport is accelerating

The EV market, although less advanced than the market for renewable energy, is also growing rapidly (Graph 4, left-hand panel). The EV share in new sales has grown from around 1% in 2015 to more than 13% in 2022 as major hindrances to widespread adoption such as driving range and input costs have declined (Graph 4, centre and right-hand panels). And this rapid adoption is not limited to the conventional passenger market; two/three-wheel vehicles, bus, van and semi-truck markets are also seeing sharp growth.[5] These trends should continue as new manufacturers expand and legacy auto manufacturers shift to the mass production of EVs, which should in turn eventually eliminate the upfront cost competitiveness of internal combustion engine (ICE) vehicles.[6]

EV choice and quality are improving rapidly and wider adoption is following — Graph 4



Sources: Ziegler and Trancik (2021); IEA; US Department of Energy; US Environmental Protection Agency; EV volumes; authors' calculations.

5 Electric buses and electric two-/three-wheel vehicles accounted for 44% and 42% of sales, respectively, in their categories (Bloomberg New Energy Finance (2022)).

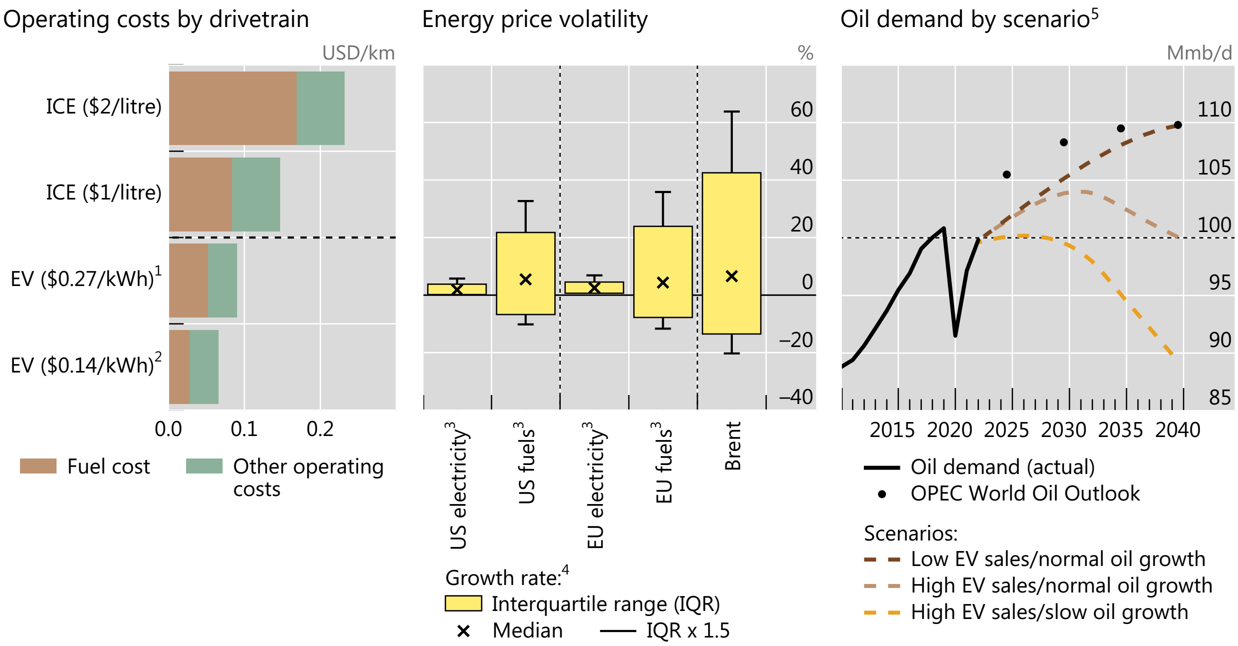
6 Battery prices have a learning rate of 20% (Ziegler and Trancik (2021)). Using IEA's Stated Policies Scenario, battery costs could fall by around 55% to around $60/kWh by 2030, which would be well below the $100/kWh needed to achieve upfront cost party with ICE vehicles.

Electrified transport will put pressure on oil demand

The recurring and volatile costs associated with ICE vehicles relative to EVs makes the outlook for oil demand very challenging. As the operating costs of EVs are well below those of ICE engines (Graph 5, left-hand panel), consumers will have less and less reason to keep buying ICE vehicles. EVs also serve as a permanent hedge against fossil fuel price volatility; electricity prices vary far less than fossil fuel prices (Graph 5, centre panel).[7]

Meanwhile, several jurisdictions (eg California, Canada, Japan) and auto manufacturers (eg General Motors, Volvo, VW Group) intend that 100% of their vehicle sales will be zero emission by 2035. If applied worldwide, this could lead to oil demand peaking within a decade (Graph 5, right-hand panel). And electrification is already displacing significant amounts of oil. EVs across all classes are reducing oil demand by around 1.5 million barrels a day (Bloomberg New Energy Finance (2022)) – roughly equivalent to the daily consumption of France – while global oil demand was around 101 million barrels a day (EIA (2023)).

EVs are cheaper to operate, have less volatile costs and should erode oil demand — Graph 5



[1] Average EU electricity price in 2021. [2] Average US electricity price over the 12 months ending March 2022. [3] Consumer price index (CPI). [4] From January 1997 to November 2022. [5] Assumptions: average LDVs consume 6.5 barrels of oil/year; lifespan of LDV vehicle equals 15 years; total LDV sales equal 95 million vehicles a year; total LDV stock equals 1.4 billion vehicles. EV scenarios: high (low) adoption equals 20% (10%) annual growth rates until market saturation. Normal oil growth is defined as 1.2% growth rate a year for non-gasoline demand (2009–19 average) while slow oil growth is defined as a growth rate of 0.6% a year.

Sources: IEA; Eurostat; Fred; authors' calculations.

[7] The lower volatility of electricity prices is due primarily to how electricity markets are regulated; end-user prices are typically set based on the seasonal cost of providing electricity, meaning that short-term fluctuations are smoothed out by the time they reach end consumers. Another factor is that a significant share of electricity prices (~40–50%) is based on the fixed costs (ie transmission and distribution), which do not fluctuate rapidly.

Other sources of oil demand (eg long-distance shipping, jet travel, petrochemicals) could offset the effects of electrification. However, historical non-gasoline growth implies that demand may still be less than what is expected by producing nations, while slower growth implies large and growing absolute declines in oil demand.

Also, it may be challenging to achieve even historical growth rates for non-gasoline demand. Electrification is accelerating in segments where diesel fuel is currently used, such as short- and middle-distance freight and transportation. Regulatory stringency on the usage of petrochemicals is increasing for climate and non-climate reasons (eg single-use plastic bans), which is likely to supress demand. Meanwhile, better-than-expected technological progress and adoption is an ongoing risk to all demand for fossil fuels.

The supply response from oil producers adds further complications to the outlook. Prices could increase sharply if producers continue to hold back on investment and if clean technologies were not to scale sufficiently. On the other hand, once peak oil demand is reached and a permanent decline becomes apparent, oil producers' incentives may change rapidly and induce a permanent price decline (Mercure et al (2021)). Oil producers would be incentivised to produce more oil in the near term to extract maximum value from their reserves, rather than hold back production and eventually be stuck with reserves that are worth less. And given the abundance of oil available in the world – proven reserves amount to 54 years of current production (BP (2021)) – there are strong incentives for oil producers to eventually do this.

