1. The next great transformation

Paradoxically, economic progress is both the cause of and the solution to the climate crisis. To head off dangerous climate change, the Paris Agreement aims to limit the global warming to 1.5°C this century. This means that greenhouse gas (GHG) emissions need to be cut by roughly 50 per cent by 2030 and reach net zero by 2050.[1] The most realistic way modern economies can achieve this goal – without cutting back living standards in richer countries and cutting short development in poorer ones – is by modernizing even more, harnessing human innovation, ingenuity and entrepreneurship to advance low-carbon technologies and to use the planet's resources more sustainably.

Dramatic advances in automation, transportation and industrialization – all powered by fossil fuels – have driven the exponential growth of the global economy over the past two and half centuries, resulting in rising living standards, increased mobility, and improved material well-being for a fast-growing global population. In important ways, the industrial revolution was also an energy revolution (Wrigley, 2010). By discovering how to convert fossil fuels into mechanical energy, starting with the steam engine, humanity unlocked seemingly limitless supplies of energy to power seemingly limitless economic growth and development.

But ever-expanding growth has also released ever-greater amounts of heat-trapping GHG emissions into the atmosphere – from electricity generation, transportation, industry, agriculture and deforestation – which in turn has contributed to the warming of the planet and its negative climactic and environmental knock-on effects. Almost three-quarters of global GHG emissions come from energy consumption; another 18.4 per cent from agriculture, forestry and land use; 5.2 per cent from industrial processes; and 3.2 per cent from waste (Ritchie, Roser and Rosado, 2020). As long as the world remains dependent on high-carbon technologies, increasing economic production will almost inevitably lead to increasing GHG emissions.

Yet, while technological and economic progress has "fuelled" the climate crisis, it is also indispensable to mitigating and overcoming it. Replacing fossil fuels with renewable energies – solar, wind and geothermal power, and others – is essential to avoid and reduce GHG emissions, as are steps to decarbonize transportation, steel production, cement manufacturing and agriculture, and to make economic ecosystems less wasteful and more resource-efficient overall.

Adapting to the adverse effects of climate change will also require technological solutions – from developing drought-resistant crops and resilient water supplies, to building flood defences, improving weather forecasting and setting up early warning systems (UNFCCC, 2016a).

Given that many lower carbon technologies – from solar panels and electric cars to vertical farms and electric arc furnaces – already exist, the challenge is to scale up their production and deployment. One influential study argues that two-thirds of economies, including major emitters like the United States, the European Union and China, could reduce their GHG emissions by 80 per cent by 2030, and achieve carbon neutrality by 2050, through the mass adoption of electrification based on existing wind, hydro and solar technologies (Jacobson et al., 2017).

Even more cutting-edge technologies, such as green hydrogen or direct air carbon capture and storage, are also advancing rapidly. Then there are the myriad "soft" climate technologies – data-crunching, information-sharing, training and education – which are easier to adopt, and which will be just as critical to shift economies towards low-carbon alternatives.

It is also important to focus not just on what technologies are needed, but on how they are used. It has long been recognized that it is only by using new technologies that we learn how to optimize and exploit their full potential (Arrow, 1962). This "learning-by-doing" dynamic can take time (David, 2002). In the same way that it took decades for the invention of the dynamo to translate into mass electrification, it could take years to realize the full potential of solar power or carbon farming. Thus, it makes sense to scale up new, clean, low-carbon technologies now, even if the initial investment costs are high, as expanding capacity early on can encourage usage, improve performance, drive down prices, and ultimately make renewable technologies more attractive and competitive.

Realizing the potential of one innovation also often hinges on marrying it to another innovation (Harford, 2017). Just as the explosion of the internet after the mid-1980s depended on parallel innovations in satellite and fibre optic telecommunications, electric vehicles are now poised to revolutionize clean-energy transportation because they are benefitting from other technological breakthroughs, including the mass production of affordable lithium-ion batteries, the roll-out of electric vehicle charging networks and more readily available renewable energy.

Conversely, the absence of synergistic technologies can significantly slow or block economic progress.

For example, the lack of affordable and efficient technological solutions to the challenge of long-term, large-scale energy storage – a challenge arising from the intermittent nature of some lower carbon energy technologies such as solar and wind power – is a key missing piece of the renewable puzzle which urgently needs to be "discovered" if renewables are to become a reliable replacement for fossil fuels worldwide.

This positive process of technological interaction, cross-fertilization and mutually reinforcing innovation takes place at the global, not just the firm, level. The fact that photovoltaic (PV) cells, which convert solar energy into electricity, are increasingly affordable and available is the result of mutually supportive back-and-forth innovations across several continents, including US investments in PV cell research and development (R&D) in the 1960s and 70s; European policies to accelerate domestic solar panel installation in the 1990s and 2000s; and Chinese efforts to improve and scale production after 2011 (IEA, 2022a).

Technological cooperation, competition and cross-fertilization do not just spur innovation; they also encourages needed technological diffusion. Many developing countries have abundant renewable energy potential that access to low-carbon technologies and infrastructure could unleash (IRENA, 2022). This is starting to happen. Kenya is already a world leader in the number of solar panel systems installed per person, while 90 per cent of Nepal's electricity comes from hydro-electric power. Locally generated renewable energy allows developing and least-developed countries to bypass many of the logistical difficulties and high costs involved in the transmission and distribution of fossil-fuel energy, improving their energy access and self-sufficiency. Bringing clean energy to the 759 million people in the developing world who still lack access to electricity would not only stimulate economic growth and job creation and reduce poverty, but would significantly improve essential services, such as healthcare, education and the internet.

The shift to low-carbon farming – especially climate-smart agriculture techniques that focus on intercropping, crop rotation, agroforestry, and improved water management – can bring similar benefits to developing-country farmers in terms of improved productivity, greater resilience, less deforestation, and reduced reliance on fertilizers and fuels (Brakarz, 2020). In short, the diffusion of low-carbon technologies can provide poorer countries with the essential tools they need both to limit GHG emissions and to accelerate their development.

Achieving a shared and "just" transition to a low-carbon global economy is not just the right thing to do; it is also in everyone's interests. Climate change will not be stopped if only wealthy economies have access to low-carbon technologies while poor economies continue to have to rely on fossil fuel-fired power plants and internal combustion engines. Since everyone is impacted by climate change, everyone has an interest in ensuring that the technological tools and resources to reduce emissions are as widely available as possible.

Wealthy economies can also benefit in more direct ways from technological development in poorer countries. A striking example of North-South technological collaboration is the ambitious plan to deliver Moroccan solar and wind farm electricity to UK consumers via an underwater cable stretching 3,800 km – the world's longest cable of this kind. When completed in 2030, it is hoped that the Xlinks Morocco-UK Power Project will deliver low-cost, clean power to over 7 million UK homes, representing 8 per cent of current UK electricity needs (Hook, 2021).

Indeed, the transition to a low-carbon global economy will create enormous investment, employment and growth opportunities – not just adjustment costs – for developed and developing countries alike. For example, global investment in the low-carbon energy transition – across sectors ranging from power generation, energy storage and electric vehicles, to sustainable materials, electrical efficiency and carbon capture – already totalled US$ 1.3 trillion in 2021, doubling the investment of US$ 655 billion in 2017 (IEA, 2022b). In order to reduce GHG emissions to net zero by 2050, cumulative investment in renewable energy would need to reach US$ 131 trillion over the next 30 years (McKinsey & Company, 2022).

Similarly, massive investment opportunities are opening up in the steel, cement, farming, forestry and waste management industries as they shift to low-carbon technologies and processes. Building low-carbon industries and infrastructure will not only require new investment and equipment; it will also require new workers and skills. Shifting to clean energy, for instance, could generate 14 million new jobs in clean energy sectors and 16 million additional jobs in energy-related sectors globally by 2030 (IEA, 2021). In short, the transition to a low-carbon economy will entail the construction of a new economy.

The good news is that low-carbon technologies are expanding – and at a faster pace than many predicted (Naam, 2020).[2] For example, renewables accounted for roughly 11 per cent of global primary energy and 30 per cent of electricity generation in 2021 (IEA, 2022b). Despite supply chain bottlenecks, rising raw material prices and growing geopolitical tensions,

the International Energy Agency (IEA) projects that renewables are on track to account for almost 95 per cent of the increase in global power capacity through 2026, with solar power alone providing more than half of that increase. The IEA expects the amount of renewable capacity added between 2021 and 2026 to be 50 per cent higher than between 2015 and 2020 – and even these optimistic forecasts may underestimate the speed and scale of the transition.

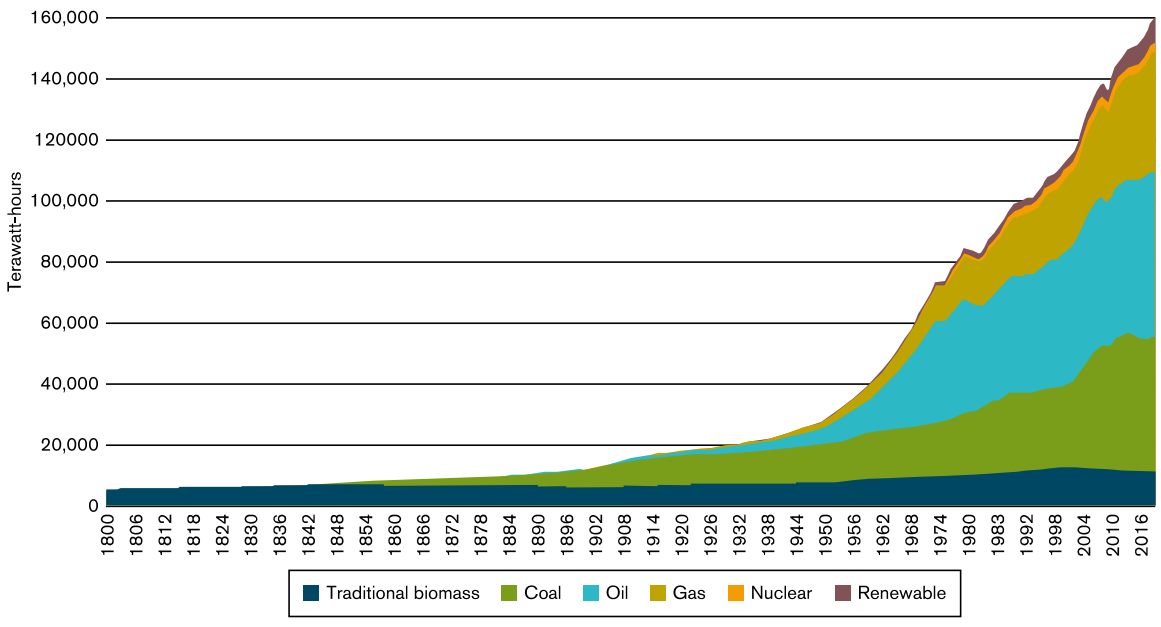
The bad news is that although global renewable energy capacity is growing rapidly, overall global energy demand is growing almost as fast, so fossil fuel consumption continues to rise (see Figure A.1). Nearly 80 per cent of the world's energy is still generated by burning fossil fuels, notably oil, coal and gas, partly because supplies of renewable energy need to be scaled up, and partly because fossil fuel consumption is still subject to strong path dependence due to technological, infastructural, institutional and behavioural lock-ins. Global energy-related carbon emissions rose by 6 per cent in 2021 to 36.3 billion tonnes – their highest level ever, and 65 per cent higher than they were in 1990 (IEA, 2022c). The IEA estimates that the current pace of renewable power capacity growth will need to double over the next decade if the global economy is to stay on a pathway to net zero emissions by mid-century.

Other sectors also face the challenge of accelerating the shift to low-carbon technologies and practices. The challenge is especially daunting in agriculture – compared to power generation or transportation, for example – because the emissions-reduction technologies are more amorphous and the sector is more diffuse, requiring changes to how over two billion people farm and how billions more eat (McKinsey & Company, 2020). At the same time, the challenge is intensified because of agriculture's unique vulnerability to climate change – including extreme weather events, frequent droughts, and invasive species and pests – and because of an expanding global population's growing need for food.

2. Harnessing the transformative power of trade

What role will trade play in the transition to a low-carbon global economy? In the past, trade has been part of the problem, contributing to climate change both directly, by generating increasing transport emissions (shipping, air freight, trucking and rail), and indirectly, by helping to drive carbon-intensive global growth. But in the future, with the right policies in place, trade can be a major part of the solution.

Figure A.1: Fossil fuels remain the dominant energy source despite increasing use of renewables



Source: Authors' calculations, based on Smil (2017) and BP Statistical Review of World Energy (2017).

Trade can increase counties' access to lower-emissions goods, services and capital equipment, and can help to diffuse critical technologies and know-how. It can drive down the costs of environmental products by encouraging efficiency, economies of scale and learning-by-doing. Perhaps most importantly, it can spur innovation by opening up new market opportunities for low-carbon exports and investments and by incentivizing entrepreneurs and industries to compete to fill them.

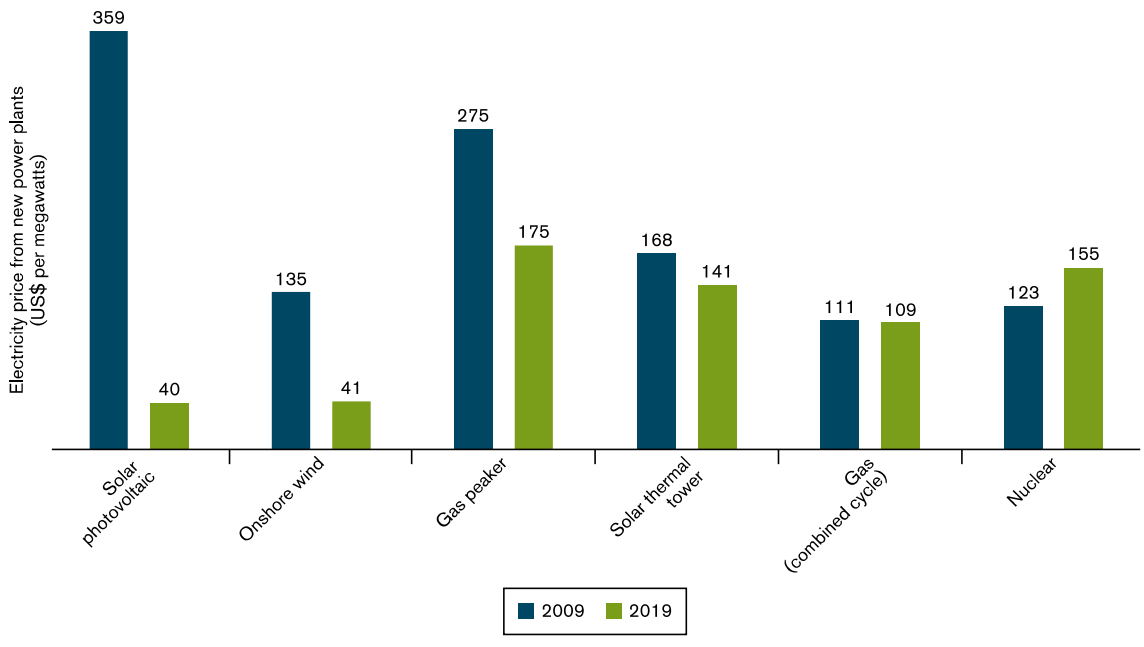
If low-carbon production reaches the point where it beats high-carbon production on price and performance – because environmental costs are internalized in high-carbon production through taxes and other policies or because technological advances alone make low-carbon alternatives cheaper and better – then market forces will increasingly drive the transition and progress will accelerate.

