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New Challenges to Climate Policies

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ABSTRACT: *The green transition faces old and new challenges. Old challenges include insufficient domestic action and insufficient international coordination. New challenges include the quest for energy security and the rising threat of geoeconomic fragmentation, the political backlash against climate policies, and a slowing growth prospect. At the same time, technological progress has been faster than expected. The success of the green transition depends on the outcome of the race between technological progress and rising inward looking policies. Energy security and green transition are mutually reinforcing provided clear policy directions are given. The challenge is to pursue collaboration to exploit technological progress in a world at risk of fragmentation.*

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1. Introduction

The 2015 Paris Agreement provided a shared mitigation goal to keep the rise in mean global temperature to below 1.5° C compared to the pre-industrial level and a framework centered on voluntary nationally determined contributions (NDC). The Agreement was historic because it was signed by almost all countries and provided a clear and monitorable target. However, it also raised domestic and international implementation challenges.

The domestic challenges include the need for deep structural change to achieve climate objectives. This structural change presents important challenges, including stranded assets in the carbon-intensive sectors well as sectoral and regional labor market dislocation. The mechanism by which this structural change would be effected, an increase in the relative price of carbon-intensive energy, presents challenges of its own, including the impacts of green policies on the economy, potentially large distributional effects and strong political opposition, or the effects on the competitiveness of carbon-intensive industries (Timilsina 2022).

Macroeconomic estimates of the costs of the green transition vary widely. Some, such as Pisani-Ferry (2021), warn that the macroeconomic costs of the climate transition might be quite high. The speed of the needed transformation required to limit catastrophic climate change, they argue, is bound to have serious and immediate negative economic implications. Others, such as Stern (2016) argue that the transition to low-carbon growth will unleash wider economic benefits. In an empirical study for Europe, Metcalf and Stock (2020; 2023) and find that carbon taxation has negligeable effects on GDP, while being very effective for emission reductions. There are thus economic upside and downside risks to modeling estimates: On the upside, future technological breakthroughs might reduce mitigation cost. An additional benefit can arise from the reduction in local air pollution, expected to improve health and increase labor productivity (Graff Zivin and Neidell 2012). Downside risks include stranded fossil fuel assets, a difficult reallocation of labor across sectors, scarcity of some key metals and material necessary for the transition, and the scale and speed of the required investments in the transition.

An IMF modeling study using the new GMMET model estimated global costs of between 0.15 and 0.25 percentage point of GDP growth[1], and an additional 0.1 to 0.4 percentage point of inflation a year when carbon prices are introduced to reduce emissions by 25 percent until 2030 (IMF 2022c). Due to decreasing international demand for fossil fuels, GDP losses among fossil fuel exporters are higher than the global average. A study with the IMF models CPAT and IMF-ENV estimates global GDP losses of 0.4 percent of global GDP by 2030 in a scenario that is consistent with 2°C (Black, Chateau, et al. 2022).[2]

These relatively modest macroeconomic costs arise in part because most climate policy scenarios are assumed to rely on carbon pricing. It is well-understood that carbon pricing is a first-best policy that addresses directly the underlying fundamental climate externality: the gap between the private and social cost of carbon-based economic activity. Carbon pricing helps close that gap while minimizing wider disruptions to economic activity. From a macroeconomic perspective, carbon pricing is also revenue generating, and these revenues can be used to offset the distortionary effect of other forms of taxation, without much broader fiscal impact.

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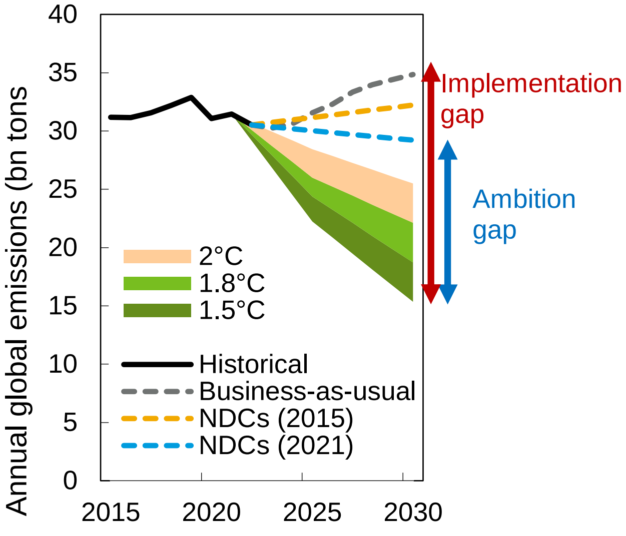
[1] The cost is largely borne by the “rest of the world” region in the model. Costs for the US, China and EU are significantly lower.

[2] In a model comparison exercise six different model introduced an economy-wide carbon tax for the United States of $25 a ton in 2020 and increased it by 5 percent annually. In 2030, average GDP cost are 0.3 percent of GDP when the revenue is recycled through labor tax cuts and there is an average GDP gain of 0.3 percent of GDP when the revenue is recycled through capital income tax cuts (IMF 2022c, Box 3.1). In any case, the helpful focus on economic cost, should not blend out that the benefits of climate policy, which can be measured as the social cost of carbon, far outweigh the cost (Aldy et al. 2021).

Hence a combination of carbon pricing and an equivalent reduction of labor income taxes has only a minor effect on GDP. Further, a gradual phasing-in can minimize the reallocation costs as the economy adapts to the change in relative prices, in particular by re-allocating capital and labor from high- to low-carbon sectors. Depending on the relative strength of different policy options, the equilibrium interest rate may increase or decrease temporarily (IMF 2023, Box 2.1). Well-designed climate policy thus has a major macroeconomic impact by accelerating structural change but does not have a major effect on aggregate numbers for GDP, employment or inflation.

But climate policy cannot rely solely on carbon pricing (Stock 2021). A comprehensive climate policy requires additional measures like R&D and just transition policies (IMF 2021). Moreover, in addition to these economic considerations, political factors could increase the costs. First, the first best policy from an economic point of view (such as carbon taxation) might encounter strong political resistance, hereby obliging authorities to go for less efficient second best (but politically feasible) approaches. Second, climate policy uncertainty causes real economic damages (Ren et al. 2022, IMF 2022c). Third, even if aggregate costs are small, distributional effects may be large and transfers and compensation may be difficult and politically problematic. Given all these reasons, countries were cautious in committing; therefore, initial NDCs were considered insufficient to deliver the expected goal (see Figure 1.)

Figure 1: Implementation and ambition gaps



Source: (Black, Chateau, et al. 2022)

The (foreseen) international challenges included insufficient pledges which needed to be increased. Moreover, the 2015 Paris agreement was based on purely voluntary basis, leaving countries freedom to pursue different approaches. The other side of this flexibility in domestic approaches was that international coordination was more challenging. With the implication that any innovation in domestic policy would entail international implications.

Against this background, new (unforeseen) challenges but also some opportunities materialized since the 2015 Paris Agreement. First, the domestic political dynamic changed in many countries. In 2016 President Trump was elected with an agenda mostly hostile to the climate mitigation agenda. The immediate consequence was that the US withdrew at once from the 2015 Paris Agreement.[3] This backlash against mitigation policies was not limited to the US; in 2018 the yellow vests (gilets jaunes) movement in France led to the cancellation of a long-planned modest fuel tax increase. In 2018, President Bolsonaro was elected in Brazil with an agenda critical of climate policies. In general, populist parties or movements are not favorable to mitigation policies which entail an increase in the price of energy. This shift towards domestic objectives led also to less collaborative international relations. Starting in 2018 a trade war between China and the US erupted with escalating tariffs and barriers; the change in domestic political objectives for the US focused on reshoring industrial activity and was motivated by worries about China making great strides towards acquiring (and contributing to) dual-use advanced technologies.[4]

Second, the Covid-19 pandemic caused a deep, if short-lived, recession and attendant increase in fiscal deficits and debt, limiting future fiscal space. In addition, the Covid-19 pandemic reminded everybody about their vulnerability to natural events (Celasun, Jaumotte, and Spilimbergo 2021). However, the Covid-19 pandemic also showed the limits of international cooperation in vaccine sharing; despite the relatively fast progress in discovering an effective vaccine, the distribution was slow, especially in Africa and other developing countries. The production and diffusion of covid vaccines to emerging and low-income economies was hampered by disputes over licensing.