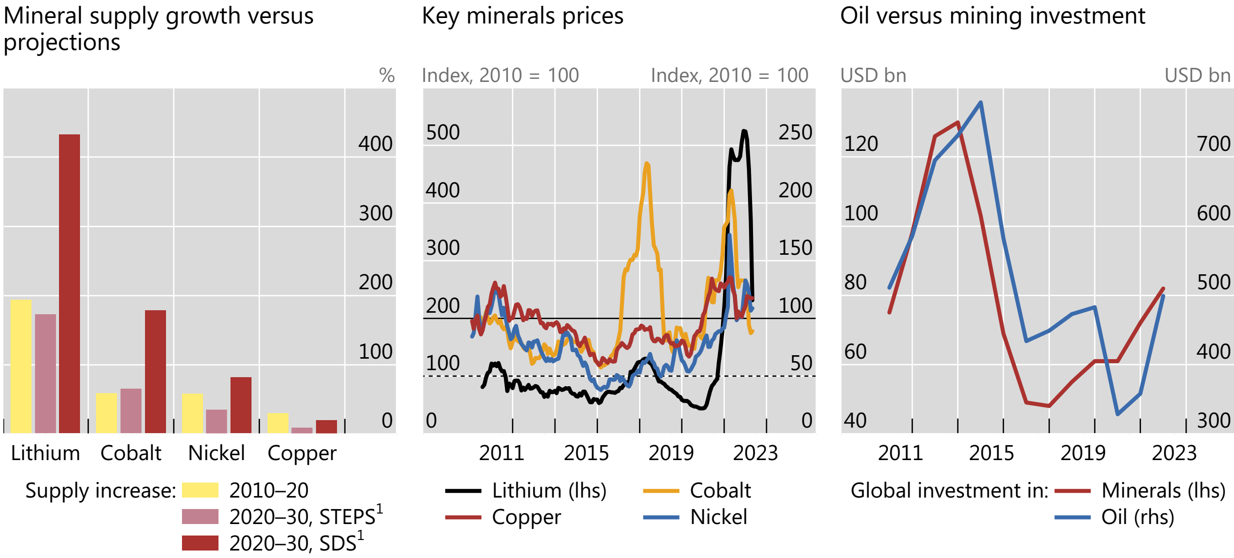
These scenarios could occur sequentially as well. A boom in fossil fuel prices could help accelerate the energy transition by increasing the relative price of traditional energy to clean energy, which would set the stage for an eventual crash once sufficient clean capacity is in place. A similar evolution occurred during and after the 1970s oil crises; the fuel economy of new light vehicles in the United States increased from 13.1 miles per gallon in 1975 to 21.3 miles per gallon in 1985 (Davis and Boundy (2022)). These technological improvements, alongside production from new oil fields, led to a 70% decline in the price of oil from 1981 to 1986 and a low oil price environment which persisted for almost two decades.

Given this high degree of uncertainty and the delicate equilibrium in which oil markets operate, large and sudden price adjustments in oil markets, both upwards and downwards, cannot be ruled out. The 2014 oil price crash occurred while oil demand was growing. Yet a widening of the supply and demand imbalance of less than 2 million barrels a day helped push prices down by approximately 70% (Baumeister and Kilian (2016)). Conversely, even though oil demand has barely recovered to its pre-pandemic levels, lower investment and the invasion of Ukraine by Russia helped push prices up by a similar magnitude.

The transition may create a metals and minerals supercycle

Just as fossil fuels may see massive downward pressure on demand in the next decade or so, the expansion of renewable energy and the electrification of transportation will require a massive expansion of the supply of minerals such as copper, lithium, cobalt and rare earths. For example, copper supply may need to increase by 20% over the next decade, cobalt and graphite supply may need to triple and lithium supply may need to quintuple under the IEA's Sustainable Development Scenario (Graph 6, left-hand panel). And tightness and volatility in these markets is already apparent; prices generally remain above their historical levels even after the recent easing of extreme price increases of the past few years (Graph 6, centre panel).

Metals and mineral markets may be tight for a while — Graph 6



[1] Increase necessary to meet new demand from renewables, EVs and electricity networks. STEPS = Stated Policies Scenario. SDS = Sustainable Development Scenario.

Sources: IEA; IEF; USGS; Datastream; PwC; authors' calculations.

Relatedly, supply bottlenecks could slow the pace of the energy transition and set the stage for a metals and minerals supercycle. The speed with which mining projects can come online should be a major determinant of how prices and supply evolve; lithium mines can take around half a decade to see production, while nickel and copper can take over a decade (IEA (2021b)). These lag times, insufficient prior investment and likely demand growth suggest that a potential long-term boom in mineral prices is plausible if not likely.

A metals and minerals supercycle may also set the stage for an eventual crash. All these metals and minerals are abundant, but a lack of previous investment and/or insufficiently high prices have impeded their development. Persistently high prices will help the development of currently less viable supplies (eg lithium deposits in Canada, Germany and Mexico), much as the previous commodity boom facilitated the development of the Canadian sands and US shale oil. And relatedly, mining investment has been increasing for several years – even as oil investment was much slower to rebound – suggesting that new supply should increasingly come online (Graph 6, right-hand panel). Finally, these aggregated figures probably understate the level of metals and minerals mining taking place given the concurrent decline in coal mining capital expenditure.

Similarly, scarcity will create powerful incentives to economise on key materials, as can be seen by the sharp drops in cobalt usage in EV batteries (McKerracher (2022)). EV manufacturers are moving away from older battery chemistries, which were heavily reliant on cobalt, to newer chemistries (eg lithium-iron phosphate) that contain no cobalt at all. Similarly, battery manufacturers are starting to produce batteries that replace relatively scarce lithium with far more abundant sodium (Crownhart (2023)). In other words, technological progress may mean that metals and mineral constraints may be weaker than currently expected.

In the very long term (ie after the next 20 years), steady-state demand for these products will probably follow a very different pattern than for fossil fuels. Whereas fossil fuels are continuously extracted and used and cannot be recycled, a large proportion of future metals and minerals demand should be front-loaded as new technologies are adopted and supporting infrastructure is built out. Subsequent demand for these minerals is likely to come just from what is needed to operate, maintain and expand the energy system. However, given the scale of change implied by the energy transition, this boom in the quantities demanded for metals and minerals – if not necessarily for their prices – could last for decades.

3. Macroeconomic and financial effects of the transition

The energy transition will have massive effects across the globe

Even though clean technologies are environmentally and economically superior to their traditional counterparts, the transition path to a more sustainable future is highly uncertain. A faster transition could depress prices for both clean technologies and traditional energy, while a slower transition could instead push energy prices up as fossil fuel supply is constrained before sufficient clean energy supplies come on stream. Longer-term, the trajectory is more apparent. The falling costs of clean energy, its relative cost superiority to their traditional counterparts and reduced demand for fossil fuels should all combine to push energy prices downwards.[8]

In this section, we will discuss the likely macroeconomic effects of the energy transition across three broad classifications of countries: fossil fuel exporters, fossil fuel importers and metals and minerals exporters. We will assess these primarily through the lens of a trade shock but will also discuss how these shocks translate into broader macroeconomic effects.

We also distinguish between the highly uncertain transition phase, for which we will discuss different scenarios, and the eventual steady state. Note that countries can fall into more than one category (eg as a fossil fuel importer and metals and minerals producer). They can also be fossil fuel importers in one region and producers in another, although for simplicity we will mostly focus on the effect at a net national level. To support this conceptual, qualitative analysis, we will look at case studies of representative countries during previous commodity booms and busts.