This is already happening. Scientific advances, more efficient production processes, and rising global demand – all supported by open world trade – have driven an astonishing reduction in price and improvement in performance of low-carbon technologies (see Figure A.2). The price of solar power, for example, has fallen by almost 90 per cent since 2010, while the efficiency of solar panels has doubled since 1980. Last year alone, the cost of electricity from onshore wind fell by 15 per cent, and from offshore wind by 13 per cent. The price of lithium-ion batteries has plunged by 97 per cent since 1990, while their energy density has nearly tripled in just 10 years.

Even more challenging sectors, such as steel production, managed to cut energy use in half between 1975 and 2015 – with reductions continuing – because of technological advances and a shift from traditional blast furnaces toward electric arc furnaces (IEA, 2020). As a result of these dramatic price and performance improvements, low-carbon technologies are becoming more economically competitive, not just more environmentally sustainable, alternatives. For example, almost two-thirds of the world's new wind and solar power plants are able to generate electricity more cheaply than the world's cheapest new coal plants (IEA, 2022a; WTO and IRENA, 2021).

The fundamental driver of this change is improvements in technology and production, which are in turn being driven by strong learning-by-doing effects. As the world gets better at building, installing and using solar panels, for example, the price falls and the technology improves. It has been estimated that every time the number of solar panels installed doubles, their price drops another 30 to 40 per cent (Naam, 2020). By helping to create a competitive, dynamic and integrated a global marketplace for solar and other clean technologies, trade plays a central

Figure A.2: The price of renewables has plunged in the last 10 years



Source: Authors' calculations, based on Lazard's Levelized Cost of Energy Analysis (2019).

role in underpinning and accelerating this process. It is significant that between 2010 and 2020, exports of solar panels increased and their prices fell sharply (see Figure A.3).

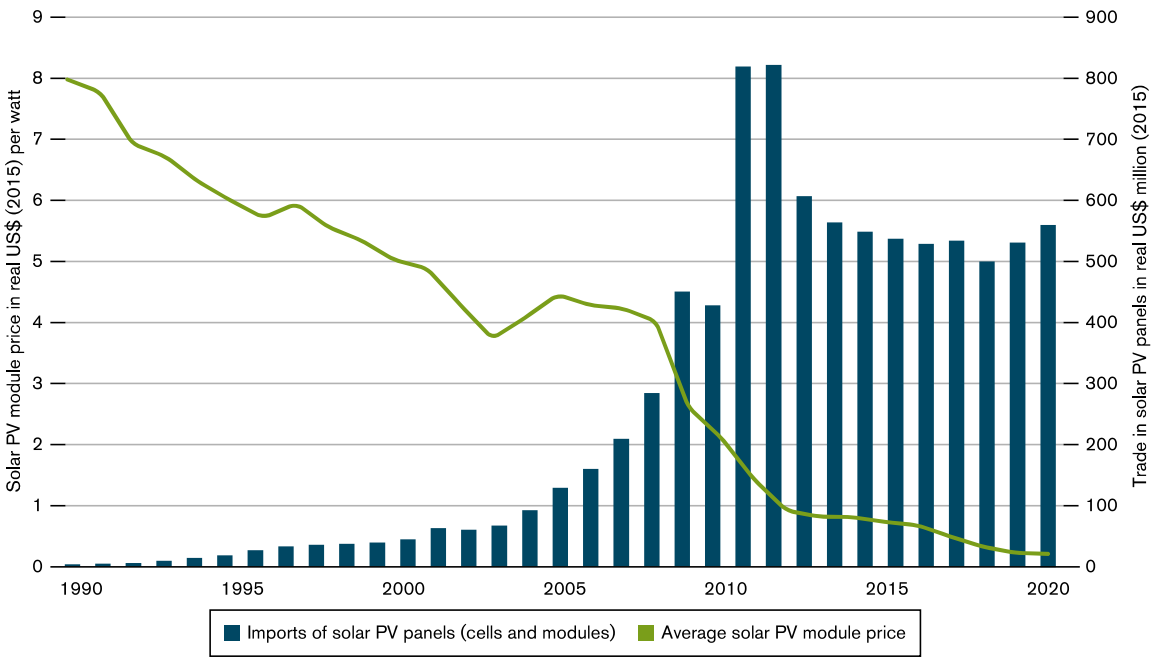
But the contribution of trade and trade policy to a just low-carbon transition could be strengthened and improved. One positive step would be to reduce trade-distorting measures on climate-friendly goods, services and technologies and to strengthen supply chains. Opening up trade across a range of low-carbon products and services would expand global access, increase competition and lower prices, making it easier and cheaper for economies to transition to low-carbon energy, mobility and production alternatives, and thus reducing overall emissions. Conversely, by making it more difficult to import key environmental technologies, e.g., by raising tariffs or imposing restrictions, the shift from a high- to a low-carbon economy will only be slowed and impeded.

Another key issue is the interface between trade and environmental subsidies and other support measures. A growing number of countries use subsidies either to encourage producers to invent, adopt and deploy low-carbon technologies, or to encourage consumers to purchase environmentally sustainable products and services. If they are well-targeted and non-discriminatory, environmental subsidies can play a positive role in scaling up new technologies and making climate-friendly products more affordable. Government incentives to insulate homes, install solar panels or buy electric vehicles are increasingly common examples.

But subsidies can also be used to support carbon-intensive production and consumption, making the climate crisis even worse. In the case of fossil fuel subsidies – which amounted to US$ 440 billion in 2021 (IEA, 2022d) – many governments find themselves in the contradictory position of encouraging oil, gas and coal industries even as they are discouraging them with carbon taxes and regulations. Moreover, subsidies can negatively impact other trade partners by distorting markets or unfairly boosting exports. The challenge is to find an optimal balance between maximizing positive spillovers from environmental support measures – both nationally and globally – and minimizing negative ones.

One of the most challenging issues is the relationship between trade and carbon pricing. Environmental

Figure A.3: As the use of solar panel exports increases, their price falls



Source: Authors' calculations, based on data on solar PV module costs from Kavlak, McNerney and Trancik (2018) and Bloomberg Terminal and trade figures from the UN Comtrade database.

Note: The trade data covers the Harmonized System (HS) code 85414.03, which does not distinguish between solar PV cells and modules and other products such as light-emitting diodes.

subsidies and carbon prices are essentially the opposite sides of the same coin. The former makes environmentally friendly purchases cheaper, while the latter makes environmentally damaging ones more expensive, all with the aim of persuading firms and consumers to switch to less carbon-intensive alternatives.

Ideally there would be a global agreement on carbon prices. Instead, close to 70 separate carbon pricing initiatives have been adopted in 46 national jurisdictions worldwide – which risks creating a patchwork of different systems, tax rates, covered products and certification procedures. As a result, countries with high carbon taxes worry that their industries will shift to low- or no-carbon tax countries – i.e., "carbon leakage" concerns. Conversely, countries with no carbon taxes worry that their exports will be unfairly shut out of carbon-taxing countries – i.e., "hidden protectionism" concerns. Although WTO rules – especially those concerning national treatment – allow tax adjustments at the border, adjusting taxes for carbon could prove far more complex than adjusting them for alcohol, for example. The challenge is to find a policy mix that balances the need to discourage carbon emissions with the need to encourage trade to support a low-carbon transition.

Arguably the most important way trade can contribute to a "just" transition to a low-carbon global economy is by helping to expand, diffuse and share technological progress. Today's world economy is an increasingly interdependent system, and climate change is the most challenging collective action problem it has ever faced. It is unrealistic, not to mention unfair, to expect poorer countries to take the same steps to curb carbon emissions as advanced ones if they lack the technological and financial resources to do so. Indeed, this is explicitly recognized in the core concept of "common but differentiated responsibilities" set out in the Paris Agreement. The developed world has a direct stake in helping the developing world to manufacture, deploy and maintain low-carbon technologies, if only because no one country can solve the climate crisis on its own. Trade cooperation is key to driving this global transformation; trade fragmentation would invariably set it back.

3. Overview of the report

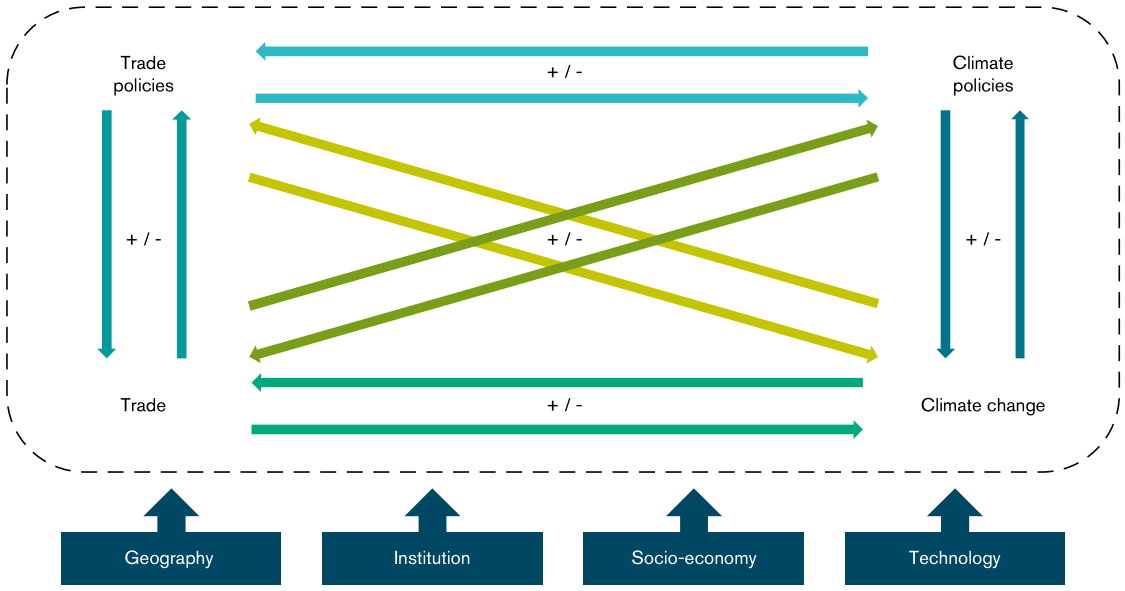
This year's *World Trade Report* looks at the relationship between climate change and trade, examines why trade is an indispensable part of the solution to tackling climate change, and discusses areas where policies need to improve. A core message of the report is that solving the climate crisis depends on a far-reaching transformation of the global economy, and that trade will be critical to driving the needed technological and economic shift to a low-carbon future.

The other core message is that this unprecedented global shift will require unprecedented international cooperation – and that there is no alternative to achieving a just transition where the costs and benefits are more evenly and equitably shared. Thirty years after the adoption of the United Nations Framework Convention on Climate Change (UNFCCC), this report underscores how the goals of environmental sustainability and economic development are not only compatible, but inextricably and mutually dependent.

Although the issue of trade and climate change is by no means new, the relationship is complex, multifaceted and fast-evolving. This is partly due to the fact that the relationship not only involves the interplay between international trade and climate change, but also covers linkages with trade policies and climate policies (see Figure A.4). Their interactions occur in several directions, with both direct and indirect mechanisms which are in part determined by geographical, institutional, socio-economic and technological conditions. The global nature of climate change further amplifies this complexity (WTO and UNEP, 2009).

The report opens with a chapter on adapting to the consequences of climate change. While reducing GHG emissions to limit the rise in global temperature to well below 2°C – and preferably to below 1.5°C – is essential to limit the consequences of climate change, past GHG emissions have already caused, and continue to cause, global temperatures and sea levels to rise, and have increased extreme weather events. Many consequences of climate change are already hard to reverse. Adapting to the changing climate and its cascading impacts is therefore a sustainable development imperative. Chapter B explores how the geophysical effects of climate change will affect international trade, and identifies the effects of such changes on trade costs, supply chains and the most vulnerable regions and sectors. It discusses ways in which international trade and trade policy can help with climate change adaptation strategies, and outlines how international cooperation, and the WTO in particular, can contribute to helping countries, and in particular developing and least-developed countries, adapt to some of the disruptive consequences of climate change.

Figure A.4: The relationship between climate change and trade is complex and multifaceted



Source: Authors' elaboration.

Mitigating climate change by reducing GHG emissions is essential but requires a large-scale transition to a low-carbon economy. Chapter C examines the role of ambitious climate change mitigation policies and well-functioning financial markets in supporting and accelerating the transition to a low-carbon economy. It discusses how the transition to a low-carbon economy could change trade patterns and provide new economic opportunities, as well as certain initial disadvantages for some economies. Such changes require enhanced international cooperation, and the WTO can play an important role in supporting climate-change mitigation efforts.

Among the many policies to mitigate climate change, carbon pricing has attracted increasing attention as it puts a price on carbon emissions as a means of reducing emissions and supporting investment into lower-carbon alternatives. Chapter D explores the role of carbon pricing in reducing GHG emissions and the relationship between carbon pricing, trade and trade policies. The necessity of developing a solution to the current patchwork of uncoordinated carbon pricing policies, which could lead to tensions in the global trading system, is discussed, as well as the importance of international cooperation to achieve convergence on global carbon pricing approaches.