Third, medium-term world growth projections have been repeatedly revised downward, limiting even more the available fiscal space; the recent surge in inflation and the consequent tightening monetary policy cycle are also weighing negatively on growth prospects as debt servicing costs are rising worldwide. Finally, the Russian invasion of Ukraine and the attendant sanctions disrupted energy markets and undermined even more multilateralism, sharply increasing the risk of geo-economic fragmentation. Crucially, and somewhat paradoxically, the loss of access to Russian pipeline gas led the EU to both accelerate its plans for the green transition and simultaneously to reopen some coal plants. More fundamentally, geo-economic fragmentation and trade tensions could derail the climate agenda (Rajan 2022; Aiyar et al. 2023).

On the other side of the ledger, the last seven years since the 2015 Paris agreement have also brought very important positive surprises on the cost of green technology. Especially solar panel energy and wind energy have become cheaper at much faster rate than anticipated (Wiser et al. 2021). These technological breakthroughs are making the green transition less costly than initially expected. With the rapidly declining cost of renewable energy, green transition becomes also more politically acceptable.

In sum since the 2015 Paris Agreement, the green transition depends on the outcome of a race between the negative political backlashes mentioned above and the positive effects of rapid technological progress.

This paper focuses on three aspects of this race: energy security and the green transition, the macroeconomic implications of different policy approaches, and the prospects for green technology improvements. The new quest for energy security after the Russian invasion of Ukraine has implications for the green transition. The new political climate in key countries have conditioned the types of feasible transition policies with the result that key players like the EU and US are adopting different macro approaches; this poses an issue of macro

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[3] The Biden administration rejoined the Paris 2015 agreement in 2021.

[4] Differently from the case of the withdrawal from 2015 Paris agreement, the Biden administration did not roll back the tariffs introduced during the Trump administration.

international coordination. At the same time technology can be the savior of green transition but it too, relies on international cooperation.

The reminder of the paper is organized as follows. Section 2 considers the impact of the new focus on energy security on the direction of energy investments. Section 3 turns to the different approaches taken for climate policy and how these approaches interact. Finally, Section 4 discusses the central role of technology and the role of government in supporting R&D and directing it. Section 5 concludes.

2. Energy security

In this section, we explore the interaction of energy security and the transition to net zero emissions. Energy security has many aspects. Here, we focus on the diversification of energy imports at the national level since this topic has surged in importance after Russia's invasion of Ukraine. We find that the invasion is having both beneficial and harmful effects on the transition.

The ongoing transition to renewable energy is reducing the dependence on energy imports for electricity generation. The share of renewables in electricity generation is expected to increase steadily towards 100 percent (Haegel et al. 2019) and at the same time energy uses are becoming increasingly electrified (Luderer et al. 2022). While the predominant type of renewable energy (wind, hydro, solar) varies, every country can use its own renewable resources (Bogdanov et al. 2019).[5] The currently existing challenges for energy security in fossil fuels will diminish only gradually, but they are expected to decrease steadily as the transition proceeds. The use of coal will decrease faster than the use of natural gas because it is more polluting. The IEA, however, recommends not investing into exploring and exploiting new sources of fossil fuels (IEA 2021b). This includes natural gas. Major Integrated Assessment Models show that decarbonization can rely almost exclusively on wind, solar and hydro power (Luderer et al. 2019). The cost for the energy transition range from negative (cost savings) to small positive, depending on the model (McCollum et al. 2018). The reason for these surprisingly low-cost estimates are energy efficiency gains and lower investment needs for fossil fuels.

The import of zero carbon fuels (including green hydrogen) from countries with the best renewable energy potential is intended to replace natural gas during the transition and for aviation, maritime transport, and industry. Energy security is thus expected to improve during the transition with two caveats. First, most countries will still need to import key materials and equipment to expand production capacity with renewable energy. Second, renewable energy poses the problem of intermittency, hence the need for expanding national and international grids and making use of existing batteries (Xu et al. 2023). Finally, we discuss that challenges to energy security emerging from the transition to renewable energy can be met effectively through strategic investments into infrastructure.

2.1 Energy security and Russia's invasion of Ukraine

The Russian invasion of Ukraine has put energy security back on the agenda. Energy security had been an important concern during the oil price shocks of 1973 and 1979. In recent years, however, it was not a major concern. To illustrate how energy security suddenly gained saliency, Figure 2 shows that the number of references to energy security in newspaper articles surged to a multiple of its previous level around the day of

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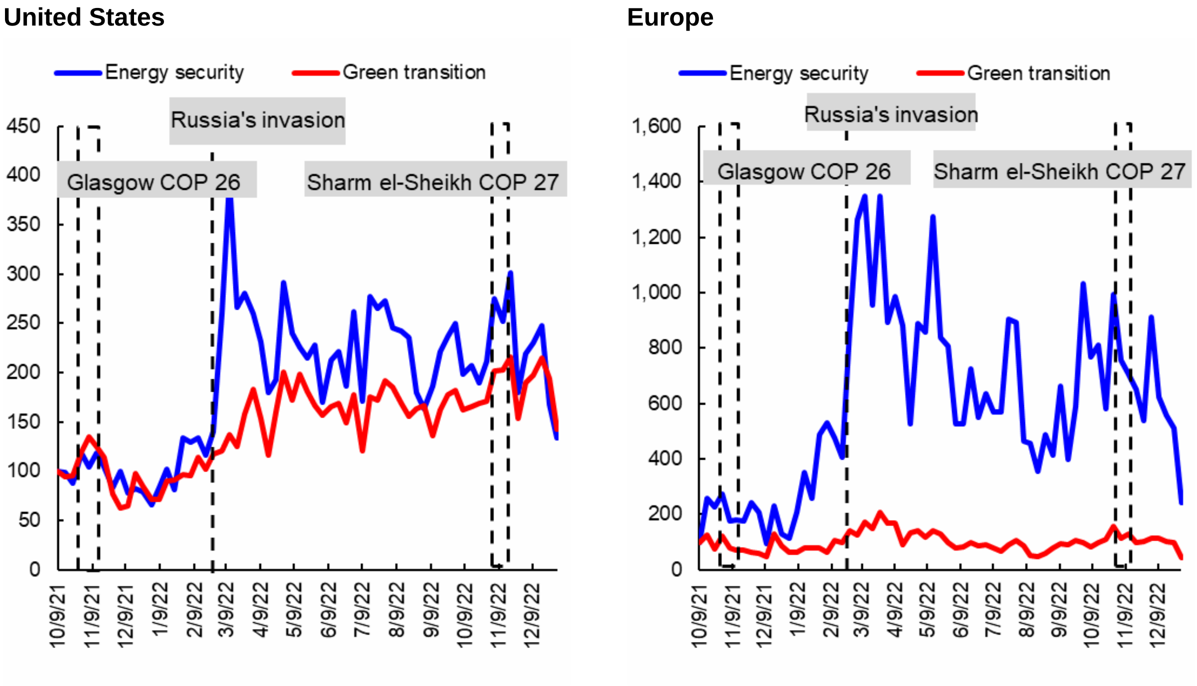
[5] Even a country like Germany, with less-than-ideal solar energy potential, can generate it's electricity need with renewable energy domestically (Jost et al. 2015; Hansen, Mathiesen, and Skov 2019; Traber, Hegner, and Fell 2021).

the invasion. Saliency in public debate is a precursor of where public opinion and ultimately policies are going. It shows also how different regions reacted differently. Reflecting Europe's dependence on energy imports from Russia at the time, the newspaper references increased much more strongly in Europe than in the United States. In this section, we will discuss how the sudden focus on energy security affects climate policy.

Figure 2: Weekly number of newspaper articles
(10/9/2021 = 100)



Source: ProQuest; IMF staff calculations.
Note: The graph displays an index of weekly number of newspaper articles in which the terms "energy security" and "green transition" appeared. The green transition line consists of "green transition", "energy transition", and "low-carbon transition".