[8] For brevity, we do not evaluate the economic effects of reduced air pollution that would be associated with the energy transition. However, these effects should be substantial, particularly in many lower-income countries. Indoor and outdoor air pollution has been estimated to kill 6.7–8.8 million people prematurely each year worldwide (Roser and Ritchie (2021)). Meanwhile, the global costs of air pollution have been estimated at 6–14% of global GDP (World Bank (2022), IRENA (2016)).

Effects on fossil fuel exporters

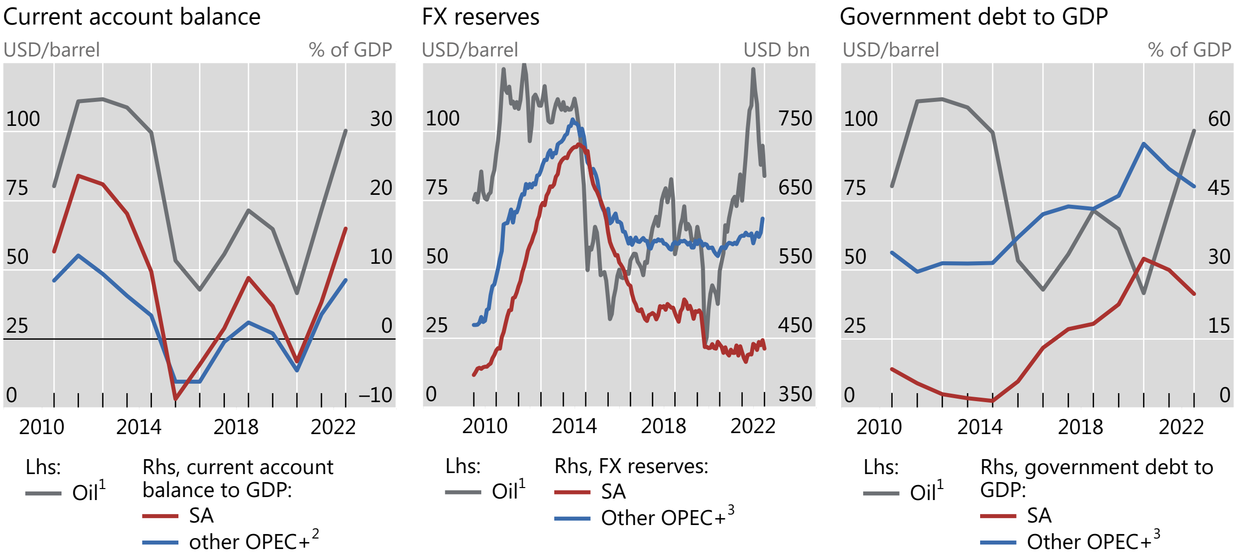
Transition phase

A rapid transition would be highly disruptive to fossil fuel producers – although the degree will depend on their pre-existing economic diversity – and would probably be felt first through a negative terms of trade shock. A rapid price decline due to lower-than-expected oil demand would obviously put severe pressure on fossil fuel producers' current accounts, thus creating balance of payments and/or exchange rate challenges. Similarly, a shock would pressure fiscal accounts and hinder governments in their attempts to respond. These issues were particularly apparent in Russia following the effects of sanctions imposed on it after its invasion of Ukraine.

Furthermore, worsening prospects for fossil fuels would place pressure on investment, thus cutting off a key growth channel. These issues may also be aggravated by financial stresses; commodity price crashes are typically associated with rising non-performing loans and bank funding costs in commodity-producing countries (Kinda et al (2016)).

These effects can be observed in the experience of oil producers following the 2014 oil price crash. Many fossil fuel producers saw a collapse in their current account (Graph 7, left-hand panel), which in turn depleted their foreign reserves and sharply increased public debt levels (centre and right-hand panels). The shock of the oil price crash significantly raised the risk premium in affected countries and constrained policy responses as the shock hit as well (Bouri et al (2020)).

The 2014 oil price crash had major macroeconomic impacts on producers — Graph 7



[1] Brent crude index. [2] BH, DZ, AO, GA, GQ, IR, IQ, KW, LY, NG, CG, SA, AE, AZ, BN, KZ, MY, MX, OM, SD, SS, VE. [3] AE, AO, AZ, DZ, IQ, KW, KZ, MX, MY and OM.

Sources: IMF; Bloomberg; Datastream; BIS; authors' calculations.

However, as may be the case now, if capital pulls back from the sector faster than actual demand for fossil fuels falls, existing and low-cost producers – particularly those which are state-owned, low-cost and/or less sensitive to investor pressures – could see one final windfall. This windfall would have essentially the opposite effects of the rapid transition that was just described and could buy affected countries' additional time to deal with the transition.

Steady state

The steady state for fossil fuel producers will be dependent on their existing economic structures and policy choices made well before the transition becomes macroeconomically relevant. In the absence of reforms to diversify their economies and tax bases, undiversified producers may see major threats to their fiscal sustainability and balance of payments. And given the scale of the potential impact from the transition, even countries with substantial savings could see these funds erode quickly away.

Some oil and gas producers, particularly the more diversified producers, may see only a shift in economic activity. Weaker exchange rates, less competition for highly skilled workers and lower wage pressures could make certain industries and regions more competitive and set the stage for new forms of development. And the reduced availability of fossil fuel revenues may force governments and industry to orient themselves towards different economic models.

And while direct fossil fuel employment typically accounts for a relatively small share of the overall labour force, there could be noticeable effects on a regional level. Workers in fossil fuel production or in fossil fuel-producing regions will probably need time to move to other sectors or parts of their countries. Relatedly, fossil fuel-producing regions could see long-term weakness even as other regions of the country prosper and workers move on. Also, the relatively high pay of oil and gas jobs mean that displaced workers may never find equally lucrative jobs.