While international trade separates production and consumption across space, the emissions generated in one country to produce goods and services are not necessarily the same as the ones required for its consumption. Chapter E analyses how the emissions originating from international trade can be measured, and examines how trade both contributes to GHG emissions and diffuses the technology and know-how needed to make production processes cleaner. The necessity for greater international cooperation to establish adequate carbon measurement and verification, improve carbon efficiency in transportation, and ensure the environmental sustainability of global value chains, is reviewed.

The development and diffusion of climate-friendly technologies, including renewable energy and energy efficient technologies, are key to tackle climate change. Chapter F discusses how trade in environmental goods and services can enable access, deployment and diffusion of environmental technologies, which are instrumental in mitigating carbon emissions and developing ways in which people and trade can adapt to climate change. While the WTO agreements ensure that trade in environmental technologies flows as smoothly and predictably as possible, the WTO could make an even greater contribution to promoting trade in environmental goods and services.

Endnotes

1 "Net Zero" involves reducing greenhouse gases (GHGs) to as close to zero as possible, so that any GHGs that are produced can be absorbed from the atmosphere. GHGs are gases in the atmosphere such as water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that can absorb infrared radiation, trapping heat in the atmosphere. This greenhouse effect means that emissions of GHGs due to human activity cause global warming. The species of gases reported under the common reporting format of the United Nations Framework Convention on Climate Change (UNFCCC) are: CO_2 from fossil fuel combustion and industrial processes (CO_2-FFI); net CO_2 emissions from land use, land-use change and forestry (CO_2-LULUCF); methane (CH_4); nitrous oxide (N_2O); and fluorinated gases (F-gases), comprising hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) (IPCC, 2022a). Although carbon dioxide is the primary GHG emitted through human activities, methane has become an emerging GHG given its more potent heat-trapping ability.

2 It has been pointed out that economic authorities have dramatically underestimated the rapid expansion and declining costs of renewables every year since 2000 (Beinhocker, Farmer and Hepburn, 2021).

B The role of trade in adapting to climate change

While reducing greenhouse gas emissions is essential to limit the consequences of climate change, climate change is already having a major impact on the environment, people and, as a result, the global economy. This chapter explores the impacts of climate change on international trade and discusses the role that trade, trade policy and international cooperation can play in supporting climate change adaptation strategies. Climate change increases trade costs and disrupts production and supply chains. However, trade and trade policies, in conjunction with relevant policies and international cooperation, can help to alleviate some of the impacts of climate change, including on food security, by contributing to enhancing economic resilience.

Contents

Key facts and findings

- Climate change can impact international trade by affecting trade costs, altering comparative advantages, and disrupting global value chains. A rise of 1°C has been found to reduce the annual growth of developing countries' exports by between 2.0 and 5.7 percentage points.
- Climate change adaptation encompasses actions that reduce the negative impacts of climate change, while taking advantage of potential new opportunities.
- International trade can help support climate change strategies, such as prevention and reduction of, and preparedness for, climate risk, as well as recovery and rehabilitation from climate disasters. Trade can also contribute to strengthening food security during climate-induced supply-side disruptions.
- Although climate change adaptation initiatives are mostly locally-led, international cooperation is essential to enhance the resilience of international trade with regard to climate-induced shocks and to improve economies' capacity to adapt to climate change.

1. Introduction

The consequences of climate change, including global warming, rising sea levels and extreme weather events (EWEs), are already tangible and are affecting lives, livelihoods and ecosystems around the world. The future holds higher global temperature, a faster sea level rise, more frequent and intense EWEs, and other short- and longer-term climate hazards (IPCC, 2021). Although reducing greenhouse gas (GHG) emissions is necessary to mitigate climate change and limit the most severe consequences of climate change, finding ways of adapting to climate change and its current and future consequences is a sustainable development imperative.

This chapter discusses how climate change can affect international trade through productivity alteration, supply chain disruptions, changes in trade costs and modified comparative advantages. It then reviews how international trade and trade policy can support climate change adaptation strategies. The chapter concludes by examining the role of international cooperation, and in particular that of the WTO, in helping with climate change adaptation.

2. Why does climate change adaptation matter?

Climate change is not only an environmental problem, but also a systemic risk affecting people and the economy. Its effects on international trade can already be seen. Global warming reduces capital and labour productivity, and EWEs can disrupt transport infrastructure. Without adaptation and mitigation, these effects will continue to increase in the future, impacting trade costs and factors of comparative advantage.

(a) Climate change has severe effects on people and the economy

Climate change affects almost all aspects of human life. Between 2030 and 2050, climate change could cause 250,000 additional deaths per annum as a result of malnutrition, malaria, diarrhoea and heat stress alone (WHO, 2018). It may also have severe social and political implications, including domestic or communal violence, resulting, for example, from forced migrations from one region to another due to rising sea levels or drought, especially in countries with weak property rights (see Box B.1) (Burke, Hsiang and Miguel, 2014).

Climate change poses a severe threat to the global economy. Projections by the OECD suggest that a warming of between 1.6°C and 3.6°C above pre-industrial levels by 2060 could cause global annual GDP losses of between 1 and 3.3 per cent relative to a hypothetical reference scenario in which climate change damages do not occur (Dellink, Lanzi and

Box B.1: Climate change impacts on security in the Sahel

The Sahel is a semi-arid transition zone dividing the Sahara Desert to the North and tropical Africa to the South. Agriculture and cattle-herding remain the main economic pillar of the region. Food, water and energy availability, and ultimately security in the region, are at risk as a consequence of climate change (Rose, 2015).

Successive years of poor rainfall and frequent droughts have pushed pastoralist populations to migrate to more humid regions for longer periods of time (Brottem, 2016; Nyong, 2007). Migrations of herders to land occupied by sedentary farmers can lead to conflicts over land use and other resources (Nyong, 2007). Confrontations tend to occur periodically, particularly around water resources and fodder, and in areas with a lower level of agricultural productivity (Nyong, Fiki and McLeman, 2006).

Climate change is expected to exacerbate these issues by extending the annual dry season and, thus, the period during which the same land is used both for maturing crops and for roaming cattle, further increasing the risk of conflict. A 1°C rise in temperature has been found to increase the probability of conflict between farmers and herders by 54 per cent in the Sahel, compared to a 17 per cent increase in the probability of conflict in places where farmers and herders do not have to compete over access to limited land and water resources (Eberle, Rohner and Thoening, 2020). Such conflicts limit the ability of local communities to adapt to climate change, potentially creating a "climate-conflict trap" (Granguillhome et al., 2021).

Climate change-induced instability can also affect trade, including small scale cross-border trade. Conflicts destroy food supply and the production capacity of farms, and ultimately deter investment across the agricultural value chain (Kimenyi et al., 2014). Such instability in agricultural markets often translates into increased food prices, which affect the poorest households disproportionately. In this context, risk management strategies, including climate-resistant agricultural investment, crop diversification, insurance and safety nets, can help farmers adapt to climate change, while mitigating conflict risks.

Chateau, 2019). Although the range of projected GDP losses at the global level is broadly consistent in the literature,[1] such projections are necessarily speculative, due to the uncertainty of how climate change will progress and how economies will adapt. Projections also vary based on modelling and calibration approaches. There is also considerable heterogeneity in projections across regions. For example, GDP losses are expected to be much higher in regions highly exposed and vulnerable to weather-related hazards and with lower resilience to losses, such as the Middle East and North Africa, South and Southeast Asia, and Sub-Saharan Africa (Dellink, Hwang, et al., 2017). The most vulnerable populations, in particular those in developing countries and in small-island developing states (SIDS), are likely to bear a disproportionate share of the burden due to their higher exposure and lesser capacity to adapt to climate change.

(b) The impacts of climate change on trade are heterogenous across regions and sectors

Climate change, both in terms of gradual changes – such as temperature and sea level rise or changes in precipitation regimes – and in terms of the increasing frequency and intensity of EWEs, can have severe effects on trade. In the short term, the damage caused by EWEs can reduce productivity, increase trade costs and disrupt supply chains. In the long term, climate change can affect trade through its impact on factor endowments and comparative advantage. As discussed by Danae Kyriakopoulou in her opinion piece, the risk of inaction in climate change has profound implications on international trade.

(i) Climate change will alter patterns of comparative advantage, leaving some economies at a disadvantage

The availability and productivity of arable land, water, capital and labour are being affected by climate change, and the effect differs across regions. Higher temperatures and the increased frequency and intensity of droughts, floods and rain are degrading land quality in some regions and reducing crop yields (Sleeter et al., 2018). Rising temperatures and sea levels and melting glaciers are altering the hydrological cycle (i.e., the circulation of water between the ground and the atmosphere), leading to flooding and loss of land. Meanwhile, groundwater reservoirs are declining in regions with low water runoff. Overall, the distribution of water is expected to become even more uneven (Lall et al., 2018; World Bank, 2016).

Human exposure to increased temperatures reduces labour productivity by diminishing capacity for physical work and mental tasks and by increasing the risks of accidents and of heat exhaustion or stroke (Kjellstrom, Holmer and Lemke, 2009; Somanathan et al., 2021; UNDP, 2016). Empirical evidence suggests that for every 1°C temperature rise above 25°C, labour productivity falls by 2 per cent (Seppanen, Fisk and Faulkner, 2003). One measure of adaptation to counteract the impact of increasing temperatures on human capital productivity is an increased use of energy-efficient air conditioning in workplaces. But this would entail higher costs both in terms of acquiring air conditioning systems and of energy costs to run them, with a consequent loss of competitiveness for firms.[2]

Rising temperatures may also reduce capital productivity. For example, higher temperatures can cause heavy machinery to overheat more often, requiring more frequent and longer cool-down periods. Outdoor infrastructure may depreciate faster, which would reduce its lifespan (IPCC, 2014a). Overall, the impact of climate change on trade through changes in productivity channels depends on the geographical localization of countries and on what they produce, and this is likely to alter comparative advantages.

Changes in the patterns of demand, beyond changes in production specialization, will also matter to shape the impact of climate change on trade. In this respect, a country's reliance on trade with climate-vulnerable countries and communities, and its levels of global integration more broadly, will also matter, as they determine the exposure of that country to climate impacts from abroad. In this regard, trade can be a channel through which climate change damages can spread across countries (Schenker, 2013; Schenker and Stephan, 2014; WTO, 2021c).

The impact of climate change is expected to be stronger on countries in lower-latitude regions, many of which are developing economies whose comparative advantage stems from climatic or geophysical factors. Based on projections, an increase in global temperatures of 2.5°C by 2060 could decrease export volumes by as much as 5 to 6 per cent for countries in South Asia and Sub-Saharan Africa, 3 to 4 per cent for the Middle East, North Africa, and South-East Asia, and 2 per cent in Latin America, compared with less than 1 per cent in Europe and North America (Dellink, Hwang, et al., 2017). However, the complex set of linkages that exist within and across economies makes it particularly difficult to predict to what extent an economy will gain or lose competitiveness in a given sector in response to a climate-related shock. At

OPINION PIECE

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Climate inaction: implications for international trade

The pandemic-related disruption of supply chains and the political imperative to reorient partnerships following the outbreak of the Ukraine war have exposed the vulnerability of global trade to risks originating outside of the economy. Climate-related risks are increasing in frequency, intensity and geographic spread. Unlike the pandemic and the war, we can anticipate and manage them, albeit against a diminishing window of opportunity.

Policies aimed at mitigating climate change and adapting to its effects are occasionally dismissed as "too costly". In a post-pandemic environment of stressed finances for governments, businesses and households, an "expensive and unaffordable green transition" makes an easy target. Such narratives are dangerously short-sighted: delaying climate action bears the much greater opportunity cost of inaction.

Continuing with "business as usual" is becoming visibly more costly, not only in terms of the natural environment, but also in the global economic, financial and trade system. The trade implications of more frequent and intense extreme weather events (EWEs), of gradual climatic changes and of policy adjustments, such as climate-driven taxes and regulation, are already manifesting through multiple channels.

EWEs, such as hurricanes and floods, are directly damaging critical infrastructure, including roads, bridges, ports, railway tracks and airports. More frequent disruptions hurt both goods and services trade, such as tourism. Food and agriculture trade is particularly exposed to heatwaves and droughts that can affect crop yields and tempt countries to restrict exports. In May 2022, India – a major wheat producer – banned exports on the grounds of national food security amid a heatwave.

But there doesn't have to be a natural disaster for there to be an economic one: gradual changes in temperature that expose capital equipment and labour to heat stress, or increase cooling costs in storage facilities, can also hurt productivity and disrupt global value chains (GVCs). Economies whose comparative advantage is tied to climatic processes are highly exposed: degraded land and water stress will impact agriculture, while ecosystem damage and shifts in weather conditions will affect tourism in sea or ski resorts. Such processes can shift patterns of comparative advantage and structurally change global trade.

While some risks can be partly managed by diversifying supply chains and building buffer stocks, these strategies have limits and would involve compromising on the fundamental building blocks of the modern trade system: specialization according to comparative advantage, economies of scale, and optimizing of global value chains (GVCs).

And it is not just the physical climatic disruptions that threaten global trade, but also the so-called "transition risks" inherent in the changing strategies, policies or investments needed in the green transition. The uneven pace of climate action across countries has led some governments to consider border carbon adjustment measures involving charges on imports and/or export rebates, to level the playing field among firms subject to different climate-related regulations and taxes. Such measures, while addressing carbon leakage, can unravel trade patterns by incentivizing re-shoring or short-circuiting supply chains.

The risks of inaction highlight the urgent need to redesign our economies in a way that works for the planet and its people, now and for the future. But this is not only a negative story about risks. It is a growth, investment and trade story of change towards a future that is enormously attractive, with more productive economies, healthier societies and more fruitful ecosystems.

the same time, understanding the mechanism through which this happens provides insights as to which economies are most at risk.

Whether an economy gains or loses comparative advantage in a given sector depends broadly on its initial productivity, and how its productivity and prices respond to a climatic change relative to other competing economies. It also depends on the linkages between different economic sectors, both within and across regions. For example, an analysis of the relative ability of a country to produce food products vis-à-vis its trading partners, commonly known as revealed comparative advantage (RCA),[3] shows that, in the case of an increase in global temperatures of 2.5°C by 2060, RCA could increase for some economies. However, it could also decrease for other economies faced with a similar agricultural yield shock if the latter depend more on domestic agricultural output for exports of manufactured food products. These impacts could be further amplified by the negative effect of climate change on income and, thus, on final demand (Dellink, Hwang, et al., 2017).