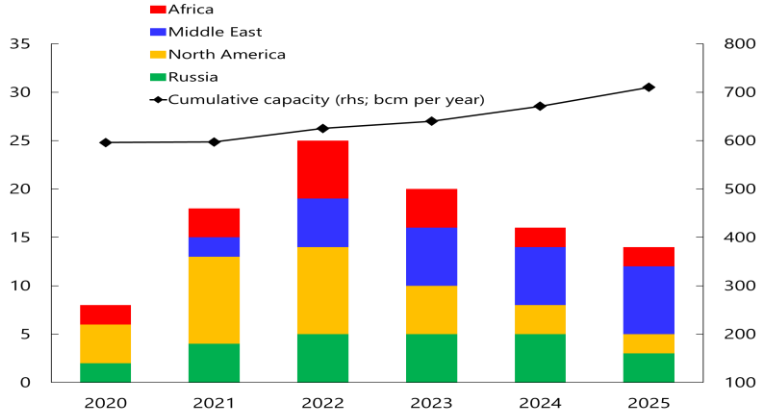
The Russian invasion of Ukraine reduced the imports of natural gas from Russia to OECD Europe from 104.3 in 2021 to 68.9 billion cubic meters in 2022 with only 7.5 billion cubic meters in the fourth quarter of 2022 (IEA 2023b). Natural gas played a key role as transition fuel in Europe. While the use of natural gas is less emission-intensive than the use of coal or oil, it is not consistent with the zero-emission goal in the long run. In some sense, Europe was caught in the middle of the transition; it could go back to more use of coal and oil, or it could move forward towards renewable sources of energy.

As an immediate reaction, new supply for natural gas was sought, substitutes for natural gas were mobilized (Rojas-Romagosa forthcoming) and energy consumption was reduced strongly through greater energy efficiency (Ruhnau et al. 2023). Additional supply was secured mostly from Norway, the United States, and Qatar. The switch to new suppliers increased the cost of natural gas in Europe -and elsewhere- and consequently reduced consumption. The US, Qatar and other possible suppliers can only deliver natural gas to Europe in the form of liquefied natural gas (LNG). Investment in new LNG capacity increased from 18 USD billion in 2021 to 25 USD billion in 2022, which is the highest value since 2016 (IEA 2022b), see Figure 3. Several European countries also sought to substitute away from natural gas in electricity generation by reactivating retired coal power plants. As a result, European coal consumption in 2022 increased by 5.5 percent to 685 Mt. Europe consumed only 8.5 percent of global coal (IEA 2022c), so the 2022 increase in

Europe did not make a major impact at the global level. In addition to a substitution among fuels, European producers also imported more energy intensive intermediate products, while maintaining production of final products (Chiacchio et al. 2023).

Figure 3: Investment in New LNG Capacity, 2020-2025

(Announced projects plus Qatari expansion plans)



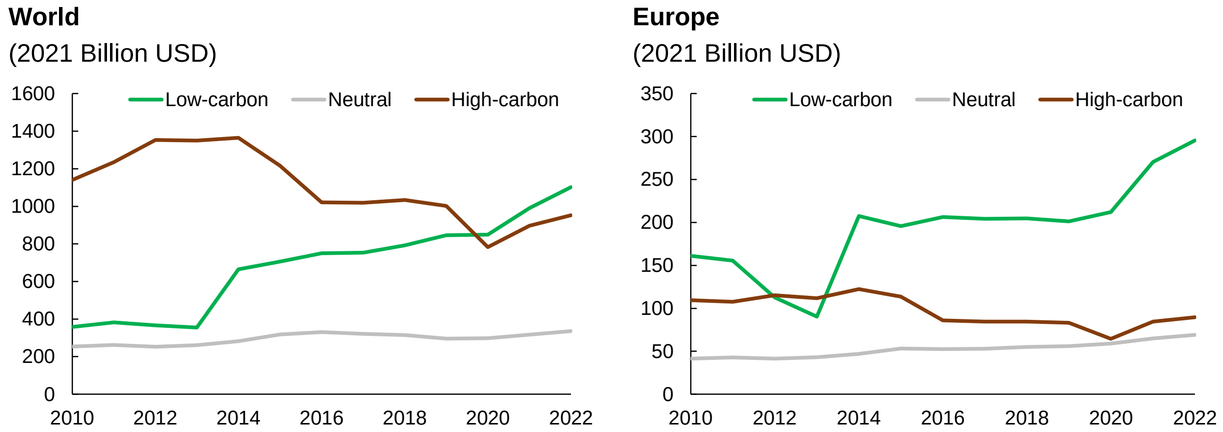
Sources: IEA; Haver Analytics; and Staff Calculations

Further, China and India imports of Russian natural gas and oil surged, on the back of discounted prices from Russia (IEA 2023c). The effect of this change in trade pattern on emissions depends on how India and China use the additional oil and gas supply. If it just adds to total energy supply, it will have a negative effect on the transition. However, if this supply substitutes for coal, emissions will decrease. The net effect of the Russian invasion will thus depend on the individual country, but also on the time horizon, as emissions compared to the baseline might change over time.

At the same time, investments in renewable energy also surged. More than 90 percent of the global growth in electricity generation came from renewable energy in 2022 (IEA 2023a). Investment in energy transition technologies reached a record high in 2022 (IRENA and CPI 2023). The additional surge in investments into low-carbon technology reinforces a long-term trend, see

Figure 4. Low-carbon technology investments are on an upward trend since 2010 and have overtaken high-carbon investments in 2020. Green investment has become dominant in Europe in the last 10 years, and the concerns over energy security are strengthening this trend. In addition to investments, there are also efforts to reduce energy demand. For example, the EU's climate law "Fit for 55" includes raising national energy efficiency targets, accelerating the renovation of buildings, and direct informational campaigns to help households cut energy demand.

Figure 4: Global energy investment



Source: International Energy Agency; and IMF staff calculation.
Note: Low-carbon = renewables, nuclear, low-carbon fuels, and energy efficiency; Neutral = electricity networks and storage; High-carbon = fossil fuels generation and fuel production; 2022 numbers are IEA estimates from June 2022.

2.2 Aligning energy security and climate policy

Energy security has two components. The first component is the ability of substituting across different sources of energy (for instance the ability of substituting gas for oil or nuclear.) This substitutability depends on technology and, by nature, is difficult to change in the short run. A second component is the substitutability of the same fuel across different supplier countries. The latter is commonly measured as the diversification of fossil fuel imports by trade partner, for example with the Herfindahl–Hirschman index.[6] The risk for each trade partner can be measured through indices of political risk (Cohen, Joutz, and Loungani 2011).

In addition to measures of energy security at the country level, energy security can also be measured at the global level for each fuel. Since 2008 this global measure of energy security has shown a slow deterioration of energy security for each fuel (Kim, Panton, and Schwerhoff forthcoming). This trend is driven by the increasing concentration of production in few large producers with high political risk.

Considering only one fossil fuel at the time, there are three strategic options for improving energy security. The first strategy is to reduce dependence on a single trade partner and achieve better diversification. Between

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[6] The Herfindahl–Hirschman index has limitations because it does not take into account the different degrees of substitutability across sources of energy and countries. For instance, natural gas used to be mostly transported by pipelines, making its supply from a particular source very difficult to substitute. Currently, a large and increasing share of natural gas is transported by vessel, making it easy to substitute across sources.

2000 and 2020, Türkiye was exceptionally successful in this: Türkiye moved from an almost complete dependence on imports of natural gas from Russia to more and more trade partners until it was much more diversified in 2020. The second strategy is to move to trade partners with lower political risk. Lithuania is a textbook example for this: While in 2000, the country imported all its natural gas from Russia, by 2020 it was importing 70 percent of its consumption from the US and Norway. The third strategy is to expand the domestic production of fossil fuels. The best example for this is the United States. US natural gas production closely tracked domestic consumption since 1950 and in recent years the US became a net exporter of oil products as well.

These strategies do not require a deep structural transformation because the same type of fossil fuel is used. A more structural way of improving energy security is to diversify across sources of energy. And this has implications for the green transition. However, the three strategies for improving energy security for natural gas do have a benefit for the net-zero transition: By reducing reliance on individual countries with high political risk, there is less of a risk to revert to coal use when a supply from one trade partner is disrupted.