Effects on fossil fuel importers

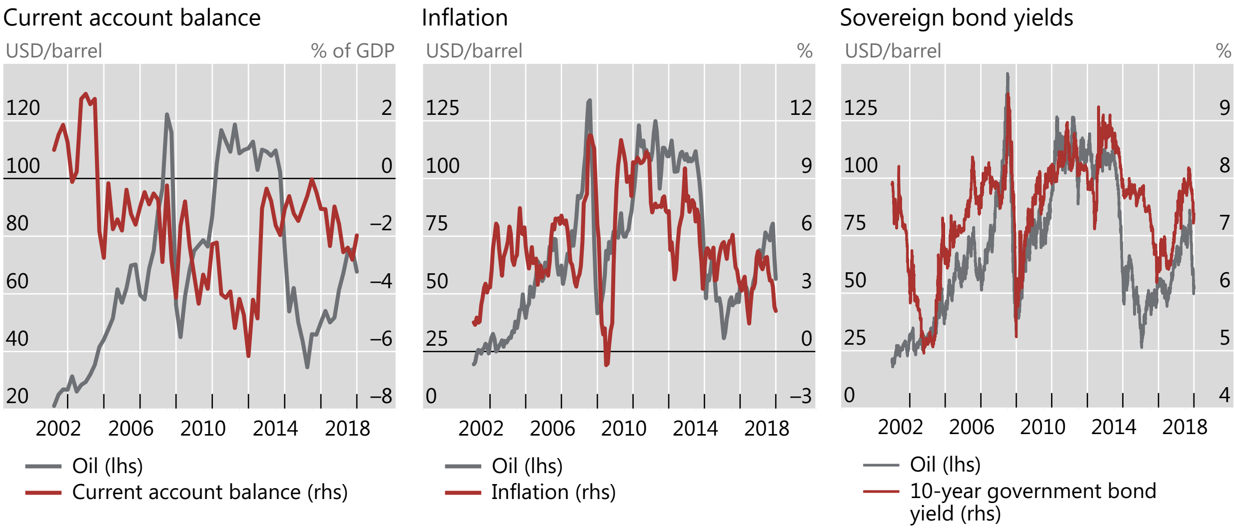
Transition phase

Whatever the experience of fossil fuel exporters, importers – particularly those in lower income countries – will experience the inverse. If fossil fuel supplies are tight and the transition lags, fossil fuel importers could see worsening terms of trade, current account balances, exchange rates and inflation; essentially, importers would experience a negative supply shock to their economies. This would probably flow through to the broader economy through lower investment and consumption. And in many cases, it would worsen fiscal balances both through slower growth and the direct effects of rising energy subsidies.

However, if the energy transition moves faster and fossil fuel demand is thus lower than expected, importers could benefit twice over. A sharp fall in price fossil fuel prices would act as a positive supply shock, benefiting importers' current accounts, fiscal balances, investment, consumption and inflation. Meanwhile, the increased use of lower-cost domestic energy sources would reinforce these effects, but on a permanent basis.

India's experience during the previous commodity supercycle and the subsequent bust supports these predictions. India's current account went from being roughly in balance prior to the sharp spike in oil prices from 2003 to being deeply negative until the oil price crash in 2014 and close to balance thereafter (Graph 8, left-hand panel). Inflation behaved likewise; a surge during the initial price boom was followed by persistently elevated inflation during the high oil price period and then a sudden decline after 2014 (centre panel). Consistent with this, the tightness of Indian financial conditions correlated strongly with oil prices over the period (right-hand panel).

Economic and financial conditions in India are tightly linked to oil prices — Graph 8



Sources: OECD; Bloomberg; BIS; authors' calculations.

However, two factors may dampen or delay the positive effects of the transition described above. As mentioned earlier, constraints in some metals and minerals markets are already an issue (IEA (2021b), Boer et al (2021)). The need to invest in new infrastructure will also contribute significantly to the macroeconomic impact; some estimates suggest that clean energy investment will need to increase from around \$1.4 trillion a year (1.3% of current global GDP) currently to around \$4 trillion in 2030 (approximately 2.7% of forecast 2030 global GDP) to reach net zero by 2050 (IEA (2021a)). This increase in investment demand may support growth but could also create medium-term inflationary pressures (Schnabel (2022)).[9]

Whether these pressures actually manifest themselves will depend not only on clean energy investment but on how energy spending (around 5% of global GDP) and fossil fuel investment (approximately 1% of global GDP) evolve at same time. If clean energy investment does reach these high levels, it is also highly likely that fossil fuel spending and investment will fall sharply at the same time, thus reducing inflationary pressures. Also, reduced healthcare costs and higher productivity from lower pollution could further dampen the inflationary effects from increased energy investment.

Steady state

In the long term, we expect the energy transition to deliver a positive supply shock to the global economy. The cost trajectory of renewables and electrified transport, their

[9] However, given the persistent underestimation of technological progress in most large-scale energy system models, the level of financial investment needed to facilitate the transition may be less than currently expected. This could occur if progress in clean technologies continues to exceed expectations. Even the most optimistic scenarios used in most large-scale macroeconomic models consistently underestimate the cost declines of clean technologies (Xiao et al (2021)).

already lower operating costs and lower spending on natural resources should reduce the price level from what it otherwise would be and generally weaken energy's influence on inflation and overall economic activity. The transition should lead to a permanent improvement in the trade balances of importers as the advance of renewables drives down energy costs and reduces fossil fuel imports. Reduced energy costs and the easing of external constrains should, in turn, lead to higher domestic consumption and a structural easing of financial conditions as a greater share of domestic resources is held locally.

The energy transition may also make headline inflation less volatile since electricity prices are less volatile than gasoline prices, the costs of cleaner technologies are front-loaded and cost pressures for clean technology can be amortised over time. A similar sequence of events followed the energy price shocks of the 1970s; subsequent improvements in energy efficiency led to a permanent decline in energy inflation pass-through to overall inflation in the United States (Clark and Terry (2010)).

Effects on suppliers of metals and minerals

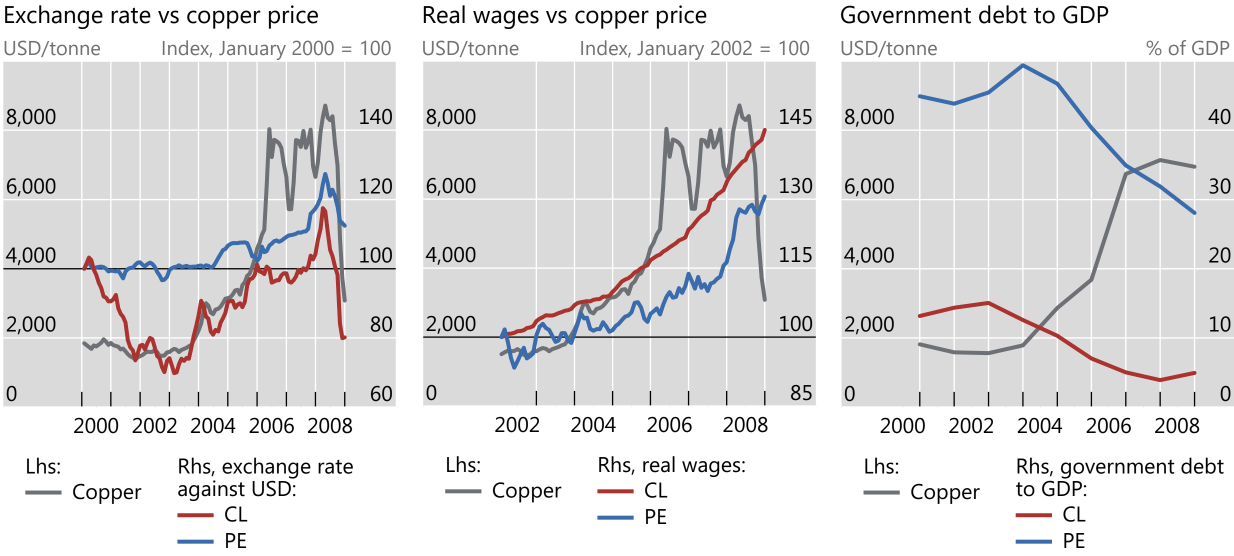
Transition phase

The energy transition will be clearly positive for producers of metals and minerals but will present some challenges. Potential supply and demand mismatches in commodities markets could shift the terms of trade sharply in favour of exporters until sufficient supply comes online. The build-up of new mining capacity should further support growth by increasing investment demand, while capital inflows associated with the boom are likely to significantly ease financial conditions for a while (Drechsel and Tenreyro (2018)).