Geography-related temperature levels are a driving force behind the disproportionate impacts of climate change on developing economies and least developed countries (LDCs). Since the current temperatures in many developing economies and LDCs are already higher than in developed ones, the marginal negative impact of increasing temperatures on the former is also higher (while some developed countries in colder northern regions may even experience productivity gains in some sectors). A given temperature increase is likely to cause productivity to decline more in developing economies and LDCs, as their productivity in non-agriculture sectors is often lower than in developed economies, meaning these economies would lose not only their existing comparative advantages, but would also find it particularly challenging to develop comparative advantage in other sectors (Conte et al., 2021; Schenker, 2013). Since productivity losses and gains tend to be geographically concentrated, and neighbouring economies tend to trade more with each other than with more distant economies, losses and gains in trade are likely to be shaped by geographical patterns of productivity changes, which could increase international inequalities (Dingel, Meng and Hsiang, 2019).

These impacts can be amplified by economic factors such as commodity dependence or a lack of diversification (UNCTAD, 2019). Countries that have less diversified exports tend to be generally more vulnerable to climate change (see Figure B.1). For instance, Sub-Saharan Africa, in which most countries' exports are dominated by the agriculture, energy or mineral sectors, is one of the regions most exposed to climate change.

(ii) Climate change is likely to increase trade costs unevenly across regions

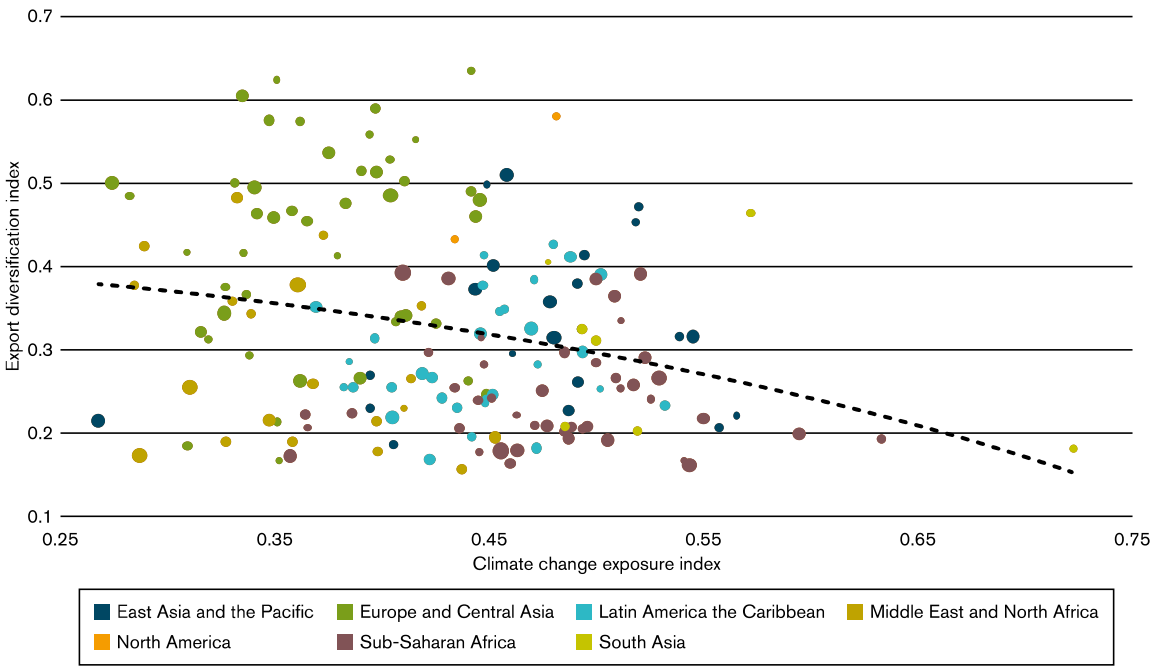
Transport infrastructure is dangerously at risk of damage both from gradual climatic changes and from EWEs (Koks et al., 2019; WTO, 2019). Increasing temperatures can cause roads, bridges, runways and railway tracks to depreciate faster. Transport infrastructure and inland waterways can become partially or completely inoperable due to EWEs and sea level rises in coastal regions (EEA, 2017; IPCC, 2014b). Climate change will increase infrastructure maintenance and repair costs, indirectly adding to trade costs. The unpredictability of damages related to EWEs is a source of uncertainties and high operational risks that can increase disruptions and delays, and in turn create additional costs, such as requirements for freight insurance (Barrot and Sauvagnat, 2016; Boehm, Flaaen and Pandalai-Nayar, 2019; WTO, 2021c). In particular, climate change can affect strategically important junctures on transport routes through which exceptional volumes of trade pass in the global trade network,[4] and this can create vulnerabilities for the trade system (Bailey and Wellesley, 2017).

While all modes of transport are likely to be negatively affected by EWEs, maritime transport – which accounts for 80 per cent of world trade by volume – is particularly vulnerable and exposed to climate change. In a worst-case "high emission" scenario where GHG emissions continue to rise unchecked and global temperatures rise by around 4°C by 2100, the number of ports at extremely high, very high or high risk from multiple climate hazards could almost double, from 385 to 691 key ports globally (out of 2,013 examined) (Izaguirre et al., 2021).

Greater heat stress and increased coastal flooding and overtopping due to sea level rise, can have a strong impact on waterways and port capacity, and negatively impact trade by exacerbating bottlenecks, capacity constraints, congestion and delays, thereby increasing trade costs. For example, in the three months following Hurricane Katrina in 2005, Gulfport and the Port of New Orleans saw a direct reduction of between 71 per cent and 86 per cent of both exports and imports due to the destruction of their port facilities, although there was no overall impact on aggregate US trade because other ports took up the slack (Friedt, 2021).

However, while developed and larger economies tend to have a more diversified and resilient transport infrastructure, small or landlocked countries, whose

Figure B.1: Economies with less diversified exports tend to be more exposed to climate change



Source: Authors' calculations, based on ND-GAIN Climate Vulnerability Index and IMF Export Diversification Index for 2014.

Note: The climate change exposure index measures how much societies and economies will be stressed by the physical impacts of climate change. The size of the dots represents each country's vulnerability to climate change. The climate change vulnerability index considers countries' exposure to climate change, their sensitivity to related impacts, and their adaptive capacity.[5] The export diversification index ranges from zero (no diversification) to one (complete diversification).

trade flows through a limited number of ports and trade routes, are especially vulnerable in this regard (Bahagia, Sandee and Meeuws, 2013; Izaguirre et al., 2021). For instance, the Paraná River, which transports 90 per cent of Paraguay's international trade of agricultural goods, 85 per cent of Argentina's and 50 per cent of Bolivia's, now frequently reaches very low levels due to recurrent severe droughts. Shallow water forces cargo ships to operate at half or lower capacity in order to navigate and transport agricultural commodities and other goods, causing significant congestion and delays around the waterways and ports (Batista and Gilbert, 2021). Other rivers, including the Danube and the Rhine, are experiencing similar situations with low water levels, making it impossible for many vessels to operate.

Although climate impact on transportation is expected to be largely negative, climate change could positively affect some regional transportation networks (WTO, 2019). For instance, a reduction in sea-ice may lead to the availability of new and shorter shipping routes. In the Arctic, the ice cap loss caused by warmer temperatures could open up the possibility of a northwest passage during portions of the year, which would reduce maritime shipping times and distances between parts of Asia and Europe by up to 40 per cent (Rojas-Romagosa, Bekkers and Francois, 2015). However, the benefits of these new routes remain uncertain because of factors such as underdeveloped communication and transportation infrastructure in the region and reduced speeds and potential damage to ships due to hazardous sailing conditions. Increased shipping activity in the region could also have adverse consequences for ecosystems.

(iii) Trade in agriculture and tourism are particularly vulnerable to climate change

If temperatures continue to rise in the absence of robust adaptation measures, climate change will have profound effects on trade in agriculture. Existing models emphasize two potential effects.

First, the effects of climate change on trade in agriculture are heterogenous across regions. For countries that would experience a loss in agricultural productivity, or negative yield shock, all else being equal, the impact on trade could depend on the magnitude of the shock relative to that experienced in other countries. Sub-Saharan Africa and South

Asia are the regions often projected as the most vulnerable to climate change effects. Economies in these regions are reliant on exports of agriculture, but are also major importers of agricultural commodities for domestic consumption. They are expected to suffer larger negative yield shocks compared to other regions (IPCC, 2022a; Jägermeyr et al., 2021). This means that as their production suffers, their exports could decline, forcing them to import more to meet domestic demand (Dellink, Chateau, et al., 2017; Gouel and Laborde, 2021; Hertel, 2018).

Second, under more severe climate damages, only a few economies in colder regions would experience productivity gains in agriculture. In such a scenario, international markets for agriculture could become concentrated, with few dominant exporters (FAO, 2018a).

Climate change is also likely to increase agricultural trade volatility. By increasing the risk of simultaneous failure of crop systems in multiple grain- or food-producing economies, climate change increases concerns about food security (Adams et al., 2021). For instance, the possibility of simultaneous production losses greater than 10 per cent happening in the four largest maize-exporting economies in any given year could increase from 0 per cent to 7 per cent as a result of global warming of 2°C, and to 86 per cent as a result of global warming of 4°C (Tigchelaar et al., 2018). Such an occurrence would cause widespread shortages and a surge in world prices of these commodities. This is especially worrisome in view of the evidence that governments often react to rising food prices by imposing export restrictions, which would exacerbate these effects (Giordani, Rocha and Ruta, 2012). Such higher global prices can make it even more difficult for net food-importing developing countries to purchase food (Welton, 2011).

Since climate is an important factor in the choice of tourist destinations, tourism is also expected to be affected by moving towards higher altitudes and latitudes as climactic zones shift northward (Biango, Hamilton and Tol, 2007; Hamilton, Maddison and Tol, 2005). Due to increasing temperatures, traditional summer destinations may lose their appeal in summer months but become more suitable in other seasons. More favourable climates in northern regions may also divert tourist flows, further increasing competition between tourist destinations. For instance, as the Atlantic and Northern European coasts become warmer, they could gain tourists at the expense of Mediterranean beach destinations which are becoming too hot (EEA, 2017). Similarly, warmer winters are a risk to winter and mountain destinations (WTO, 2019).

Low-lying island nations whose economies are highly dependent on tourism are particularly vulnerable to climate change. Sea level rise and EWEs could make these destinations permanently unattractive to visitors by causing damages to tourism infrastructure and sites. For example, in Pacific island countries, such as the Marshall Islands, Kiribati and Tuvalu, over 95 per cent of the built infrastructure is located in coastal regions vulnerable to risks caused by sea level rise and EWEs (Kumar and Taylor, 2015; Wolf et al., 2021).

(iv) Manufacturing sectors are exposed to climate-induced global value chain disruptions

Manufacturing sectors tend to be less vulnerable to climate change, partially because of a lower sensitivity and higher adaptive capacity to climatic variability. However, industrial sectors dependent on climate-sensitive inputs (such as food processing), labour-intensive sectors and sectors highly integrated into global value chains (GVCs) are likely to be affected. For example, export growth of agriculture products (e.g., cereals, dairy and eggs, leather, animal feed) and light manufacturing (e.g., clothes, shoes, furniture, consumer electronics and home appliances) from low-income economies to the United States have been found to decrease by between 2 and 5.7 per cent in response to a 1°C temperature increase (Jones and Olken, 2010). While the impact of temperature increase on agriculture-related exports is generally a result of climate-induced damage to agricultural productivity, the impact on light manufacturing trade is likely a result of reduced labour productivity at higher temperatures.[5]

Climate change will also affect the manufacturing sectors through disruptions in supply chains. For instance, the 2022 floods in Pakistan destroyed approximately 40 per cent of the country's cotton crop, severely impacting the textile industry – Pakistan's largest export – which relies heavily on domestic cotton production for raw materials. Adverse effects of local weather events can, under certain conditions, propagate along supply chains and across countries (WTO, 2021c). For example, in 2011, flooding in Thailand disrupted the global electronic and automotive industries, causing an 80 per cent decline in year-on-year global production in November 2011 (McKinsey Global Institute, 2020) and an estimated 2.5 per cent decline in global industrial production growth (Kasman, Lupton and Hensley, 2011). Japanese manufacturers, heavily dependent on intermediate inputs from Thailand, produced at least 423,000 fewer cars in 2011 because of the floods (Haraguchi and Lall, 2015).

Among GVC-intensive sectors, the potential impacts of climate-induced GVC disruptions are more severe, with effects lasting up to many months, for relation-specific supply chains than for other types of supply chains[6] because each supplier manufactures a unique and highly differentiated input that is difficult to replace in the short term. For instance, the supply chain of advanced semiconductors is relation-specific, with many components manufactured in the Asia-Pacific region. The probability of disruptive hurricanes in these manufacturing hubs is expected to increase two to three times by 2040. Any disruption could have cascading effects. For a five-month supply disruption, downstream industries could lose between 5 and 30 per cent of their revenue, depending on their level of preparation (McKinsey Global Institute, 2020).

Climate-induced supply chain risks can be further exacerbated by firms' limited capabilities to assess emerging risks from climate change and adopt risk management strategies. Firms, including in developed economies, do not always prioritize climate change as an operational risk (Tenggren et al., 2020). In addition, the complex structure of many supply chains makes comprehensive climate-related risk assessment and management particularly challenging.

3. International trade and trade policy can support climate change adaptation strategies

Even if the Paris Agreement's long-term goal of limiting the rise in global temperature to well below 2°C – and preferably to below 1.5°C – is met, past GHG emissions have already caused, and continue to cause, global temperatures and sea levels to rise, and more frequent and intense EWEs, making climate change adaptation an imperative. Climate change adaptation strategies encompass actions that reduce the negative impact of climate change, while taking advantage of potential new opportunities that climate change might create. Reducing the consequences of climate change can be achieved by identifying, preventing and reducing actual or expected climate risks, exposure and vulnerabilities, and by being prepared to cope with the effects of climate change and to minimize unavoidable losses and damages from climate change by adjusting existing systems (IPCC, 2007a, 2022b).

In practice, adjusting existing systems means adapting the behaviours of people, firms and governments, and modifying infrastructure to deal with the current and future changing climate.[7] Common examples of adaptation strategies include early warning and information-sharing systems, flood risk control, insurance, the introduction of new crop varieties, livelihood diversification, soil and water conservation, and sustainable forest management.