Nevertheless, energy security requires a comprehensive approach, moving from a partial analysis of each energy source to a system perspective. Renewable energy offers the promise of large domestic production and thus should reduce reliance on energy imports with the caveats discussed above (Kim, Panton, and Schwerhoff forthcoming). This is where improvements in energy security coincide with efforts to reach net zero emissions. Renewable energy requires specific imports, for example of solar panels and components for extending the electricity grid. However, if imports of these goods are disrupted, energy production is not threatened in the way that a disruption of fossil fuel trade does in a conventional energy system because renewable sources of energies require minimum inputs once installed. The shift to renewable energy is already well under way (albeit starting from low bases) in many countries. Technical options to decarbonize the electricity sector exist, and the challenge is to redirect investments from fossil fuels to renewables as well as increasing investment. According to IEA estimates, the needed increase in investment is not negligeable (IEA 2021b). One of these investments is into the interconnectedness of the electricity grid, both domestically and internationally (Kim, Panton, and Schwerhoff forthcoming).

Outside the electricity sector, however, low-carbon alternatives are in many cases not yet competitive. Important examples are steel production, transportation, and in particular aviation. In both sectors, zero-carbon fuels based on green are technical alternatives (Englert et al. 2021), but these require strategic support by governments in terms of regulation and infrastructure investments.

Overall, there is also a need for an increase in energy investment (IEA 2021b), albeit estimates fluctuate across sources and countries. A large fraction of this investment should come from private sources, as borrowing conditions for sovereigns have tightened in the wake of the COVID-19 crisis, especially for emerging markets (IMF 2022b, Chapter 2). Given the difficult conditions for private finance of low-carbon projects, this requires policy action. Carbon pricing would help to make low-carbon projects more attractive relative to fossil fuel investments and a strong climate information architecture (data, disclosures, and taxonomies) would make it easier for investors to identify viable low-carbon projects.

2.3 Emerging challenges for energy security

The transition from fossil fuels to renewable energy reduces the import dependence for energy from fossil sources but creates new challenges for energy security. The production of renewable energy and batteries requires large amounts of transition metals like copper, nickel, cobalt and lithium (Boer, Pescatori, and

Stuermer 2021). Production of these metals is concentrated in a small number of countries, so that most countries will rely on importing these metals to scale up their production capacity of renewable energy. However, there is a key difference between the import of fossil fuels and of transition metals: once renewable energy capacity is built, it can be used for energy production without further imports of transition metals. Fossil fuels are constantly needed for energy production, whereas transition metals are needed only for the expansion in capacity. This difference between stock and flow needs will leave importers much less exposed to the effect of a disruption in imports. Renewable energy facilities will also need to be renewed, but when old equipment is replaced, it might be possible to recycle the transition metals they contain for the construction of new facilities.

Despite this fundamental difference, the concentration of transition metal production is a concern. The processing of many transition metals is concentrated in China, from 35 percent for nickel to more than 80 percent for Rare Earths (IEA 2021). The extraction of transition metals, by contrast, is less concentrated and for each metal, a different country is the largest producer (IEA 2021). A strong dependence on a single supplier could thus be avoided by an intentional effort to diversify suppliers. Further, disrupted supply in one of the transition metals is not expected to cause a bottleneck, as different sub-technologies, for example for solar PV, rely on different transition metals (Månberger and Stenqvist, 2018). This means that possibly producers can substitute away from any of the metals in due course.

Finally, wind and solar power are intermittent energy sources, which means that the reliability of electricity production is a challenge. However, many flexibility options have emerged to counteract the effects of the intermittency. Flexibility options include making the electricity grid more interconnected (Tröndle et al., 2020), battery storage (Comello and Reichelstein, 2019), supply side flexibility through hydropower (Dimanchev, Hodge, and Parsons, 2021) or any remaining fossil fuels, demand side flexibility (Müller and Möst 2018) and the complementary production of green hydrogen (Lyseng et al. 2018). When all these flexibility options are used in an efficient manner, electricity production can be stabilized even with a very high share of wind and solar power. Some estimates show that such a system would be in a similar cost range as electricity production based on fossil fuels (Bogdanov et al. 2019; Way et al. 2022). There is a strong focus on wind and solar power because other renewable energy sources are not expected to contribute much to capacity additions. Hydropower, for example, grows very slowly (IEA 2022a), because the locations with the best potential are already in use and hydropower has important negative environmental and social effects.

2.4 The way forward: the urgent vs. the important

Countries most affected by the energy crisis have been concerned about energy security. This happened in the past and led to important (and permanent) transformations. On the wake of the energy crises in the 70s there was an effort to reduce demand for energy and to diversity energy supply. Following the oil crisis in the 1970s, France commissioned 58 nuclear reactors conditioning its energy mix for the following fifty years (Perrier 2018). As a reaction to the oil crisis in the 1970s, the US government already invested into the development of solar energy (Nemet, 2019). This investment was limited, and the technology was not yet far advanced. It was also partially reversed during the Reagan years that famously took off solar panel from the roof of the White House. However, it did lay the foundation for today's development of solar energy. Most of the investments in the 70s, however, were directed at accessing new oil sources. Given the need for emission reduction, this is not a viable option in the current energy crisis.

Investment decisions taken under the urgency of the energy crisis have long-term consequences. Fixed investment in carbon-intensive infrastructure undertaken to address the urgency of the crisis creates carbon-intensive stranded assets (Semieniuk et al. 2022). However, the strongest reaction to the energy crisis were investments in renewable energy. In 2022, a record 41 GW of solar capacity was installed in the EU, which is an increase of 47 percent compared to 2021 (Jones 2023). As a result, solar generation increased by a record 39 TWh, an increase of 24 percent. Total electricity generation increased by 28 TWh, meaning that the expansion of solar came as other generation technologies reduced their production. This accelerates the transition to low-carbon energy. The transition to renewable energy is already well underway. The share of wind, solar and hydro power in the global capacity additions increased from 32 percent in 2015 to 53 percent in 2015 and to 82 percent in 2021 (Maia, Demoro, and Foroni 2022). The energy crisis might reinforce this trend.[7] As investments in fossil fuels fall, it is important that investments in renewable energy fully fill the gap to avoid a shortfall in total energy investments.

The high energy prices caused by the crisis do not have the same effect on emissions as climate policy would. The 2022 energy crisis is an opportunity for governments, mostly in Europe, to anticipate decisions and investments that would otherwise have occurred later. The transition will not happen automatically but requires dedicated government action: Indeed, it could be that the energy crisis per se will not help reduce global emissions much, because there is a strong pick up in the supply of natural gas by other suppliers than Russia. For the benefit of reducing emissions, only the minimum needed should be invested into fossil fuels. Natural gas has been described as a “transition fuel”, but investments into natural gas are not compatible with a transition to net zero emissions by 2050 (Kemfert et al. 2022). An accelerated investment into renewable energy improves energy security and brings countries closer to a pathway to the temperature target of 1.5°C. Renewable energy also brings along some challenges for energy security, but they can be minimized through well-designed investments. Concerns for the concentrated production of transition metals can be addressed by encouraging a variety of countries to develop their production potential. Concerns about intermittency can be addressed through more interconnected electricity grids, energy storage and other flexibility options.

Nuclear energy should remain an option for diversification and enhancing energy security. As discussed above, France embarked in an ambitious nuclear program in response to the energy crisis in the 70s. The large share of nuclear energy helped France enhance its energy security by diversifying the sources of energy. At the same time, nuclear energy is not cost competitive, especially when the cost for insurance are factored in (Laureto and Pearce 2016). France is also considering new nuclear technologies that could reduce the risks.[8]

To summarize, energy security concerns can be reconciled with the transition by net-zero emissions by

- Phasing out emergency investments into fossil fuels made in 2022 in response to the energy crisis,
- Accelerating investments in renewable energy,
- Planning for energy infrastructure complementary to renewable energy.

3. Differential climate policy approaches

In 2009, the Waxman-Markey Bill was introduced to the US Congress. It would have established a national emission trading system in the US, similar to the EU ETS. It was passed in the House of Representatives, but not introduced to the Senate, because it was not expected to be able to overcome a filibuster, after a massive

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[7] In some respect the energy crisis and the covid-19 pandemic crisis were similar because both entailed acceleration of pre-existing trends. The energy crisis is accelerating the green transition; the covid-19 pandemic crisis is accelerating the trend toward new forms and flexibility of working. In both cases there is a necessity of the role of the state.