These predictions are verified to some extent by the onset of the 2000s commodity supercycle. As would be the case in a rapid energy transition, the commodities supercycle was driven by a sharp increase in demand that outstripped global capacity. This induced a massive and broad increase in commodity prices, benefiting an array of commodity-exporting nations, including the world's two largest copper producers, Peru and Chile. As these countries also stand to benefit from the energy transition, they will be the focus of our discussion.

From January 2003 to April 2008, nominal copper prices quadrupled. At the same time, the Peruvian sol and the Chilean peso appreciated by a respective 19% and 60% vis-à-vis the US dollar (Graph 9, left-hand panel). Meanwhile, labour market conditions also improved markedly; for example, real wages grew by 45% in Chile and 30% in Peru (centre panel). The commodity boom allowed each country to sharply improve their fiscal position (right-hand panel). Finally, the supercycle also led to sharp reductions in poverty in these countries and across Latin America more generally (Balakrishnan and Toscani (2018)).

The commodity supercycle was a major boom for Peru and Chile | Graph 9



Sources: IMF; Bloomberg; Datastream; BIS; authors' calculations.

Steady state

For many countries, commodity booms can create a permanent dividend. Even after the end of the commodity supercycle, Chile and Peru both retained most of the large gains they reaped in terms of wage increases, labour market formalisation and poverty reduction. That is, a well managed boom can contribute to a permanent improvement in economic conditions for much of the population.

That said, there are some issues that metals and minerals producers may have to confront in the long term. The real exchange rate and wage pressures that accompany a boom could make some regions and industries less competitive – that is, they may succumb to Dutch Disease (Corden (1984), Alberola and Benigno (2017)). Furthermore, in the absence of effective budgeting strategies or improvement of institutions, countries may also see more economic volatility due to a greater dependence on volatile resource revenues.

Finally, fiscal and financial factors could aggravate the end of the boom, particularly in lower- and middle-income countries. Fiscal spending and non-commodity revenues tend to move procyclically with commodity prices (Bova et al (2018)). Also, commodity exporters typically enjoy strong capital inflows and easier financial conditions during the boom phase, but once the bust begins, they often experience sudden stops. This brings to the surface underlying macroeconomic imbalances, which are often caused by mistaken confidence in the boom's durability. As a result, emerging market economies (EMEs) are significantly more likely to experience financial crises following a sustained commodity price boom (Reinhart and Reinhart (2009)). But as the experience of Chile and Peru shows, sound policy can mitigate many of these risks.

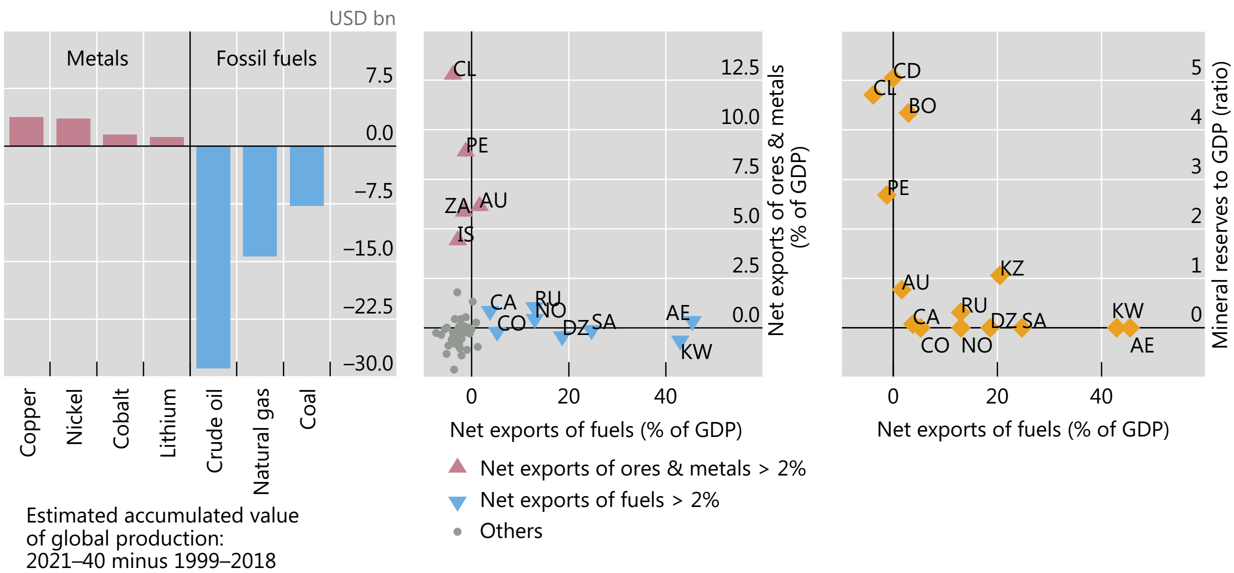
4. Countries' exposure to the transition

Spending on fossil fuels is likely to permanently fall over the coming decades while metals and minerals spending should increase but to a far lesser degree (Graph 10, left-hand panel). This owes largely to the fact that metals and minerals can be used indefinitely once extracted, while fossil fuels are consumed once only and thus must be extracted continuously. The energy transition will affect every country somewhat differently for a range of reasons, including their resource endowments, institutional quality and their macro-financial situations.

Given the lack of overlap between countries with large fossil fuel endowments and those with large metal and mineral resources (Graph 10, centre and right-hand panels), this shift implies a large shift in economic activity away from fossil fuel producers and towards metals and minerals producers and an even larger shift away from fossil fuel producers and towards energy importers. In this section we will assess which countries are most exposed to the transition, both negatively and positively.[10]

Potential winners and losers at first sight | Graph 10

Global production projection compared with the last 20 years | Fossil fuel versus metals exports for selected resource producers[1] | Fossil fuel exports versus mineral resources[2] for selected resource producers



[1] 2019 or previous latest available figures. [2] 2020 data for mineral reserves.

Sources: Boer et al (2021); IMF; World Bank; USGS; authors' calculations.