Although climate change adaptation and mitigation are often considered separately, they can be considered as two sides of the same coin. For instance, well-managed afforestation and reforestation can increase carbon storage capacity, while at the same time reducing exposure and vulnerability to weather-related risks, such as landslides.[8] Given the urgency to scale-up climate change actions, synergies between climate change adaptation and mitigation can help achieve climate resilience more effectively.

While international trade affects climate change (see Chapter E), it can also play an important role in climate risk prevention, reduction and preparedness, and in climate disaster recovery and rehabilitation, even though the consequences of climate change will remain disruptive and costly. Trade can help strengthen food security, and facilitate access to essential goods and services after EWEs hit. In that context, trade policies can also be integrated into climate change adaptation strategies. However, other coordinated policies and actions are important to mitigate the costly adjustment to changes caused by climate change.

(a) Trade can support climate change adaptation actions through economic growth

Adapting to climate change requires important investment in infrastructure to increase resilience and reduce vulnerability at the community, local, regional, sectoral and national level. Investing in improved climate resilience offers a significant cost-benefit ratio, ranging from 2:1 to 10:1, and in some cases even higher, since it can avoid far worse damage later on (GCA, 2019). Yet, efforts to adapt to the impacts of climate change are still lagging.

Although developing countries are considered to be those most vulnerable to a rapidly changing climate, progress in climate change adaptation strategies tends to be more frequently and rapidly achieved in advanced economies. For many developing countries, lack of finance remains an obstacle to invest in climate change adaptation.

In this context, international trade, as a driving force for sustained economic prosperity,[9] can indirectly help economies steer some of their financial resources towards climate change adaptation

strategies. Developing economies that opened up to trade have, on average, enjoyed a 1 to 1.5 per cent higher rate of growth, culminating in 10 to 20 per cent higher growth after a decade (Irwin, 2019). Higher economic growth can, in turn, provide financial support and material preparation for essential climate change adaptation, such as investment in climate-resilient infrastructure.

(b) Trade can enhance economic resilience to climate change shocks

International trade can help countries prepare for, cope with and recover from climate-related shocks more effectively. Risk prevention and reduction can be achieved by explicitly integrating risk management into decision-making, including financial appraisal of risks and early warning systems. Climate risk screening, resilience performance rating or sustainability standard can be used to identify climate risks and evaluate and reward resilience attributes of public and private investments (World Bank, 2021). In parallel, preparedness encompasses strategies and actions effectively designed to anticipate, respond to and enable recovery from the impacts of likely, imminent or current climate-related shocks. Some of these strategies can include developing disaster responses and contingency plans, identifying priorities and reviewing insurance coverage. In that context, trade in services, including weather forecasting, insurance, telecommunications, transportation, logistics and health services, can play a key role in the preparation of firms, citizens and governments for climate-related shocks (WTO, 2021c).

When an extreme weather-related shock hits, international trade can, under certain conditions, spread its effects across countries, but at the same time it can contribute to making economies more resilient by ensuring the timely availability of essential goods and services. Imports provide a vital channel for increasing the availability of goods and services that may be in short supply in a disaster-struck country. Such goods and services include food, medical supplies, emergency equipment and expertise to aid relief and recovery efforts. Efficient customs clearance, transit procedures and public procurement processes are essential for trade to play this role effectively.

Allowing trade to resume faster in the aftermath of climate-induced shocks and disruptions can be an important economic stimulus that supports economic recovery (WTO, 2021c). For instance, facilitating imports of construction materials can contribute to sustaining infrastructure and post-disaster reconstruction.

(c) Trade can contribute to improving food security arising from changing comparative advantages

Open trade can help countries to adapt to changes in comparative advantages caused by climate change, and to benefit from potential new opportunities, although systemic cascading risks from climate change will remain. Extreme heat has been found to reduce productivity in manufacturing and services less than in agriculture, which could ultimately change countries' comparative advantages (Conte et al., 2021; Nath, 2022), as warmer countries could be forced to adapt to climate change by shifting domestic production toward manufacturing and services, while increasing food imports from relatively more temperate regions. Some developing countries have already started to shift away from agriculture and manufacturing towards services. High trade costs could, however, prevent such trade-related adjustments (Conte et al., 2021), as countries more exposed to the direct impacts of climate change tend to bear higher trade costs (see Figure B.2).

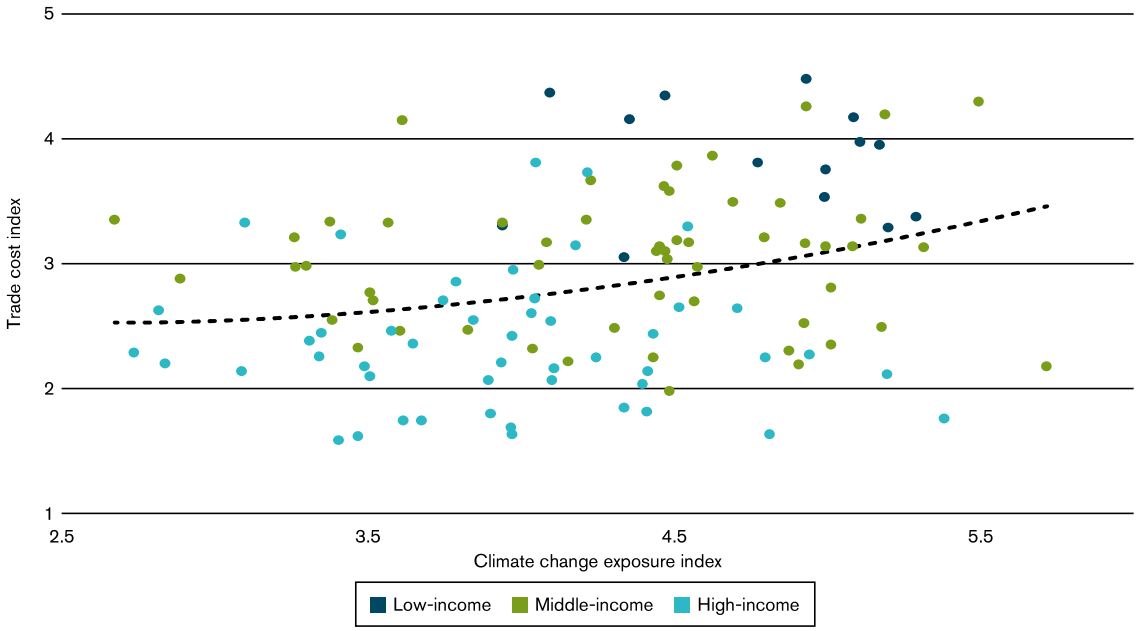
Policies aimed at reducing trade costs can support part of the adjustment caused by changes in comparative advantages due to climate change, while minimizing changes in patterns of consumption through imports, and thus potentially minimizing welfare losses. Simulations suggest that reducing trade costs in lower-income economies would, all things being equal, reduce their welfare losses caused by climate change by up to 68 per cent (Nath, 2022). Promoting trade could also reduce the incidence of climate-induced migrations, as trade and international labour mobility tend to be substitutes rather than complements (Conte et al., 2021).[10]

Trade and well-functioning markets can contribute to improving food security across multiple dimensions, including food availability, nutrition, access and utilization (FAO, 1996; 2018b, 2018c). Trade can directly contribute to improving the availability of food by easing its movement between surplus and deficit economies. However, low levels of purchasing power among vulnerable population groups are likely to be further exacerbated by climate change and continue to compromise people's access to food.

(d) Trade can facilitate the acquisition and deployment of technologies that can contribute to climate change adaptation

Adapting to climate change can require adopting specific technologies to adjust existing systems

Figure B.2: Countries more exposed to climate change tend to face higher trade costs



Source: Authors' calculations, based on ND-GAIN Climate Vulnerability Index and WTO Trade Cost Index for 2017.

Note: The climate change exposure index measures how much societies and economies will be stressed by the physical impacts of climate change. The trade cost index measures the cost of trading internationally relative to trading domestically.

to deal with current and future consequences of climate change. For instance, technologies that can offset negative agricultural yield shocks include crop varieties with higher heat or salinity tolerance, early warning system for biopesticide use, fertilizers and machinery, as well as irrigation, water conservation and storage systems (Kuhl, 2020). Trade and trade policies can increase access to these technologies, especially in countries most vulnerable to climate shocks. The removal of unnecessary barriers to trade could improve farmers' access to new technologies and reduce their exposure to climate-induced shocks. For example, barriers to trade in seeds, such as inconsistent or unnecessarily strict control procedures, can cause delays that reduce seed yield and productivity (Brenton and Chemutai, 2021).

Another potential mechanism for technology transfer is participation in GVCs (Sampson, 2022). GVC integration can facilitate access to foreign non-codified knowledge and technology transfers for firms to optimize production processes, help boost domestic innovation through international knowledge spillovers, and enhance absorptive capacity for new technologies (Branstetter and Maskus, 2022; Piermartini and Rubínová, 2022). For instance, some large retailers are collaborating with their food suppliers on resilient strategies to better manage growing conditions, improve yields and reduce the need for fertilizers.[11]

(e) Trade policies can be integrated into climate change adaptation strategies

By their very nature, climate change adaptation policies are varied. Although there is no comprehensive typology of climate change policies, they can be broadly classified into three types: structural, social and institutional (IPCC, 2014a). Structural and physical measures include, among other things, the application of technologies and the use of ecosystems and their services to serve adaptation needs (e.g., reforestation). Social measures target the specific vulnerabilities of disadvantaged groups and propose solutions (e.g., increasing investment in education and improving labour mobility). Institutional measures relate to specific economic and regulatory policies, which foster investments in adaptation to climate change. In that context, trade policy can also support climate change adaptation actions.

A review of all explicitly environment-related trade measures notified by members to the WTO between 2009 and 2020 shows that, while a large majority of notified climate change-related trade measures relate to mitigation, only 3 per cent of all notified climate-related trade measures (161 out of 4,629) can be explicitly linked to climate change adaption.[12] Trade-related climate change adaptation measures predominantly take the form of support measures, with more than three-quarters of notified measures

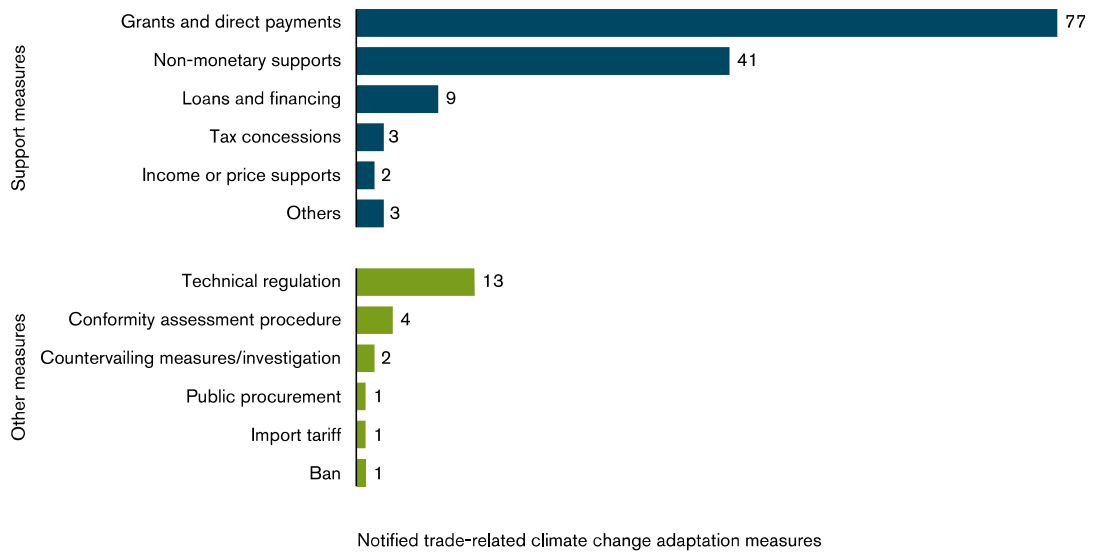
covering grants and direct payments, non-monetary support and/or loans and financing. Technical regulations and conformity assessment measures are other common types of adaptation measures (see Figure B.3). More than half of the notified climate change adaptation measures cover the agricultural sector, illustrating its vulnerability to climate change and its need to adapt.

While international trade can be an important component of climate change adaptation strategies, trade policies alone cannot reduce the negative impact of climate change and help take advantage of potential new opportunities. Other policies and actions are essential to adjust to current or expected effects of climate change. Macro-fiscal policy planning is important to address climate adaptation, such as identifying contingent liabilities from natural disasters and environmental shocks, developing a financial strategy to manage contingent liabilities and evaluating climate and disaster risks of the financial system (Hallegatte, Rentschler and Rozenberg, 2020).

In that context, ensuring mutual supportiveness between economic policies, including trade policies, and climate change adaptation policies is essential to strengthen the role of trade while addressing broader challenges of adaptation (see Box B.2). For instance, the role of international trade in improving food security can be strengthened by improving the functioning of markets for food and agriculture, including by reducing distortions,[13] improving competition, and ensuring that the true costs of food and farmed goods are reflected when traded internationally. The resilience of vulnerable economic actors can be enhanced by redressing the under-provision of public goods, for example, by improving the availability of advisory services or investing in research into new crop varieties and livestock breeds that are more resistant to climate impacts (FAO, UNDP and UNEP, 2021; Gadhok et al., 2020).

Policies that support social inclusion, such as access to basic services, digital technologies, financial inclusion, and social protection are essential to attenuate some of the consequences of climate change. While the disruptions caused by climate change are unlikely to be fully avoided, well-functioning labour markets are important to help economies both maintain existing comparative advantages and build comparative advantages in new sectors. For example, while trade can provide access to new technologies such as high-yield climate-

Figure B.3: Financial support and technical regulations are the most common trade-related climate change adaptation measures



Source: Authors' calculations, based on the WTO Environmental Database.

Note: The figure reports climate change adaptation measures notified to the WTO between 2009 and 2020 by types of policies. One notified measure can cover more than one type of policy.

Box B.2: Making the "blue economy" last in Mauritius by leveraging trade and sustainability

Mauritius is one of the most vulnerable countries to climate change and EWEs. Over the coming 35 years, 7 per cent of its GDP could be lost to cyclones alone (Beejadhur et al., 2017). What the island will produce and trade in the future could depend on the decisions it takes today in terms of the adaptation, resilience, restoration and sustainable development of its natural "blue", or ocean, capital and its pathways for a just transition to a low-carbon economy.