[8] Note that none of the Integrated Assessment Models which are used for the IPCC has a growing share of nuclear. It’s considered too expensive, and it cannot be used complementary to renewables because it’s not very flexible (and so cannot address the issues of intermittency.) Finally, nuclear energy is politically very charged.

lobbying effort (Meng and Rode 2019).[9] Carbon pricing in the US was thus not always considered as “politically infeasible” as it is now. Populism, which has intensified in US politics since the Paris 2015 Agreement, often discredits climate policy by pitching climate advocates seen as representing the ‘elites’ against the will of ‘the people’ (Fiorino, 2022). Carbon pricing is an especially popular target, given the perceived increases in consumer prices (Raymond, 2020). As a result, the US -and many other countries- appear to be politically restricted to other policy instruments than carbon pricing for the foreseeable future.

Similarly in France the “yellow vests” (*gilets jaunes*) in November 2018 started as a protest against a planned modest increase in the tax on gasoline. As a result of the protests, the planned fuel tax increase was rescinded and increases in the price of electricity were also delayed. This is another instance where (unexpected) domestic political developments put a hard constraint on climate policy. Domestic policy has also led to a (temporary) stop of climate policies in emerging markets. For instance, Brazil, under the Bolsonaro administration, took a more critical view of climate (and in general environmental) policies. In Ecuador, mass protests forced the government in October 2019 to retract a policy that would have phased out fuel subsidies.[10]

Moreover, the political resistance to carbon pricing in some jurisdictions can also have negative and potentially large effects on other jurisdictions that are contemplating or have already adopted carbon pricing. This is particularly relevant when considering the EU and the US. The former has adopted one of the most stringent carbon pricing policies. The latter has instead put all the emphasis on tax subsidies. Nevertheless, carbon pricing is introduced in a steadily increasing number of countries (World Bank 2022) and countries also encourage each other to introduce it (Linsenmeier, Mohommad, and Schwerhoff 2022). Important examples are the existing emission trading system in China and the planned systemin Japan.

As a result of the difficulty to introduce carbon pricing, some countries have resorted to other types of climate policy, like subsidies and industrial policies. Carbon pricing and other types of climate policy thus co-exist. In this section, we discuss the effect of differential climate policy approaches in the US and EU. First, we summarize the policy packages of both jurisdictions. We then analyze the economic effect of this difference, first in a closed, then an open economy setting. We then explore how possible adverse effects can be dealt with constructively.

3.1 Climate policy design in the United States and European Union

Comprehensive climate policy consists of a policy package (IMF 2021). Each component of the package should address a different type of market failure. For the externalities caused by greenhouse gas emissions, carbon pricing is widely recognized as the most efficient policy instruments. In practice, countries use very different policy mixes to reduce emissions (Black, Minnett, et al., 2022). The differences in policy package are to some extend driven by differences in economic structure, but mostly by political considerations, for example regarding political feasibility. Apart from being not optimal from a public finance consideration, some packages pose acute challenges for international cooperation.

Consider the US and EU, which recently adopted key but starkly different climate policies. These policies not only have implications for domestic emissions but will also inform the international dialogue. The EU tightened

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[9] The British Thermal Unit tax proposed by President Clinton in 1993 had a similar destiny. It passed the House but was rejected by the Senate. Many House democrats who voted for the tax lost their seats in 1994. Hence the expression “getting BTU’ed”, i.e. not being re-elected after supporting controversial legislation.

[10] https://www.theguardian.com/world/2019/oct/14/ecuador-protests-end-after-deal-struck-with-indigenous-leaders

the emission reduction target in the EU Emission Trading System (ETS) from 43 percent by 2030, compared to 2005, to 62 percent. It also extended the ETS to additional sectors: maritime transport, buildings, and road transport. The EU's approach is thus putting carbon pricing as its centerpiece. In addition, however, the EU is also subsidizing low-carbon technologies, in particular renewable energy. In the US, the 2021 Infrastructure Investment and Jobs Act[11] and the 2022 Inflation Reduction Act (IRA), are based on investment in infrastructure and on subsidizing the development, production, and adoption of low-carbon technology, respectively. At the same time, thirteen US states are using emission trading systems. In this section we describe the two packages and then summarize first their domestic effects and then their interaction with the global economy.

Climate policy in the European Union is based on the Fit for 55 package (European Council 2023), which aims at reducing greenhouse gas emissions by 55 percent from 1990 levels by 2030. The EU institutions decided in December 2022 to cut emissions in the sectors covered by the ETS by 62 percent of 2005 levels until 2030. Further, carbon pricing will be extended to new sectors such as maritime transport, building, and road transport. Starting in October 2023, a Carbon Border Adjustment Mechanism, an import tariff proportional to the carbon content of products, will be phased in. In the initial phase it will only collect data before taking full effect in 2026. Another building block of the Fit for 55 package is regulation. For example, EU airports will have to increase the share of sustainable fuels to 2 percent in 2025 and then gradually increase it to 63 percent by 2050. The EU also uses large amounts of subsidies for low-carbon technology, in particular renewable energy (Kleimann et al. 2023).[12]

The IRA is a set of policy measures in the areas of climate change, health, and revenue. The climate-related part is a spending program for an estimated $391 billion, of which $234 billion take the form of tax credits for clean production (CRFB 2022). Another large block of expenses is on issues like air pollution, conservation, and building efficiency. Beyond efforts for scaling up the adoption of existing technologies, the IRA also incentivizes investment in technologies viewed as essential for reaching net zero emissions, but not yet economically viable. These include green hydrogen, carbon capture and direct air capture. Without the IRA, emissions were estimated to decline by 24-35 percent between 2005 and 2030. The IRA moves this estimated range to 32-42 percent (Larsen et al., 2022). In other words, the marginal effect of the IRA is to reduce emissions by a further 10 percent with respect to 2005, a commendable goal but still short of the desired reduction of 50 to 52 percent of 2005 values by 2030. Reaching this target will require policy action beyond the IRA.

3.2 Macroeconomic cost

Chateau, Jaumotte, and Schwerhoff (2022) present an illustrative modeling study of the US and EU climate packages, including the IRA. Given the focus of this research, only those parts of the climate packages that target the electricity and energy-intensive and trade exposed (EITE) sectors are modeled (for all countries). Aggregate emissions of the modeled policies are estimated to be 17 percent below baseline emissions for the US and 20 percent for the EU. In both regions, most of the reductions would come from the electricity sector. In both regions total GDP losses would be slightly above 0.4 percent of baseline GDP, see Figure 5.[13] Differences

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[11] https://www.congress.gov/bill/117th-congress/house-bill/3684/text

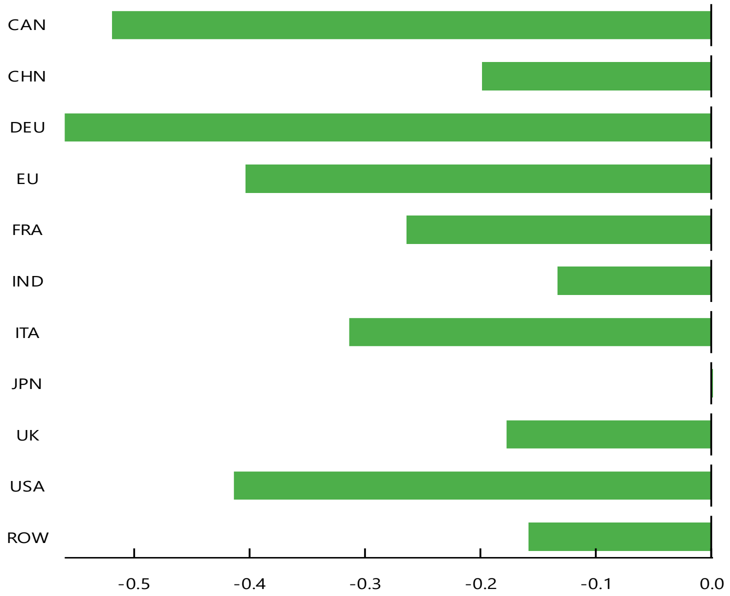
[12] Note also existing subsidies for solar panels are much higher in Europe (Kleimann et al. 2023, Table 1)

[13] A possible upside not considered in the model is increased labor productivity from reduced air pollution. Air pollution co-benefits have been estimated to offset GDP cost of climate policy (Vandyck et al. 2018). Also, technological progress is a possible upside.

emerge for trade shares: While the US is estimated to experience a minuscule loss in trade shares, the EU might experience a loss in trade share in the EITE sector of 0.7 percent. The EITE sector covers only a small share of total exports, so overall competitiveness is only marginally affected, but the political implications could be large.