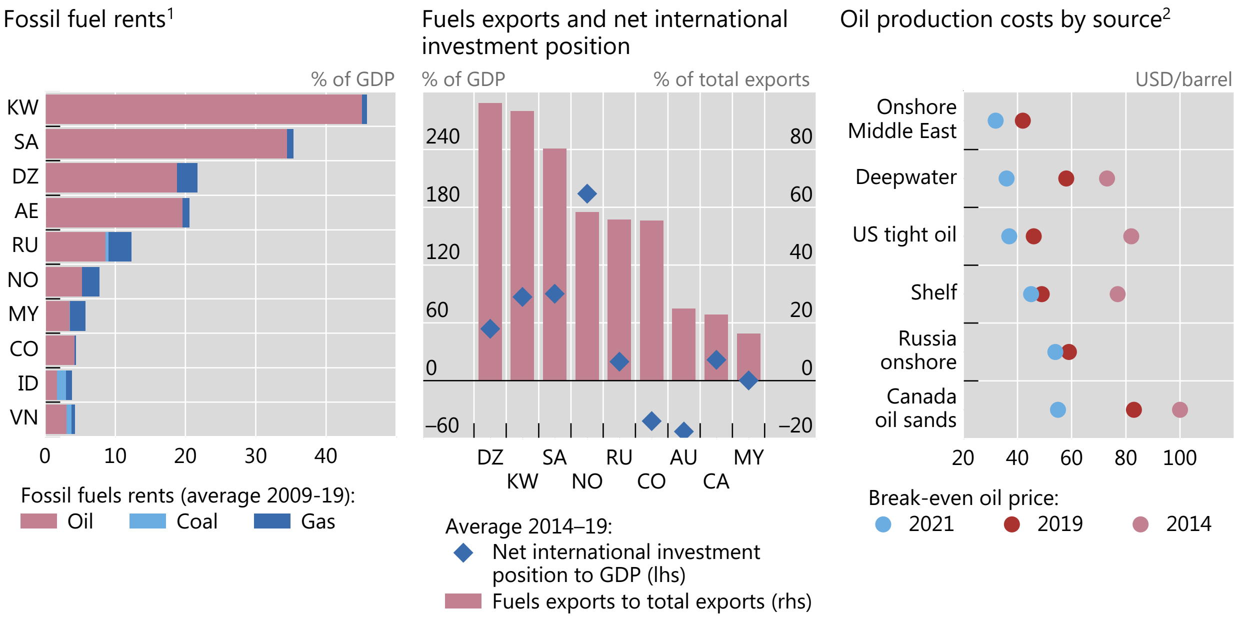
Fossil fuel exporters

A handful of countries are highly vulnerable to the eventual demise of the fossil fuel industry. Algeria, Kuwait, Saudi Arabia and the United Arab Emirates stand out as

[10] Due to issues around data availability, we focus most of our analysis on the impact on the countries of Bank for International Settlements shareholders. However, there are numerous countries which are even more exposed to the transition. Small island nations and many less developed nations are heavily reliant on fossil fuel imports. Meanwhile a range of countries, particularly in the Middle East, North Africa, Central Asia and South America, rely on fossil fuel exports to an even higher degree than the countries highlighted here.

being reliant on fossil fuel production (Graph 11, left-hand and centre panels). However, these countries have large savings which can provide a buffer against the transition, while others (eg Australia, Colombia and Russia) do not have this luxury. Nevertheless, the former group's higher reliance on fossil fuel exports means that even their large savings could deplete rapidly. In any case, major fuel exporters, regardless of their financial positions, should see current accounts, exchange rates and inflation rates come under significant pressure as the transition proceeds.

The transition's burden will be concentrated among a few fossil fuel producers Graph 11



[1] Rents as the difference between the value of production and the total costs of production. [2] Real Brent oil price that gives an NPV of zero given a real discount rate of 7.5%. The break-even price includes only future costs.

Sources: IMF; World Bank; Rystad Energy; authors' calculations.

Other major fossil fuel producers should experience more localised disruptions. The United States is the largest producer of oil and its sixth largest exporter, Canada is the fourth largest producer and third largest exporter and Brazil is the ninth largest producer and tenth largest exporter. However, as fossil fuel production accounts for a relatively small proportion of activity in these countries, the macroeconomic impact of the transition should be minimal at the national level. Also, because of their economic diversity and the likely downward pressure on exchange rates, non-fossil fuel activity should be able to absorb some of the impact as well.

The cost structure of the local fossil fuel production industry should also play an important role as to when and how severely effects will manifest themselves in a particular country. New Canadian and Russian production would likely be pulled back first, while production in the Middle East should be the last affected. Also, important to note is that continued cost reductions (Graph 11, right-hand panel), if they persist, could allow oil production to be sustained longer than currently anticipated.

Finally, even though reliance on fossil fuels is the primary factor that will determine how vulnerable a particular country is to the energy transition, the degree of that exposure will be determined by a wide array of structural economic and geographic factors. Some countries could use their abundant sun and/or wind resources to cut their high domestic consumption of fossil fuels, reduce domestic energy costs and open new export markets. However, their ability to capitalise on their natural endowments may be constrained by weak institutions or a lack of nearby energy-hungry neighbours.

Fossil fuel exporters' relative exposure to the transition

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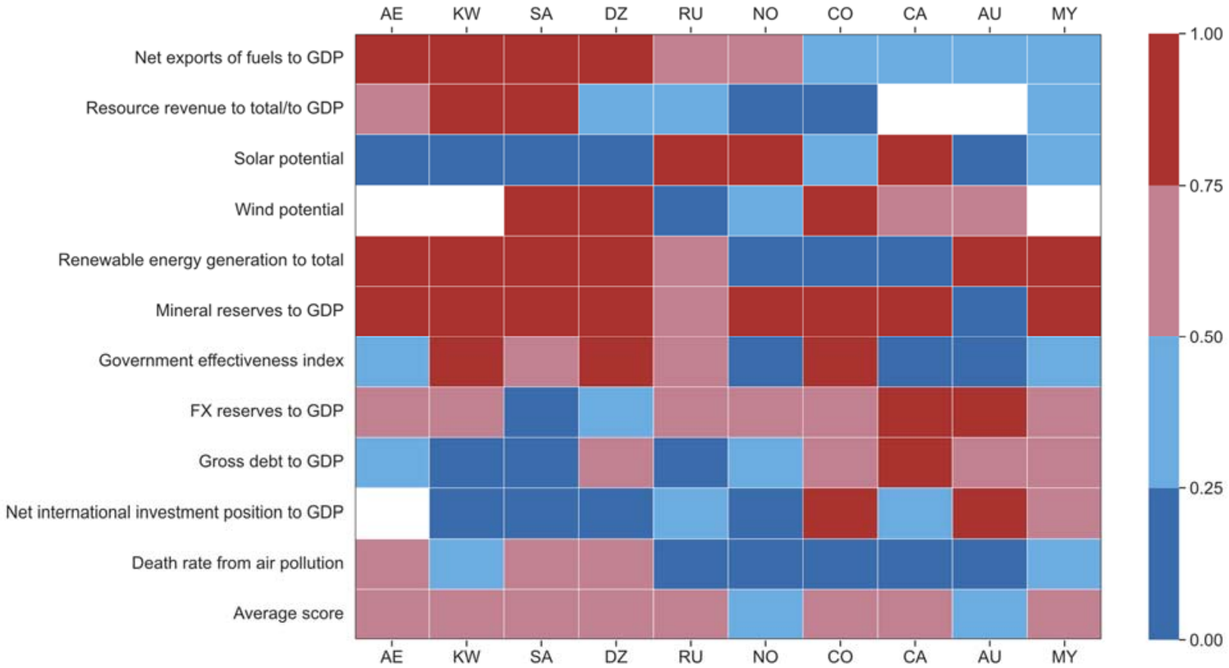
Graph 12



The data are normalised such that 1 (dark red) indicates the maximum degree of vulnerability, while zero (dark blue) represents the lowest degree of vulnerability. The normalisation via the min-max technique has been reversed arbitrarily for certain variables in order to provide a homogenous interpretation to the colours and values. The sample used for the min-max normalisation comprises the countries of BIS members. Blank cells refer to missing data.