To build back better from the COVID-19 recession, the Mauritian Government's "Vision 2030" aims to promote the blue economy as one of its main pillars of development (WTO, 2021e). The goal is to increase the contribution of the blue economy, which constituted nearly 12 per cent of the country's GDP before the pandemic, to 25 per cent by 2025, by strengthening traditional economic ocean activities such as tourism, fisheries and seaport activities, and by developing emerging industries such as aquaculture, maritime services, ship-building and repairs, marine biotechnology, and mineral exploration. A set of incentives under new premium investment certificates for aquaculture, industrial fishing and seafood processing have been launched to promote innovative and sustainable solutions, but challenges remain.

The fact that Mauritius is an island increases the pressure on the sustainability of its ecosystem. Recent shocks with concomitant impacts on health or food and energy security have exposed the country's vulnerabilities. Building a sustainable blue economy requires a robust plan that takes into account several conflicting objectives within and across sectors. This process has started in sectors such as port infrastructure, shipping, tourism, seafood, aquaculture and energy. For instance, for economic diversification and to better meet its energy needs, Mauritius recently evaluated its offshore hydrocarbon potential. Economic gains from hydrocarbon exploitation for Mauritius could outweigh the costs of less effective climate actions (Moolna, 2021). However, climate policies to deal with, for example, ocean acidification or sea-level rise are not an either/or option for Mauritius.

Mauritius can also, through international trade, better leverage the benefits of the ocean economy. Strategically located at the crossroads of Asian and African sea routes, Mauritius' seaport has the potential to become a hub of global trade flows, including container transhipment. However, it is urgent that trade and environmental policies, which have often evolved independently, be integrated to support the blue economy (de Melo, 2020).

Steps are already being taken to align the blue economy with the Sustainable Development Goals (SDGs). A new Ministry of Blue Economy, Marine Resources, Fisheries and Shipping was created in 2019 to improve coordination and management of ocean-related matters. Mauritius is a party to a number of fisheries management arrangements and multilateral environment agreements. The island has adopted legislation on coastal zone protection as part of its Integrated Coastal Zone Management framework. The Environment Protection Act and Climate Change Act also provide for the protection of the coastal environment. More capacity-building and technical assistance are needed, and economic, including trade, and climate policies need to support one another in order to address the short- and long-term costs and opportunities accompanying the expansion of the blue economy.

resistant crops, the lack of technical skills of some farmers can slow down their uptake and ultimately negatively impact agricultural productivity further exacerbating the impacts of climate change. Labour mobility obstacles or frictions can also slow down or prevent shifts to new comparative advantages. Individuals working in sectors that are contracting due to climate change may lose their jobs, and may only be able to find new job opportunities in expanding sectors if they possess the relevant skills and have the financial resources to relocate to a different region if necessary. Labour market adjustment policies, including skills development programmes, are important to reduce labour mobility frictions (WTO, 2017).

Certain vulnerable groups, such as micro, small and medium-sized enterprises (MSMEs) and women in certain socio-economic groups, face even greater difficulties in adjusting due to social, economic and cultural reasons (IPCC, 2014a; Nellemann, Verma and Hislop, 2011) (see Box B.3). For example, in low- and lower-middle-income countries, 52 per cent of the female workforce is employed in agriculture (World Bank and WTO, 2020), and as climate change puts a strain on agricultural sectors, social norms or

household responsibilities may prevent these women from seeking employment in other sectors – especially if this means having to move to a different area – and this can negatively affect both households and economies at large. In addition, the consequences of climate change may cause some individuals to lose their means of livelihood permanently. However, social policies, such as education and compensation policies, like lump sum payments, can support the groups most exposed to the economic consequences of climate change.

4. International cooperation is essential to assist countries in adapting to climate change

Although climate change adaptation initiatives are often locally led, international cooperation in climate change adaptation is key to leverage synergies and help limit and manage the risk of losses and damages from climate change. This is because unilateral national policies aimed at tackling the effect of climate change can produce negative spillovers on other countries. It is important to coordinate responses to climate shocks and to assist countries, particularly the developing economies that are the most affected, in their adaptation efforts. Although climate change will remain highly disruptive, cooperation on international trade is essential to enhance the resilience of global trade to climate-related shocks and crises and to improve economies' capacity to adapt to climate change, while minimizing negative cross-country spillovers. International trade cooperation toward adaptation to climate change can, however, be challenging in situations where climate change issues intersect with national security priorities (see Box B.4).

(a) International cooperation on climate change adaptation is cross-cutting

The need for the widest possible international cooperation on climate change has been recognized in the UN 2030 Sustainable Development Agenda, in keeping with which the international community has committed to take urgent action to combat climate change and its impacts under Sustainable Development Goal 13 ("Climate Action"). Climate change adaptation is addressed through several extensive international cooperation initiatives. Parties to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement

Box B.3: Climate change impacts on MSMEs

MSMEs are the most vulnerable of all types of firms to EWEs, and are set increasingly to experience trade- and climate-related disruptions (Skouloudis et al., 2020). For example, trade in tourism, a sector in which many MSMEs are active, will continue to be challenged as EWEs interrupt travel and impact destinations (Badoc-Gonzales, Mandigma and Tan, 2022). Yet, when it comes to adaptation, only 38 per cent of small businesses have made investments to reduce climate-related risks, compared to 60 per cent of large firms (ITC, 2021). MSMEs tend to be "reactive" rather than "proactive" when it comes to adaptation, and respond to regulation or market requirements (Burch et al., 2016). Some reasons for this lag are that their access to information, financial resources, expertise and time is more limited (Burch et al., 2016; ITC, 2021; WTO, 2022a). MSMEs led by women and young people tend to struggle even more with adaptation, and may have less capacity and fewer skills to take advantage of new opportunities (ITC, 2021).

On the flip side, efforts to adapt to climate change can create opportunities and benefits for those MSMEs that have re-focused on environmental themes, such as "ecopreneurs" who develop new products and services. In addition, MSMEs that succeed in increasing production efficiency and lowering business costs may thereby discover new opportunities. According to a recent survey, more than half of African firms reported that improving their companies' environmental performance had led to improvements in the output and quality of their products, access to new markets, reduced input costs and a better ability to access green finance (ITC, 2021).

Even though MSMEs are slow to initiate change, and international trade can spread climate-related business disruptions, trade can also drive MSME climate adaptation, especially through consumer demand and exposure to "external actors" (ITC, 2021; Klewitz and Hansen, 2014). Although MSMEs may not be able to take the most drastic changes, they are generally more nimble than larger firms and can better identify new market opportunities to fill the related gaps (Burch et al., 2016). However, further research is required to better understand the interlinkages between climate change adaptation and MSMEs' trade challenges and opportunities.

Box B.4: Climate change and the emerging "geoeconomic order"

A growing suspicion towards globalization has led to the emergence of "geoeconomics", a macro-level change in the relationship between economics and security in the regime governing international trade and investment (Roberts, Choer Moraes and Ferguson, 2019). The development of geoeconomics may lead to the expansion of economic isolationism, leading to a technological and trade decoupling of national economies, eventually lowering welfare and increasing geopolitical frictions.

Climate change could impede the pursuit of geoeconomic policies by countries heavily dependent on imports of environmental technologies or of agricultural products, the domestic production of which is negatively affected by climate change. Likewise, countries applying ambitious climate change policies could limit their vulnerability to geoeconomic measures from countries producing carbon-intensive products by reducing their dependence on fossil fuels and, in the case of other raw materials, by boosting recycling and the use of secondary materials. They would thus reduce risks of geopolitical frictions without undermining the multilateral trading system. However, countries may also adopt restrictive trade measures impacting environment-friendly goods and services in an attempt to preserve the strategic resources, foreign supplies or trade routes put at risk by climate change, and which they deem essential for their survival.

The extent to which geoeconomics can threaten climate change adaptation is already visible from the consequences of the conflict in Ukraine, such as blocking the planting, harvesting and transportation of grains. In a geopolitically volatile context, geoeconomic strategies pursued aggressively with "beggar-thy-neighbour" intents could lead to a carbon "race to the bottom" as countries in crisis lower their environmental standards and "self-sufficiency" policies lead to the opening or re-opening of domestic carbon-intensive industries.

Ideally, the response to such risks should be to increase international cooperation, both on climate change and on related trade policies. However, should geoeconomic policies become prevalent as the impact of climate change on trade worsens, countries may eventually equate the protection of their essential economic interests with national security. Given that such measures may not be amenable to justification under the WTO "General Exceptions", such as those found in Article XX of the General Agreement on Tariffs and Trade (GATT) and Article XIV of the General Agreement on Trade in Services (GATS) because of their strategic or geopolitical dimension, WTO members may invoke the "Security Exceptions" of Article XXI of the GATT, XIV bis of the GATS or Article 73 of the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). These exceptions on national security would nonetheless continue to provide a multilateral legal framework with which unilateral geoeconomic measures would have to comply. Improved transparency and monitoring of these measures could also contribute to limiting their impact on the multilateral trading system.

recognize that adaptation is a global challenge and a key component of the long-term global response to climate change. The UNFCCC Nairobi work programme (NWP) assists countries, in particular developing countries, in improving their understanding and assessment of impacts, vulnerability and adaptation, and in making informed decisions on practical adaptation actions and measures. The Least Developed Countries Expert Group (LEG) further provides technical guidance and support to the LDCs to formulate and implement national adaptation plans and programmes of actions. Climate change adaptation is recognized by UNFCCC as having the same importance as mitigation, and is supported by financial mechanisms such as the Green Climate Fund (GCF) and dedicated funds such as the Special Climate Change Fund (SCCF), the UNFCCC Least Developed Countries Fund (LDCF), and the Adaptation Fund.

In addition, many international organizations and regional development banks are engaged in different aspects of climate change adaptation. For instance, the United Nations Office for Disaster Risk Reduction (UNDRR) supports the implementation of the intergovernmental Sendai Framework on Disaster Risk Reduction to strengthen resilience to climate change-related, and other natural and man-made, disasters (WTO, 2021f). Similarly, the World Meteorological Organization (WMO) tracks weather records and disseminates weather information that can facilitate better preparation and forewarning of EWEs.

(b) International cooperation on trade can help increase the ambition and viability of climate adaptation strategies

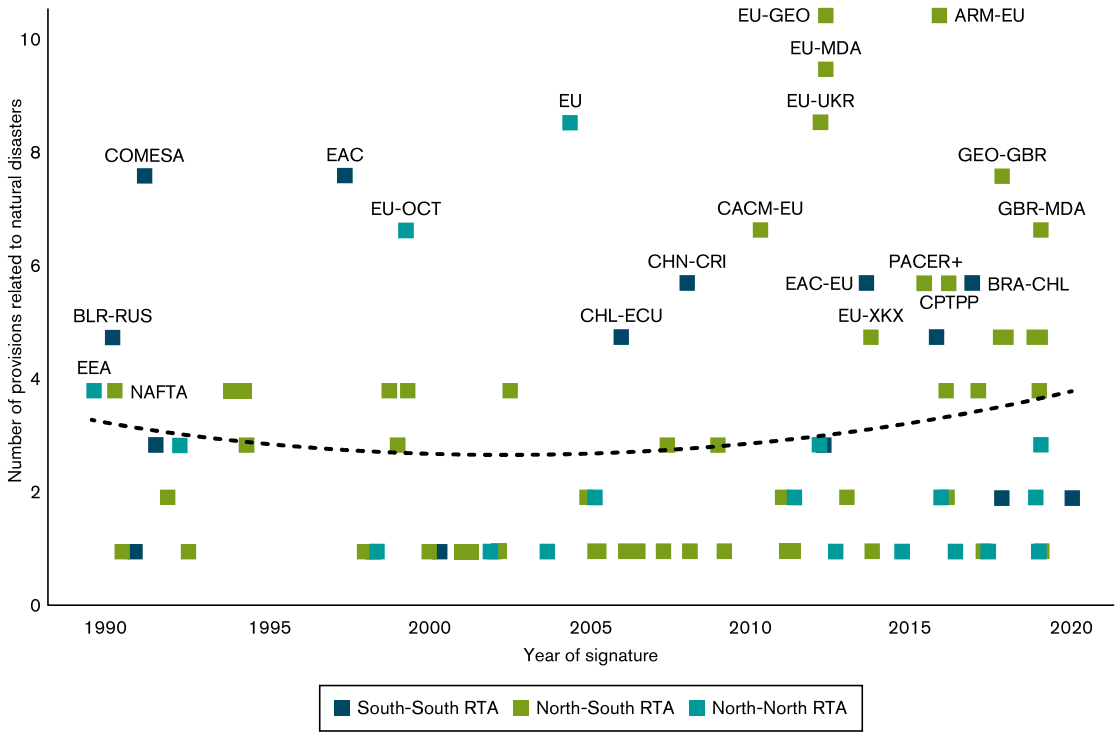
International cooperation on trade and trade-related policies can help support different dimensions of climate change adaptation, from climate risk prevention, reduction and preparedness to climate disaster response and recovery. International cooperation on trade policies can assist governments in reducing climate risks and vulnerabilities and in coping with and recovering from the consequences of climate-induced shocks.

Regional trade agreements (RTAs) are increasingly considered as laboratories for negotiating new types of provisions to address recent trade-related issues. A limited number of RTAs incorporate provisions explicitly addressing climate change adaptation. These provisions cover various commitments, from adopting measures for evaluating the vulnerability and adaptation to climate change[14] to facilitating the removal of trade and investment barriers to goods, services and technologies that can contribute to adaptation.[15] Other most common explicit provisions promote cooperation activities, including vulnerability and adaptation assessments.

These provisions on climate change adaptation are complemented by other explicit provisions addressing natural disasters (WTO, 2021f). Although the inclusion of provisions explicitly addressing natural disasters in RTAs is not a recent phenomenon, the number of these provisions in any given agreement has increased over the years (Figure B.4). These provisions cover a broad range of issues. Several RTAs require the adoption of natural disaster management measures.[16] Some RTAs lay down exemptions in case of natural disasters, such as full rebate of customs duties on imports for rescue and relief assistance.[17] Cooperation provisions remain the most common explicit provisions on natural disasters, covering various issues, including disaster prevention, mitigation and response; early warning systems, and recovery and rehabilitation.