Figure 5: Effect of climate policy packages on GDP according to IMF-ENV

(Percent deviation from baseline)



Source: (Chateau, Jaumotte, and Schwerhoff 2022)
Note: The figure shows a scenario of climate policies which have already passed the legislative process in the G7 countries, China, India, and South Korea. Policies in the electricity and EITE industrial sectors are considered: (i) explicit carbon pricing policies; (ii) coal power phase-out plans; (iii) renewable share targets, and (iv) sector-specific emission intensity targets for the industrial sectors.

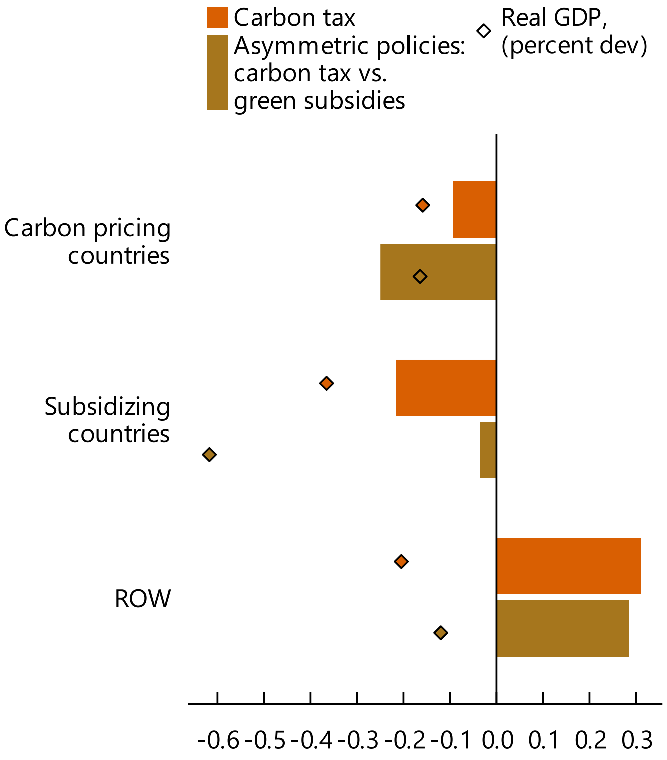
More generally, Chateau, Jaumotte, and Schwerhoff (2022) find that a carbon tax, feebates and regulation in the electricity sector have similar effects on macroeconomic variables like GDP, employment and consumption. Since electricity is a homogenous good, regulation can be designed in a way that leaves a large degree of flexibility to producers. This allows to keep cost moderate, a finding in line with the literature. Subsidies for renewable energy increases the supply of electricity and thus decreases electricity prices. However, the subsidies need to be financed through higher taxes and this tax hike causes higher GDP losses than the three other policy types. In the EITE sector regulation as modeled in this study causes much higher GDP cost than carbon taxes, although different designs for regulation might make it more efficient. The reason is that the different subsectors of the EITE industry have very different substitution elasticities between inputs, so that some sectors have very high cost for adjusting to broad regulation.

3.3 Trade interactions

Chateau, Jaumotte, and Schwerhoff (2022) also analyze the international interactions of different climate policy instruments. Figure 6 shows an illustrative scenario focused on reducing emissions in the electricity sector and examines its effect on countries' global market shares for energy-intensive and trade-exposed sectors. The orange bars show the effects when all countries introduce carbon taxes. The brown bars show the case where the three regions at the top (Canada, EU, and UK) maintain carbon pricing, but China, India, Japan, and the US use green subsidies instead. Countries using green subsidies have small gains in market share. These are bought at the price of higher GDP losses, however, as shown in the diamonds. The reason is that using subsidies instead of carbon pricing to gain market share is an expensive strategy: the subsidies need to be financed through higher taxes and this generates a larger economic cost than carbon pricing. Carbon prices, by contrast, can be used to *reduce* distortionary taxes. The model, however, abstracts from potential benefits of subsidies in terms of addressing market failures for innovation and adoption of new technologies.

Figure 6: Trade share of EITE industries in 2030, Electricity sector scenarios

(Percentage point deviation from baseline)



Source: Chateau, Jaumotte, and Schwerhoff (2022)

The US would gain market share in a scenario where all considered countries introduce carbon pricing in the electricity sector. The reason is that the US has a low-cost domestic supply of natural gas, so it could relatively cheaply switch from coal to natural gas. However, this strategy is not compatible with reaching net zero emissions by 2050.

When climate policy is not only applied to the electricity sector (as discussed in the previous two paragraphs), but to the EITE sectors as well, avoiding carbon pricing becomes even less appealing. Chateau, Jaumotte, and Schwerhoff (2022) estimate that regulating the EITE sectors causes a larger fall in market share than subjecting these sectors to carbon pricing. The reason is that EITE subsectors have very heterogenous substitution options, so that the more flexible carbon pricing is easier to handle for the sectors than regulation, as it gives subsectors, where options are limited and costly to reduce emissions, the option to pay the tax instead of reducing emissions. The model results also stress that losses in market share are very small in absolute terms.

A global macro modeling study presented in IMF (2022, Chapter 2) analyzes the differential effects of carbon prices and supply-side policies like subsidies and infrastructure investment on current accounts. While the model in (Chateau, Jaumotte, and Schwerhoff 2022) focuses on sectoral detail and long-term adjustment, this model is focused on short-term transitions. A carbon price will reduce the incentive to invest in carbon-intensive sectors. A direct result is a decline in the equilibrium interest rate. If both advanced economies and emerging markets implement equivalent carbon prices, investment declines by less in the less carbon-intensive advanced economies. As a result, capital moves towards advanced economies. This decreases the current account in advanced economies and increases it in emerging markets. If only the advanced economies introduce carbon pricing, capital would move towards emerging markets. In this case, the current account would increase in advanced economies and decrease in emerging markets. The scenario is quite hypothetical, however: A carbon price generates government revenue, and this revenue can be used to reduce other taxes or for investment. The revenue use would encourage investment to offset the effect of the carbon tax.

A combination of climate policy based on subsidies in the United States and carbon pricing in the EU would have a strong effect on capital trade. The policy would discourage investment in the EU and increase investment in the US. Capital would thus flow from the EU to the US, increase the EU current account and decrease the US current account. However, neither the increase in subsidies in the US nor the carbon pricing in the EU is done in isolation. The IRA package in the US bundled a spending increase on climate mitigation of $391 billion with savings and revenue increases of $738 billion (CRFB 2022). In the EU, the carbon pricing revenue is used to fund a “social climate fund” and investments in low-carbon infrastructure (European Council 2023). Both jurisdictions are thus planning to fiscally offset their climate policy and thus largely neutralize major external sector effects.

3.4 The way forward

Both the EU and the US policy packages have features which are viewed as protectionist abroad. The IRA makes use of domestic content clauses to ensure that the subsidies and investments benefit US producers. This causes concern in the EU and other countries that production could move to the US. The EU, by contrast, is implementing a CBAM. The CBAM is designed to ensure that importers pay the same carbon price as domestic producers and to incentivize governments abroad to implement climate policy as well. To this effect, it levies a fee for importers equivalent to the carbon price differential between the exporter’s country and the EU. Both jurisdictions have considered countermeasures to the other’s policies. There is thus a risk of escalation that might contribute to fragmentation (Aiyar et al. 2023).