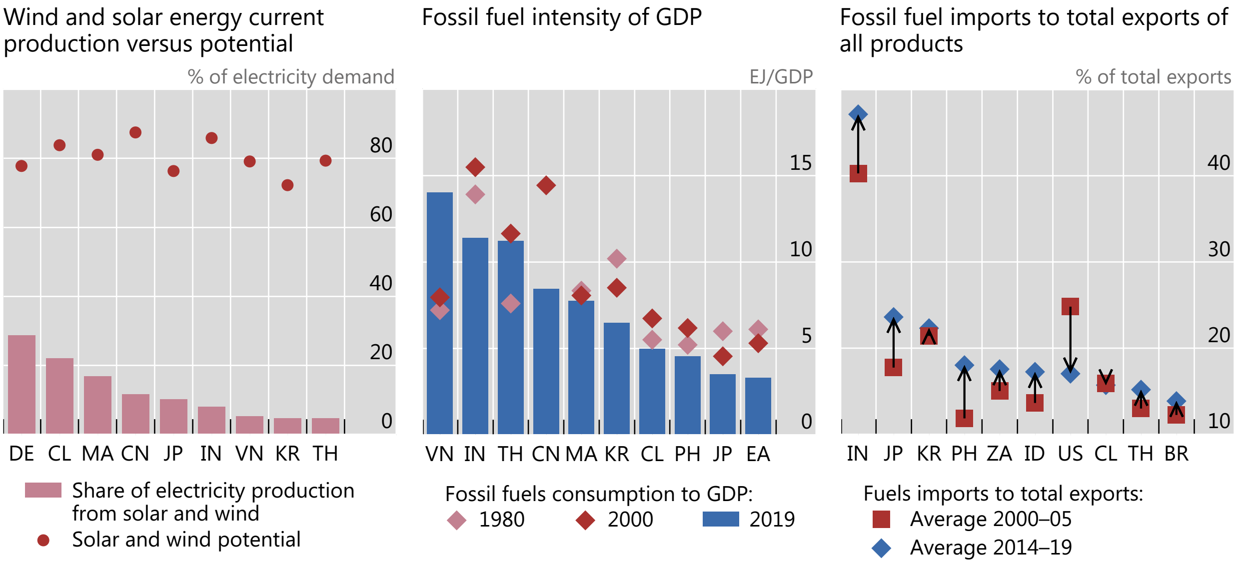
Sources: World Bank; IMF; Datastream; Solargis; ESMAP; Trucost; USGS; BIS; authors' calculations.

Fossil fuel importers

As around 80% of the world population live in countries that are net importers of fossil fuels (IRENA (2019)), the benefits of the transition will be spread out far more then costs will be. Nevertheless, some countries will experience significantly larger gains than others.

A diverse group of Asian economies are likely to get the greatest benefits from the energy transition (Graph 13). India, Korea, Thailand and Vietnam stand out as having the highest upside, while other large countries such as China, the Philippines and Japan also should also expect a positive and significant impact. Specifically, the transition should allow these economies to significantly improve their trade balances. Asia's high reliance on imported fossil fuels also gives these countries strong incentives to switch away from fossil fuels, meaning that the hopes of fossil fuel producers that these importing countries might support global demand for their products may be somewhat misplaced.

Asian economies should see the largest benefits from abandoning fossil fuels Graph 13



Sources: Tong et al (2021); IMF; World Bank; OWID; authors' calculations.

Moreover, a country's current reliance on fossil fuels, while important, is not the only factor that will influence how much and how quickly it stands to gain from the energy transition. Countries such as Germany, Japan and Korea are highly reliant on fossil fuel imports but have lower renewable energy potential than most other countries, suggesting that the energy transition could take longer there and/or they will have to rely more on alternative sources of low-carbon energy. However, even these countries may be able to get a substantial share of their electricity – between 75% and 80% – from wind and solar resources (Tong et al (2021)).

In contrast, India, Malaysia and the Philippines have abundant renewable resources, meaning that replacing fossil fuel energy may be constrained primarily by institutional capacity or higher capital costs. Some countries (eg Morocco) may be able not only to reduce their reliance on fossil fuel imports but also to become net energy exporters thanks to their abundant renewable energy resources and proximity to major economic centres (Pearce (2023)).

Fossil fuels importers' relative exposure to the transition

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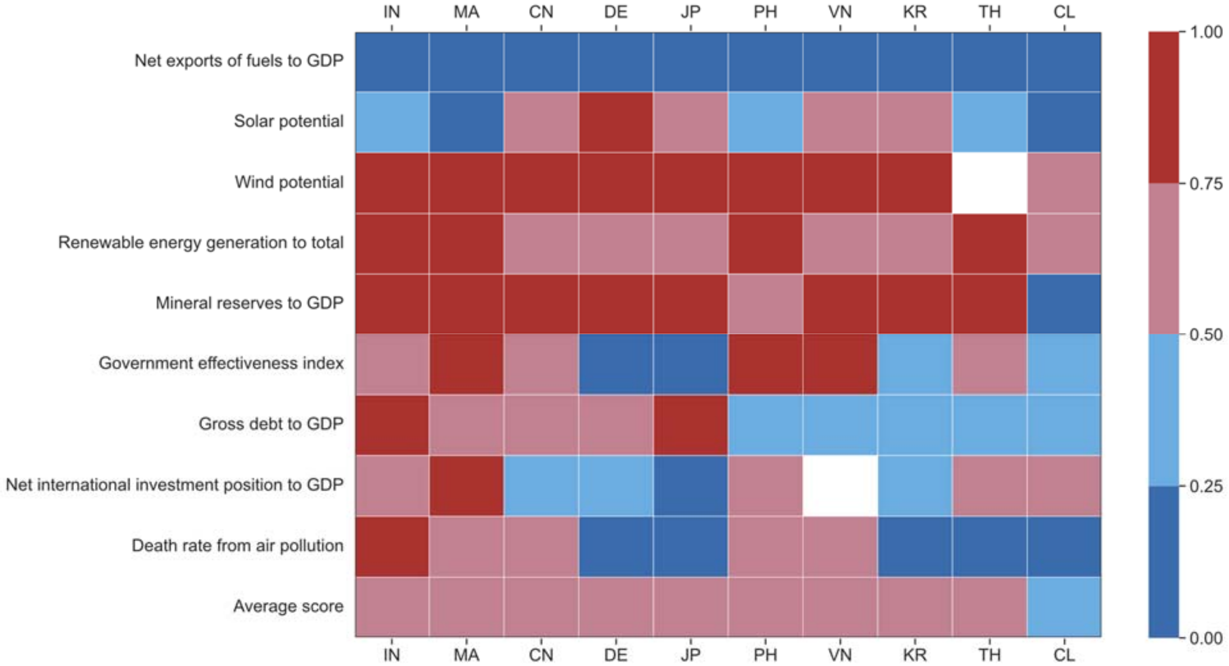


The data are normalised such that 1 (dark red) indicates the maximum degree of vulnerability, while zero (dark blue) represents the lowest degree of vulnerability. The normalisation via the min-max technique has been reversed arbitrarily for certain variables in order to provide a homogenous interpretation to the colours and values. The sample used for the min-max normalisation comprises the countries of BIS members. Blank cells refer to missing data.