While the new Agreement on Fisheries Subsidies is the first WTO agreement to put a primarily environmental objective at its core (see Box B.5),[18]

Figure B.4: The number of provisions related to natural disasters in RTAs has increased in recent years



Source: Monteiro (2022a).

Note: Analysis based on RTAs notified to the WTO. "North" is defined as high-income countries, whereas "South" is defined as middle- and low-income countries according to the World Bank's country classification.

the WTO also contributes to climate adaptation efforts by providing a framework that minimizes trade-related negative spillovers effects and maximizes positive spillovers effects. This framework comprises the following elements.

First, WTO members have the right to adopt trade-related measures aimed at protecting human, animal or plant life or health in the context of climate adaptation. At the same time, WTO rules ensure trade-related climate change adaptation measures are not disguised protection. These rules are monitored in WTO committees and councils, which allow members to exchange views and address specific trade concerns arising from certain measures. WTO rules are further enforced through the dispute settlement mechanism, which formally deals with trade conflicts among members.

Second, the WTO Agreements promote transparency by requiring formal, publicly available notifications of relevant laws and regulations affecting trade, including those related to climate change adaptation. The collective assessments of each member's trade policies and practices, under the WTO Trade Policy Review Mechanism, promote greater transparency in, and understanding of, members' trade policies and practices, including those that relate to climate change adaptation.

Third, the WTO, through its committees, councils and other bodies, serves as a platform for members to exchange views on important trade-related issues and address trade concerns, including those related to climate change adaptation. Some of these WTO bodies cover specific areas of trade measures, such as technical regulations and subsidies, or specific

Box B.5: Marine resources, climate change adaptation and the role of the WTO

Vulnerability to climate change is exacerbated by the loss of biodiversity, which occurs when natural resources, including marine resources, are not sustainably managed (World Bank, 2008). For example, overfishing and illegal fishing are serious global problems that threaten the ocean ecosystem, as well as livelihoods and food security. Although many factors are responsible for unsustainable fisheries management, certain fisheries subsidies are an important driver. Subsidies directed to the fisheries sector may be worth in excess of US$ 30 billion every year, out of which more than 60 per cent could have a capacity-enhancing effect leading to unsustainable overfishing (Sumaila et al., 2019). Climate change adds to the burden on fish stocks, because many marine fish stocks are diminished by ocean warming, and overfishing further exacerbates the vulnerability of these stocks (Free et al., 2019).

A major complication in tackling fisheries subsidies comes from the fact that marine resources do not stop at national borders. Unilateral action by a single country is not sufficient to preserve fisheries resources, and any subsidy or government intervention is likely to have international repercussions. For example, if a country institutes quotas on fish catches or increases monitoring of fishing activities, all countries benefit. Nevertheless, if other countries sharing the same fisheries resources do not commit to similar measures, the restrictions will likely be compensated by an increase in catches by other nations (Pintassilgo, 2003).

International cooperation is, therefore, the most effective means to address these externalities. In this context, the WTO is in a unique position to address fisheries subsidies, given its existing framework of binding multilateral subsidies disciplines and the multilateral nature of WTO negotiations, along with the economic and trade implications of such subsidies.

At the WTO's 12th Ministerial Conference in June 2022, WTO members concluded the WTO Agreement on Fisheries Subsidies that prohibits (i) subsidies contributing to illegal, unreported, and unregulated fishing or fishing-related activities in support of such fishing; (ii) subsidies regarding overfished stocks (except subsidies implemented to rebuild the stock to a biologically sustainable level); and (iii) subsidies provided to fishing or fishing-related activities in the unregulated high seas.

WTO members also resolved to continue work on additional provisions that would achieve a comprehensive agreement on fisheries subsidies, including through further disciplines on certain forms of fisheries subsidies that contribute to overcapacity and overfishing. Equally importantly, the WTO Agreement on Fisheries Subsidies sets out a mechanism to enhance notification and transparency on fisheries subsidies. This new agreement also contributes to achieve target 14.6 of the Sustainable Development Goals calling for the prohibition of certain forms of fisheries subsidies.

sectors, such as agriculture and services. Others deal specifically with trade-related environmental issues. For instance, the WTO Committee on Trade and Environment (CTE) provides a forum to support policy dialogue and share knowledge and best experiences in trade-related climate change adaptation strategies.

Finally, the WTO also provides trade-related technical assistance and capacity building to developing countries and LDCs, which can help to build climate-resilient trade capacity. Current initiatives include Aid for Trade, the Enhanced Integrated Framework (EIF), and the Standards and Trade Development Facility (STDF).

(c) Predictability, dialogue and coordination are key to increasing climate resilience of supply chains

Although GVCs have been very effective in lowering global production costs allowing countries to engage in international trade and maximize their comparative advantage, they can be, as discussed above, particularly exposed to the effects of climate change. International cooperation supporting preventive action against climate-related risks can help improve the adaptation and resilience of GVCs to climate change.

An open and predictable trading system can foster foreign direct investment, provide options for production diversification, and allow firms to organize their supply chains by prioritizing resilience over other concerns like fiscal considerations. WTO provisions allow and sometimes even encourage countries to take trade-related measures that may prove beneficial in responding to and building resilience against EWEs (see Table B.1).[19]

Trade facilitation plays a key role in supporting the resilience in the face of climate-related shocks. It smooths the functioning of supply chains during normal times, and, as the COVID-19 pandemic demonstrated, it is also vital for speeding imports of essential goods such as food, medical supplies and emergency equipment in response to a disaster. The WTO TFA seeks to minimize the incidence and complexity of import and export formalities in order to facilitate trade, including for goods in transit. The TFA simplifies customs processes for both regular trade and for post-disaster assistance. In this regard, the TFA requires members to take "additional trade facilitation measures" for the benefit of traders, commonly known as "authorized operators", who have been approved by or on behalf of the national customs administration as complying with specific supply chain security standards. Such measures include lighter documentary and data requirements, a reduced rate of physical inspections, elimination of fees and unnecessary delays or restrictions on goods in transit, pre-arrival filling and processing of transit documentation, rapid release time, deferred payment of duties and other charges.

Climate-related shocks and associated fears of shortages or inflation can provoke governments into taking trade-restrictive measures such as export restrictions, thus disrupting value chains. The WTO's trade policy monitoring and other transparency mechanisms play a role in enhancing information and fostering coordination among members to ensure restraint regarding restrictive trade policies. In this regard, more can be done by engaging a discussion on how to improve cooperation to avoid the imposition of restrictive uncoordinated export measures.

Further strengthening the WTO's trade policy monitoring and coordination functions could also help to identify challenges and opportunities for building supply chain resilience to climate change. The WTO's work with vaccine manufacturers during the COVID-19 pandemic could serve as a blueprint for dialogue among governments, businesses and other stakeholders to address potential climate change-induced bottlenecks in supply chains.[20] International cooperation can further strengthen the resilience of supply chains, including by disciplining reshoring policies, information-sharing, cooperating on standards, and managing risks of supply chain bottlenecks (WTO, 2021c).

(d) Well-functioning markets are important to address climate-related food security challenges

In order to maximize the opportunities that trade offers to enhance food security, it is important to have well-functioning food markets. Imports of essential commodities in countries that lack water or fertile soil, or that are subject to EWEs, need to move easily across borders. Disciplines in agriculture that foster an open, predictable and transparent environment are, thus, important, and complement rules that shape trade and markets in a number of other areas, such as trade facilitation, transport, telecommunications, financial services, competition and public procurement. Volumes of food imported or exported can be significantly reduced by port disruptions, as well as by high domestic transportation costs and lack of competition in the distribution sector, the latter particularly affecting poor people in rural areas,

Table B.1: Selected examples of resilience policies under WTO agreements and decisions

General Agreement on Tariffs and Trade (GATT) and Trade Facilitation Agreement (TFA) ▪ Define in advance domestic customs disciplines to be implemented during an emergency. ▪ Temporarily suspend regular customs charges on the entry of imported goods. ▪ Facilitate customs processes and procedures to speed up imports of relief goods and other necessities.
Technical Barriers to Trade (TBT) Agreement and WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) ▪ Ensure quality and safety of imported relief goods, including foodstuffs. ▪ Adapt technical standards for construction and building materials to local environmental constraints.
Agreement on Agriculture (AoA) ▪ Ensure access to goods of primary necessity, including food supplies. ▪ Provide financial support and government services for relief from natural disasters.
Agreement on Subsidies and Countervailing Measures (SCM) ▪ Provide financial support to enterprises to recover from climate-related natural disasters.
Enabling Clause, Decisions on waivers for preferential treatment for LDCs, Waivers under the Marrakesh Agreement ▪ Grant non-reciprocal preferences to support export diversification and, following EWEs, to promote the recovery of exports.
General Agreement on Trade in Services (GATS) ▪ Automatically recognize the professional qualification of foreign service providers for relief services and reconstruction. ▪ Improve access for the population and for businesses to cash aid resources. ▪ Improve the supply of weather-related services to build capacity to anticipate EWEs.
WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) ▪ Ensure balanced framework for innovation and diffusion of climate adaptation technologies. ▪ Support technology transfer to LDCs.
Agreement on Government Procurement 2012 (GPA 2012) (Plurilateral) ▪ Use emergency government procurement flexibilities to accelerate procurement processes for goods and services needed for recovery.

who thereby face more obstacles to benefitting from open markets.

The AoA recognises the need to take food security into account, both in existing commitments on market access and agricultural support and in ongoing negotiations.[21] In particular, WTO disciplines on agriculture promote open, fair and predictable trade in food, thus contributing to providing the necessary regulatory environment for food security.

For example, surging food prices often trigger export restrictions in key foodstuffs, which can ultimately exacerbate price increases (Giordani, Rocha and Ruta, 2012). Under the GATT, export prohibitions or restrictions temporarily applied to prevent or relieve critical shortages of foodstuffs or other essential products are allowed. However, the AoA requires WTO members to give due consideration to the effects of export restrictions on importing members' food security, as well as to consult importing

members, and to notify the Committee on Agriculture before instituting such measures.

At the WTO's 12th Ministerial Conference (MC12) in June 2022, WTO members agreed to exempt from export restrictions food bought by the World Food Programme for humanitarian purposes. Ministers also adopted a Declaration pledging to facilitate trade in food, fertilizer and other agricultural inputs. They stressed the importance of not imposing export restrictions, and encouraged members with surplus stocks to release them on international markets. Importantly, they vowed to cooperate on enhancing agricultural productivity. Implementing this decision could contribute to enhancing food production and help to manage the knock-on effects of surging food prices during a crisis, thus increasing food security.

For over a decade, the Agricultural Market Information System (AMIS) (set up by the G20 in response to the global food price hikes of 2007-08 and 2010) has been helping to share information about food supply and stockpiles, promoting policy dialogue and contributing to strengthening resilience to shocks, including those associated with climate change. While AMIS currently focuses on four major crops (wheat, maize, rice and soybeans), enlarging its product coverage could help further improve transparency on agricultural markets.

The WTO's monitoring and transparency functions also contribute to helping markets to operate efficiently. The WTO Committee on Agriculture provides a forum for members to exchange views about compliance with existing rules and to address disagreements.

Although rules on agriculture and related negotiations aim to discipline and further reduce trade-distorting domestic support, the AoA exempts from reduction commitments programmes which cause only minimal trade distortions. These "Green Box" support measures include general services, such as research, pest and disease control, and extension and advisory services for farmers. The latter are particularly important in enabling producers in low-income countries to improve productivity sustainably, thereby strengthening climate resilience in agriculture.

WTO "Green Box" disciplines also cover public stockholding programmes that are used by some governments to purchase, stockpile and distribute food to people in need. While food security is a legitimate policy objective under the AoA, some stockholding programmes are considered trade-distorting when they involve purchases from farmers at prices fixed by governments.[22] Currently, pending the negotiation of a permanent solution, WTO members have agreed to refrain from challenging developing countries that exceed their agreed limits for trade-distorting domestic support through public stockholding programmes, subject to certain conditions.

The SPS Agreement, which sets out basic rules on food safety and on animal and plant health standards, helps ensure food security by facilitating safe trade. This is important because the increase in temperatures, rainfall, humidity and drought caused by climate change can facilitate the establishment and spread of invasive species and can contribute to increased and new SPS risks, which in turn could affect agricultural production, consumption and trade. International collaboration, for instance through the STDF (see section B.4(d)), is important to help developing countries with such issues. The SPS Agreement also allows for the speeding-up of control, inspection and approval procedures for foreign relief goods, such as in the case of food shortages.

WTO members could do more to ensure that trade contributes to more sustainable, resilient and equitable markets for food and agriculture products, and to put in place disciplines more supportive of policies promoting climate change mitigation and adaptation practices in agricultural production. For example, governments could consider updating existing rules and disciplines to transition away from price and production-linked subsidies, and to increase support for programmes improving the delivery of public goods. Such adjustments could ensure that subsidy programmes do not harm the competitiveness of producers elsewhere, while also sustainably increasing farm yields, raising incomes, and supporting job creation in ways that can strengthen adaptation to climate change.

Reducing trade barriers could also increase food availability in global markets and support efforts to overcome poverty. It could complement efforts to boost domestic farm productivity and help ensure that trade enables producers to respond to future demand growth. Estimates suggest that phasing out agricultural tariffs and implementing other trade facilitating measures could reduce the climate change impact on undernourishment by up to 64 per cent in 2050, meaning that as many as 35 million fewer people would suffer from hunger (Janssens et al., 2020).

(e) More trade-related technical assistance and capacity building for climate change adaptation is needed

To adapt to climate change, low-income and vulnerable countries need to enhance the resilience of their infrastructure and upgrade their productive capacities in agriculture and other sectors. Annual adaptation costs in developing countries are estimated at US$ 70 billion and are expected to reach US$ 140 to US$ 300 billion in 2030, and US$ 280 to US$ 500 billion in 2050 (UNEP, 2021b).

Climate finance has, however, fallen short of its US$ 100 billion goal for 2020 and has not achieved the balance between adaptation and mitigation finance called for in the Paris Agreement. Climate adaptation finance only represented a quarter of total climate finance in 2019, while climate mitigation finance and cross-cutting climate adaptation and mitigation finance constituted 64 per cent and 11 per cent, respectively. Adaptation finance is particularly important for the poorest and most vulnerable countries, which represents more than 40 per cent of climate finance provided and mobilized to LDCs and SIDS, almost double the share of adaptation finance in total climate finance for all developing countries (OECD, 2021) (see also Chapter C).