The IRA has two types of effects for other countries. The first is that local-content requirements disadvantage foreign producers and force the relocation of supply chains for low-carbon technology to the US. The EU does not have similar requirements, so that an asymmetry results. The local-content requirements are considered a violation of World Trade Organization (WTO) rules (Kleimann et al., 2023). At the same time, the US has paralyzed the WTO’s ability to sanction rule violations (Pollack, 2023). The second effect is that large-scale US investments in zero-carbon technology will boost technology development in this area. For each doubling in cumulative production capacity in solar photovoltaics prices decrease by 22.5 percent (Creutzig et al. 2017). Given that the US is one of the top innovators for green technologies, this technology will diffuse to other countries (Probst et al. 2021) and facilitate decarbonization there. To counter the effect of the IRA subsidies, the EU is offering similar subsidies (Kleimann et al., 2023). There is a risk that countries, especially emerging economies, with limited fiscal space are unable to export low-carbon technology to subsidizing world regions if there is a race to subsidies.

To summarize, climate policy can be advanced despite different climate policy approaches by

- Avoiding protectionist features in climate policies,
- Appreciating the positive spillover effects of climate policy packages,
- Agreeing on methodologies on how to assess different macro approaches to climate policy.

4. Technology

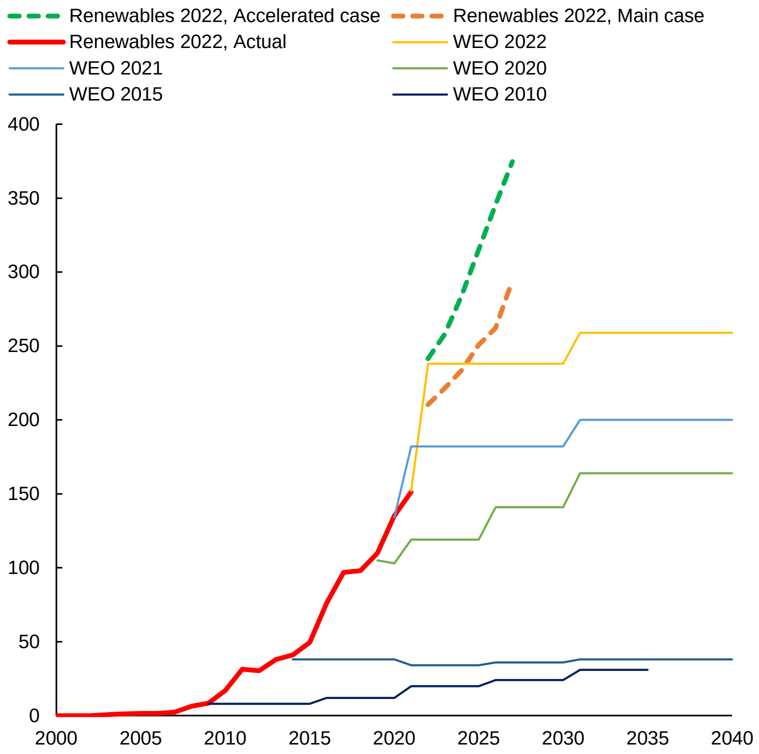
The covid pandemic provided some insights on managing a global crisis that seem transferable to the climate crisis and provide guidance. One insight is that the world was much less prepared for a pandemic than it could have been, despite warnings by scientists. This does not bode well for the political willingness to address the climate emergency. An upside is that governments were able to act decisively and cooperate on developing required technology (vaccines and specific antivirals, in the case of the pandemic). Then again, cooperation was much less effective on sharing the vaccines globally. In this section, we first discuss why technology matters for decarbonization, and which type of technology is needed. We then discuss the role of international technology diffusion. Finally, we discuss how insights from the pandemic can be transferred to the climate crisis.

4.1 The role of technology policies for climate mitigation

The levelized cost of electricity (LCOE) for solar photovoltaics has declined by 88 percent between 2010 and 2021 (IRENA 2022). From being more than twice as high as the upper bound of the fossil fuel cost range it has fallen below the lower bound of the range in 2021. Solar energy has consistently outperformed expert forecast (Creutzig et al. 2017), including those of the IEA (Figure 7). The cost for onshore wind is below the lower bound since 2018. Less well known but equally astonishing is the decline in battery cost. Battery storage to balance out intermittent solar energy is now commercially viable (Comello and Reichelstein 2019). This cost decline has brought a breakthrough for climate policy. The cost for decarbonized electricity generation are in the same range as for conventional electricity generation (Bogdanov et al. 2019; Way et al. 2022). As a result of this breakthrough, more than 85 percent of the emission reduction needed by 2030 can be accomplished with proven low-carbon technology (Pigato et al. 2020).

Figure 7: Added capacity of solar power

(Gigawatt)



Source: International Energy Agency
Note: The chart represents added electricity capacity of solar PV and CSP from (IEA 2022d) and historical World Energy Outlook (WEO) publications. Due to data limitations, annual numbers are computed by total increase in capacity divided by the number of years for each reported period.

Despite the success with technology development, reaching net zero emissions by 2050 requires an additional policy effort. An obvious point to address is the remaining 15 percent of emissions which require new low-carbon technology. The sector with the largest need for new technology is agriculture (Pigato et al. 2020, Figure ES.1). Additional technology needs arise when considering decarbonization beyond 2030. It will then become necessary to tackle the “hard-to-decarbonize” sectors. Examples for these sectors is the production of steel, which currently use coal directly to generate sufficient heat. A variety of technologies can be used to decarbonize the sector, including green hydrogen, but they are not yet economically viable (IEA 2020). A strategic policy plan will also be needed to bring down the cost for negative emission technology (Fuss et al. 2018). Negative emission technology will be needed to offset remaining emissions and to reduce the high concentrations of greenhouse gases in the atmosphere.

Climate policy has been shown to incentivize the development of low-carbon technology development (Eugster 2021). This holds both for market-based policies (like carbon pricing and feed-in tariffs) and non-market policies (like R&D subsidies and emission limits). Regulating emissions is thus an important driver for innovations, no matter which policy is used. Developing a completely new technology requires a more long-term approach. New technology requires both government sponsored fundamental research and support to a scaling up of the technology, so that learning by doing can bring down cost further. Research on solar panels for example was advanced by the US government, which developed it for space technology and in response to the 1970s oil crisis. Subsidized demand in Germany then accelerated the learning by doing experience (Nemet 2019).

Getting negative emission technology and other key technologies for hard-to-decarbonize sectors fully deployed by 2050, will thus require preparations already now.

Green hydrogen is an example for a technology that requires managing the simultaneous scaling of demand and supply, given that there are still large uncertainties around the technology (Odenweller et al. 2022). Green hydrogen can be used directly as a gaseous zero-carbon fuel, and it can be used as the basis for liquid zero-carbon fuels (also called e-fuels). Good conditions for the production of green hydrogen exist in many countries, especially among the countries with good solar energy potential (Englert et al. 2021). The European Union has taken the important step of requiring fuel suppliers at EU airports to use zero-carbon fuels for a growing percentage of their fuel.[14] This creates demand for these fuels. At the same time, it will be challenging to ramp up production enough to supply the needs of shipping, aviation, and some industries. This is why the production of green hydrogen receives government support already. At the same time, zero-carbon fuels need to be prioritized for sectors that are inaccessible to direct electrification due to their limited supply (Ueckerdt et al. 2021).

4.2 Technology diffusion

Most technology is developed in a small number of advanced economies (Keller 2004). Low-carbon innovations in particular are concentrated in Germany, Japan and the United States (Probst et al. 2021). For many countries technology acquisition happens through technology diffusion. Technology diffusion is not automatic, so countries need to create the right conditions. At the same time, technology diffusion can accelerate environmental policy adoption, because it reduces compliance cost (Lovely and Popp 2011). Technology diffusion has been found to be so effective that the EU and China could strongly limit global warming through domestic policy (Barrett 2021). The domestic emission reductions would combine with indirect emission reductions through the technology diffusion process. Given the importance of diffusion, advanced economies can support low-income countries through strong domestic climate policies. Strong climate policies would accelerate technology development, which then becomes available to other countries.

4.3 The way forward

Patents for climate mitigation technologies have experienced a boom from 1995 to 2012. In the following five years, the share of green patents in total patents fell quickly, see Figure 8. Reasons for the decline in green innovations during 2013 to 2017 were declining fossil fuel prices (related to the shale gas revolution), low carbon prices and increasing technological maturity for some technologies (Probst et al. 2021). The two price-based determinants show how sensitive innovations are to relative prices. Clear price signals are needed to maintain the momentum for long-term decarbonization.