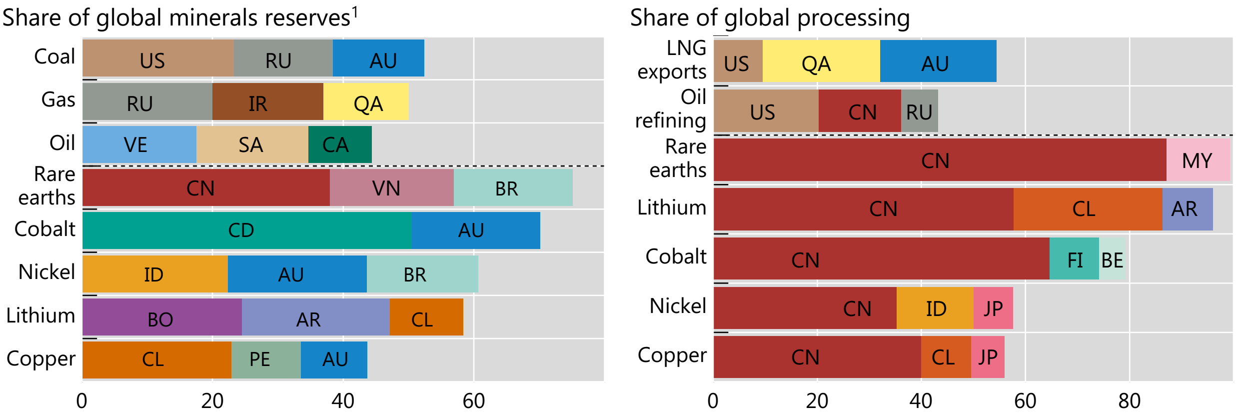
Sources: World Bank; IMF; Datastream; Solargis; ESMAP; Trucost; USGS; BIS; authors' calculations.

Suppliers of metals and minerals

Strong, long-term demand for metals and minerals should boost exports and growth for producing countries. Some countries – Australia, Brazil and Chile – stand to gain due to their large deposits of needed commodities (Graph 15, left-hand panel). Meanwhile, others may benefit from the exploitation of a single product, such as Bolivia from lithium, the Democratic Republic of Congo from cobalt, and Peru from copper. In some countries, the effects of the energy transition could still be weak even where large absolute reserves exist; for example, Mexico and the United States have large and varied mineral reserves but, due to their economic diversity, will probably see only limited macroeconomic benefits.

Mineral reserves and refining capacity are concentrated in relatively few countries

In per cent | Graph 15



[1] Share of proven reserves of selected economies; 2020. For lithium, resources, not reserves.

Sources: IEA; BP; USGS; authors' calculations.

Minerals markets are far more concentrated than those of fossil fuels, especially in refining capacity but still significantly so in terms of raw resources (Graph 15). China is the largest refiner by a massive margin in each of the minerals already mentioned and has particularly dominant positions in rare earths, cobalt and lithium. From the perspective of its own energy transition, this suggests that China may be able to avoid or moderate some supply constraints going forward.

However, recent announcements and funding measures in some countries (eg Canada and the United States) to develop their own supply chains, separate from the Chinese ones, suggest that this may not be the case permanently. Also, higher prices could eventually make currently uneconomical resources worthwhile to develop in different parts of the world, thus reducing any particular region's long-term market power. Nevertheless, the high concentration of these products relative to fossil fuels may also mean that the geopolitics of the energy transition may be a complicating factor as it progresses.

Energy transition commodities exporters' relative exposure to the transition

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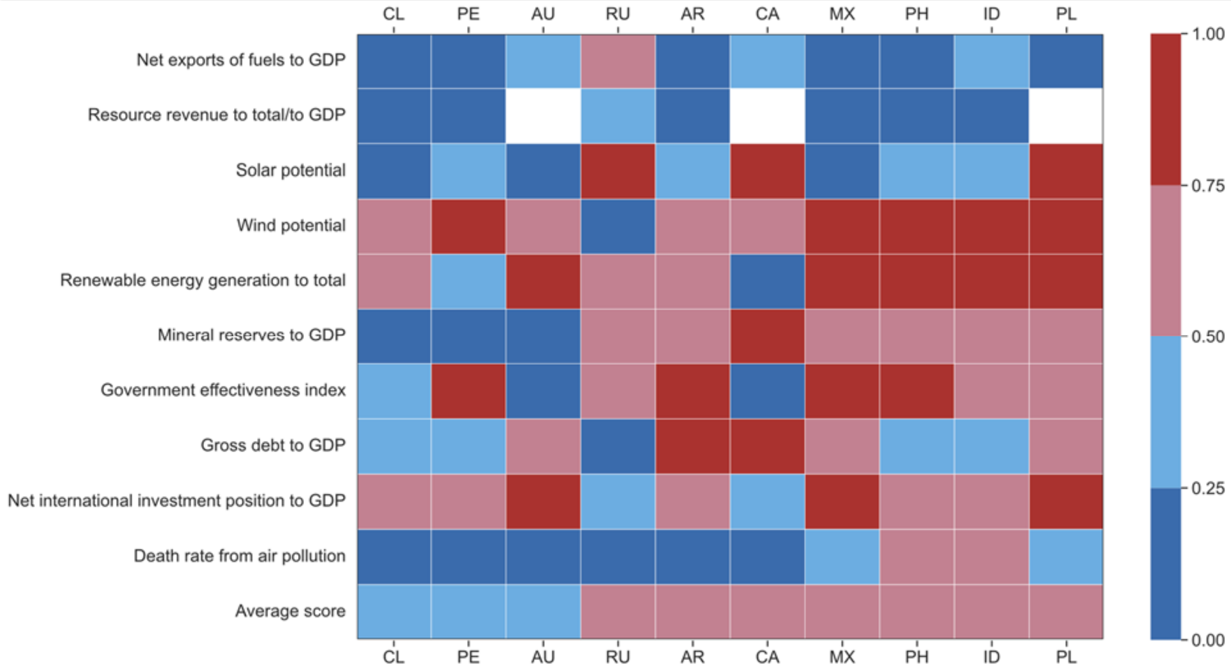

The data are normalised such that 1 indicates the maximum degree of vulnerability, while zero represents the lowest degree of vulnerability. The normalisation via the min-max technique has been reversed arbitrarily for certain variables in order to provide a homogenous interpretation to the colours and values. The sample used for the min-max normalisation comprises the countries of BIS members. Blank cells refer to missing data.

Sources: World Bank; IMF; Datastream; Solargis; ESMAP; Trucost; USGS; BIS; authors' calculations.

Conclusion

The rapidly proceeding energy transition will have profound effects across the globe. Eventual declines in fossil fuel demand pose major and acute threats to fossil fuel-producing regions, while minerals producers should see an extended increase in demand for their products. Meanwhile, most of the world should benefit significantly from lower, less volatile energy prices and reduced air pollution.

The potential paths of the energy transition are extremely varied in the short and medium terms. A disruptive path of high and volatile energy prices is plausible, but so too is a path of sharp price declines and a rapid collapse in demand for fossil fuels. As such, it would be worthwhile for all countries to immediately start building resiliency and making the appropriate preparations.

Fossil fuel exporters can build buffers and embark on the structural reforms needed to manage the long-term decline of their primary industries (eg transitioning to a less volatile tax base or to market-based exchange rates). Fossil fuel importers, particularly those in EMEs, can use the energy transition as an opportunity for structural reform. By reducing barriers to the transition – whether regulatory or financial – they can insulate themselves from volatile global energy markets, enhance domestic energy security and improve public health.

Metals and minerals producers can reform their budgeting practices to mitigate increased exposure to volatile commodity prices, take measures to reduce potential labour market displacement from higher exchange rates and modernise mining regulations to ensure that economic development does not come at the cost of environmental sustainability. Finally, in line with the repeated commitments of global leaders (G20 (2022)), the international official sector should accelerate and sharply increase the provision of accessible low-cost financing and technical assistance to fast-track the transition in EMEs.

Despite the nearer-term uncertainty, the energy transition means that the world will eventually see lower energy costs, better health and less pollution. However, while the outlook is positive for most countries and the world, some people, regions and countries may nevertheless be left behind. In other words, how potential future abundance is shared globally could be a major issue in the years and decades ahead.

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