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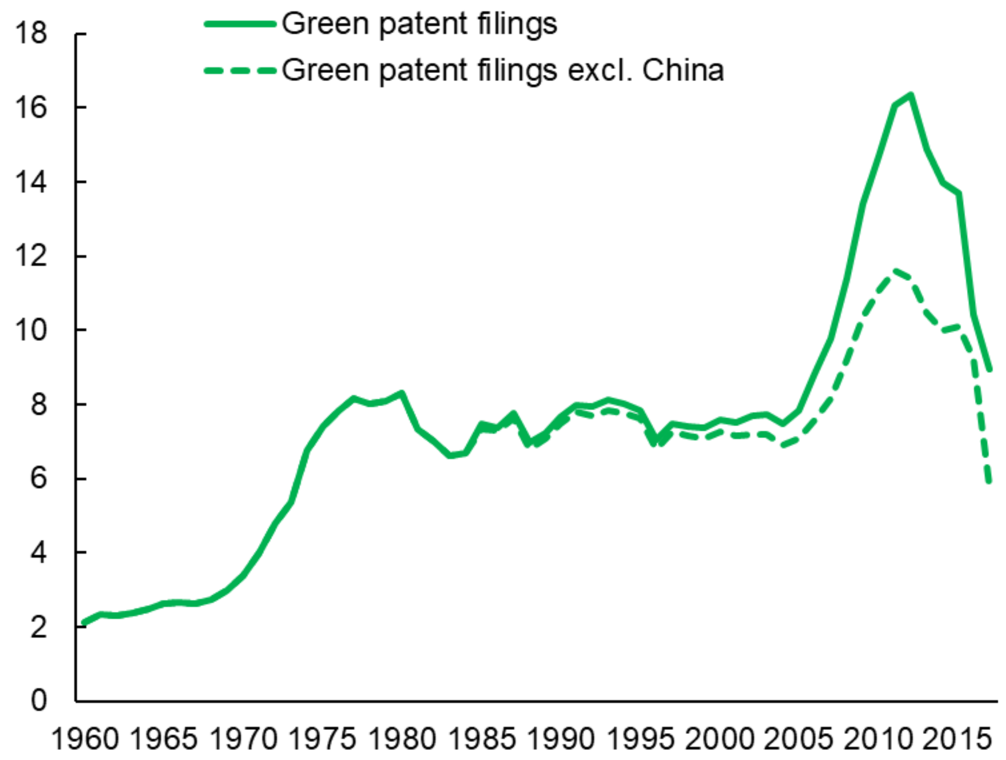
[14] https://www.consilium.europa.eu/en/press/press-releases/2022/06/02/fit-for-55-package-council-adopts-its-position-on-three-texts-relating-to-the-transport-sector/

Figure 8: Number of patents in climate mitigation technologies

(Percent of total patents)



Source: PATSTAT Global 2020 Spring; and IMF staff calculations.
Note: This chart counts the number of all patent families, including and excluding China, respectively for the period 1960 to 2017. All patents with “Y02” tag in CPC classification are classified as green patents.

The covid pandemic showed some limitations of global cooperation, but it also had some constructive lessons that could be beneficial for climate policy. The pandemic demonstrated the importance of a long-term policy perspective and of considering scientific recommendations for anticipating future crises. It also demonstrated the importance of active government management. Governments accelerated technology development (vaccines in the case of the pandemic) and coordinated international research cooperation. More efforts along those lines would also boost climate mitigation efforts. While much of the emission reductions needed until 2030 could be achieved with existing technology, key technologies like green hydrogen and negative emission technologies require investments in basic research and the creation of a market for scaling up the technology and starting a process of learning-by-doing. Finally, governments cooperated effectively on parts of the covid challenge. Facing a global challenge through international cooperation would also be needed for climate change, although the less imminent threat of climate change might make cooperation more difficult than on covid. Technology transfers and climate finance would help reducing emissions in emerging markets and developing economies (EMDEs).

Technology diffusion needs to be accelerated and be less expensive. Technology flows from the innovator countries at the frontier over time, and sometimes slowly also because of the costs. The green transition requires a faster adoption of (green) technology. Government should consider schemes to finance and accelerate the transfer and the adoption of green technologies

To summarize, technology can be enlisted to support the transition to net zero emissions by:

- Investing early into technology that will be needed in the coming decades,
- Enhancing technology transfers to EMDEs and LICS,
- Setting clear policy signals for ambitious climate policy.

5. Conclusions

Implementing the Paris Agreement remains urgent and important. Recent policy packages like the EU “Fit for 55” package and the US IRA did bring substantial progress, but policy ambition still falls short of what is needed to stay below 1.5°C with respect to the pre-industrialization era.

The new developments since the 2015 Paris Agreement – domestic policy backlash, energy security concerns, risk of international economic fragmentation, the covid pandemic, and growth concern – are interacting with well-known pre-existing challenges. The domestic policy backlash is constraining domestic policy options. As a result, less efficient approaches are chosen. In turn, the chosen domestic policies are creating international tensions that may hinder further cooperation. The covid pandemic has also shown some limits of international cooperation in vaccine distribution. Possibly the main peril to climate policies and the world economy is a fragmented world.

A fragmented world would make climate policy much more expensive to pursue. The cost of solar energy has decreased dramatically thanks to the huge economies of scale achieved because of a global market. The key research necessary for the development of new technology will depend on international cooperation as the covid-19 experience shows. The international grids necessary to overcome the challenge of intermittency also require international cooperation. Finally, a speedy green transition can happen only with prompt technology transfer across countries. In sum, the green transition requires international cooperation.

At the time when international collaboration is necessary to grasp the benefits of technology development, domestic political backlashes are on the rise. The race between these two forces will ultimately determine the success of the green transition. Governments have many options to win this race.

One key option for governments is to support low-carbon energy technology development and adoption. The pandemic has shown that governments can be very effective at stimulating research and coordinating research internationally. Reducing emissions is not as straightforward an objective as developing a vaccine, but there are key technologies (like green hydrogen and negative emission technologies), where active government intervention would be very beneficial.

A second option is to provide a clear direction when unexpected crises happen. Russia’s invasion of Ukraine and the attendant energy crisis made energy security a key issue in the political debate. Governments should provide guidance about the direction of energy policies so that temporary shocks do not disrupt the green transition. Investments in natural gas infrastructure, and the purchase of natural gas by China and India at a discount, cause concern that the energy crisis might cause a setback for climate policy. However, the 1970s oil crisis had a lasting effect on energy use and the 2022 energy crisis might have a lasting effect in a positive sense as well. The reason is that some of the affected countries have redoubled efforts to build renewable energy capacity and to improve energy efficiency. In addition, fossil fuels are now seen as a riskier form of energy, so that the green transition is becoming even more attractive than previously. Renewable energy does not eliminate all concerns for energy security. However, these challenges, including the availability of transition metals, can be minimized by anticipatory investments.

A third task is to build international cooperation which is resilient to different domestic approaches to climate policies. Populism and fragmentation have posed another challenge for governments to implement climate policy. In the US, carbon pricing is not a viable policy option in the near term, so that the US and EU need to come to terms with different approaches to emission reductions. Both the domestic content regulation of the US and the EU carbon border adjustment mechanism have raised concern on the other side of the Atlantic. Both measures can be seen as protectionist. However, a strong swing in US investments from fossil fuels to renewable energy has the potential for a boost to technology development in one of the most innovative countries. It might also boost technology diffusion and thus positive global spillovers. An appreciation of these positive spillovers could avoid a harmful round of protectionist measures and industrial policies.

Finally, in the last few years progress in green technologies has been remarkable. This was largely unexpected even for “techno-optimists.” The issue looking forward is that the technological progress may exacerbate disparities both domestically and internationally. Domestically because some industries will be threatened. Internationally because trade patterns will change as different goods will be in demand. The challenge is to make sure that domestic and international reactions do not generate backlashes. However, with incentives for innovation set in different countries and explicit technology cooperation, it should be possible to use technological progress for decarbonization without creating new imbalances.

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