The Aid for Trade initiative helps developing countries, in particular LDCs, to build the trade capacity and infrastructure they need to increase their participation in and benefit from international trade. A limited but increasing number of Aid for Trade projects integrate environmental considerations (OECD and WTO, 2022). In 2020, Aid for Trade disbursements with a climate objective (adaptation, mitigation or cross-cutting) amounted to US$ 15 billion, representing 31 per cent of total Aid for Trade. Around US$ 5.75 billion, or 12 per cent of total Aid for Trade, were allocated to projects with adaptation as a single or cross-cutting climate objective.

More than half (54 per cent) of adaptation-related Aid for Trade went to agriculture in 2020, reflecting the degree to which climate change is disproportionally affecting this sector (Figure B.5). Besides agriculture, adaptation-related Aid for Trade targeted projects in the energy (11 per cent of adaptation-related Aid for Trade in 2020), transport and storage (10 per cent), banking and financial services (8 per cent) and forestry (7 per cent) sectors.

Although Aid for Trade disbursements related to climate change adaptation are limited, many projects show how investing in adaptation to transboundary climate risks represents an opportunity to build and increase the resilience to climate impacts (Benzie and Harris, 2021). For instance, when, in 2015, Cyclone Pam destroyed much of the seafront infrastructure of Port Vila, Vanuatu, the Enhanced Integrated Framework (EIF), together with Fairtrade Australia and New Zealand, helped Vanuatu rebuild and improve the waterfront with more climate-resilient materials, and in an economically inclusive way aimed to foster interaction between tourists and local small businesses. The EIF has been active in other Aid for Trade projects targeted at adaptation, such as providing greenhouses and hail nets to small farmers in Lesotho to promote resilience to changing weather patterns, and mapping landslide risk and promoting sustainable soil and water management as a way to enhance coffee-growing communities' adaptation and preparedness in Timor-Leste (EIF, 2022; Ramsay, 2021).

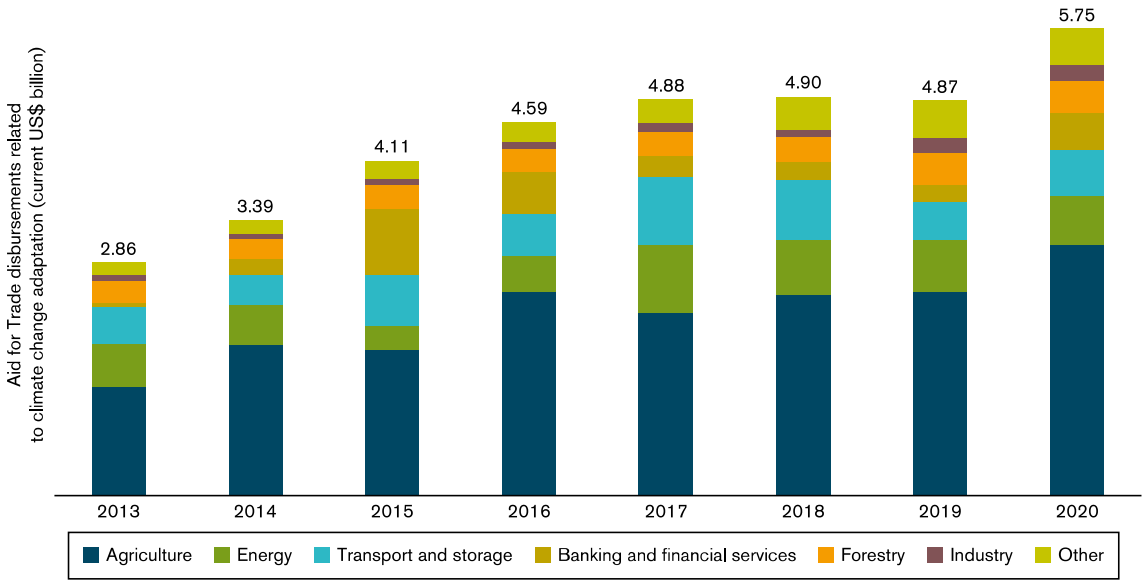
The WTO can also help countries mobilize support and build trade-related capacities for adaptation. For example, the WTO surveys LDCs' evolving technology needs and priorities and supports them by monitoring developed countries' programmes for transferring relevant technologies to LDCs in line with their obligations under the WTO TRIPS Agreement. Between 2018 and 2020, climate change adaptation, including disaster prevention and water management, was an important element in 25 per cent of the 152 environmental technology transfer programmes reported by developed members to the WTO (see also Figure C.7 in Chapter C).

The capacity-building needs of developing countries and LDCs relating to trade and climate change adaptation intersect with the work of several WTO committees, including the Committee on Trade and Environment (CTE), the Committee for Trade and Development, and the TRIPS Council.

Climate change adaptation is also increasingly incorporated into the work of the STDF, a global partnership providing a funding mechanism for innovative and collaborative SPS projects in developing countries to facilitate safe trade. The STDF also identifies and disseminates good practice on topics that cut across the areas of food safety, animal and plant health, and trade.

Although trade-related technical assistance and capacity-building for adaptation have increased in recent years, more can be done to better exploit synergies between climate finance and Aid for Trade. The Aid for Trade initiative could help to mobilize additional funding for climate change adaptation by

Figure B.5: Most Aid for Trade disbursements related to climate change adaptation cover agriculture



Source: Authors' calculations, based on Organisation for Economic Co-operation and Development (OECD) DAC-CRS (Development Assistance Committee Creditor Reporting System) Aid Activities Database.

Note: Only projects with an explicit objective of adapting to climate change and projects identifying climate change adaptation as important but secondary objective are considered as adaptation-related official development assistance.

better integrating the trade dimension into countries' national adaptation strategies and by including climate considerations in Aid for Trade projects. Strengthening the discussions on the trade-related adaptation needs of developing countries and LDCs in the WTO could also contribute to a higher degree of alignment and coherence between Aid for Trade and climate finance programmes.

5. Conclusion

Climate change is a current reality. In the short term, EWEs will continue to cause disruptions to supply chains and transport networks, shortages of key commodities, and international price fluctuations. Over the long term, further gradual climate changes and more frequent and intense EWEs will alter regional patterns of specialization. Left unchecked, climate change will lead to a humanitarian crisis characterized by increasing poverty, food insecurity, disease and unnecessary additional deaths. It may also contribute to geopolitical instability, as countries compete for access to dwindling resources and seek to protect their industries and markets through economic decoupling and the building of zones of economic and political influence.

Trade – with the multilateral trading system at its core – can help countries attenuate some of the effects of climate change by protecting themselves against, and responding to, short-term shocks like EWEs and by ensuring the timely availability of critical goods and services, such as food, healthcare, transportation and communication. Although adapting to climate change will continue to remain costly, trade may help countries adapt to climate-related changes in comparative advantages, for example by importing what they may no longer be able to produce and exporting what they may produce in excess. Trade can also facilitate access to technologies that minimize some of the costs and the economic effects of climate change.

WTO rules, supported by policy dialogue and cooperation, provide the open, non-discriminatory and predictable trading environment necessary for trade to be a means of adapting to some of the consequences of climate change. Some trade measures, such as suspending custom duties, opening markets to foreign service providers, and simplifying import procedures, can enhance the response to, recovery from and resilience to short-term climate-induced shocks, as well as support more long-term adaptation to climate change.

At the same time, a lot more can be done to help low-income and vulnerable countries to meet the challenges of climate change adaptation. Platforms for policy dialogues, like the WTO Committee on Trade and Environment, can be used by members to share knowledge and expertise necessary to develop successful climate adaptation policies. Aid for Trade and related initiatives such as EIF and STDF can also help to mobilize funding and build trade-related capacities for climate change adaptation in developing countries and LDCs.

Although international trade and trade policy can contribute to climate adaptation strategies, trade policy alone cannot automatically foster adaptation to climate change. While adapting to climate change will only get more expensive if GHG emissions are left unchecked, countries must adopt and implement comprehensive and coherent climate adaptation actions, such as strengthening transport networks, diversifying production, suppliers and customers, and making long-term investments in human capital, in order to avoid, to the extent possible, and minimize losses and damages caused by climate change.

Endnotes

1 See Bosello, Eboli and Pierfederici (2012), Bosello and Parrado (2022), Eboli, Parrado and Roson (2010), IPCC (2014a), Nordhaus (2014), and Roson and van der Mensbrugghe (2012). Larger losses have been estimated by the Swiss Re Institute (2021).

2 Some climate change adaptation actions, such as air-conditioning, can, in the absence of complementary actions, increase electricity demand and generate GHG emissions. Complementary actions include improving energy efficiency in air conditioning technology, supporting renewable energy sources and enhancing building thermal insulation.

3 Revealed comparative advantage is defined as the share of an economy's exports of given commodities in that economy's total exports, relative to the share of the world's exports of these commodities in total world exports.

4 For food trade, for example, these can be straits and canals, coastal infrastructure in major crop-exporting regions, and inland transport infrastructure in major crop-exporting regions.

5 For details on how the climate change exposure and vulnerability indexes are calculated, see Chen et al. (2015), and for the methodology of the export diversification index, see Henn et al. (2020), Loungani et al. (2017), and Papageorgiou, Spatafora and Wang (2015).

6 For example, a 1°C increase in temperature has been found to lower industrial output in low-income countries by 2.02 per cent (Dell, Jones and Olken, 2012).

7 For animals and plants, climate change adaptation implies either adjusting to the changing climate and its effects by spending more time and energy on life-sustaining measures (e.g., body temperature regulation) or moving, to the extent possible, to regions with less hostile environmental conditions.

8 Afforestation refers to the process of planting new trees in an area where there were no trees before, while reforestation refers to the process of planting trees in a forest where the number of trees has been decreasing.

9 See Alcalá and Ciccone (2004); Amiti et al. (2017); Amiti and Konings (2007); Frankel and Romer (1999); Wacziarg and Welch (2008); Gries and Redlin (2020); and Cerdeiro and Komaromi (2021).

10 For instance, an increase in international trade creates new employment opportunities and improves welfare outcomes, which tend to reduce the incentive to move abroad for job opportunities.

11 See for instance https://corporate.walmart.com/esgreport 2019/environmental#climate-change.

12 Notified trade measures with the following objectives are considered to be related to climate change, namely: afforestation or reforestation; air pollution reduction; alternative and renewable energy; climate change mitigation and adaptation; energy conservation and efficiency; and ozone layer protection. For more information, see WTO (2021d).

13 In agricultural and food markets, governments tend to create price-altering trade policies when global agricultural and food prices rise substantially.

14 For example, Korea-Peru RTA.

15 For example, Colombia-Ecuador-European Union-Peru RTA.

16 For example, Canada-Chile RTA.

17 For example, Southern African Customs Union (SACU).

18 Paragraph 14 in the Outcome Document (WTO official document number WT/MIN(22)/W/16/Rev.1, which can be consulted at https://docs.wto.org/) of the 12th WTO Ministerial Conference (June 2022) recognizes the contribution of the multilateral trading system with regard to the 2030 Agenda.

19 Some RTAs replicate or build on existing WTO disciplines relevant to build climate resilience, while others establish new commitments (WTO, 2021c).

20 For example, a "Trade 4 Climate" dialogue among businesses, members and stakeholders organized by the WTO and the International Chamber of Commerce (ICC) in October 2021 (https://www.wto.org/english/tratop_e/envir_e/trade4climate_e.htm) highlighted the links between climate change and natural disasters, and their impact on trade.

21 The important role of trade and the WTO in contributing to food security is also reflected in the international community's commitment in Sustainable Development Goal 2b to correct and prevent trade restrictions and distortions in world agricultural markets (https://sdgs.un.org/goals/goal2).

22 For more information, see https://www.wto.org/english/tratop_e/agric_e/food_security_e.htm.

C The trade implications of a low-carbon economy

The global economy needs to effect wide-ranging and immediate changes to reduce its greenhouse gas emissions sufficiently to limit climate change. This chapter explores how the transition to a low-carbon economy could impact international trade patterns, and outlines the role that trade, trade policy and international cooperation can play in supporting a just low-carbon transition. Although a low-carbon transition entails short-term investment and adjustment costs, it can also provide important economic benefits and opportunities. The WTO has an important role to play in increasing the ambition and viability of climate change mitigation actions.

Contents

Key facts and findings

- Although the COVID-19 pandemic temporarily reduced greenhouse gas emissions, overall emissions have increased by more than 85 per cent since 1990. This highlights the urgency of transitioning to a low-carbon economy.
- Some of the available options to support a low-carbon transition include shifting the energy mix away from fossil fuels, promoting alternative and renewable energy, improving energy efficiency, and reducing production and consumption.
- A net-zero carbon economy could modify trade patterns by altering comparative advantages. While some economies could export more renewable electricity, others could benefit from opportunities to produce and export goods and services using clean energy.
- Unilateral and uncoordinated trade-related climate policies can, depending on their design and implementation, create trade tensions that can ultimately undermine climate change mitigation efforts.
- The fight against climate change calls for greater multilateral cooperation and coherent actions to support a just low-carbon transition. The WTO contributes to supporting climate change actions by helping to prevent unproductive trade frictions and promoting efficient trade-related climate policies.

1. Introduction

Although the COVID-19 pandemic caused a temporary reduction in greenhouse gas (GHG) emissions, levels of atmospheric carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have increased by more than 85 per cent since 1990.[1] GHG emissions from human activities are already responsible for approximately 1.1°C of global warming since the pre-industrial period.

The 2015 Paris Agreement commits countries to limit the global average temperature from rising to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature rise to 1.5°C. GHG emissions need to be cut by roughly 50 per cent by 2030 and reach net zero by 2050 in order to stay below 1.5 °C of global warming (IPCC, 2022b).

Reaching net zero emissions requires reducing GHG emissions to as close to zero as possible and offsetting any remaining emissions by removing an equivalent amount of GHG from the atmosphere and storing it permanently in soil, plants, or materials. For this to occur, important changes would have to be made in the structure of production and consumption, including specialization patterns and international trade. This raises the question of how trade, trade policy and international trade cooperation, as well as the WTO, can support the transition to a low-carbon economy.

This chapter discusses how ambitious climate change mitigation policies and well-functioning financial markets are essential to support and accelerate the transition to a low-carbon economy. It then discusses how a low-carbon economy could change trade patterns and provide new economic opportunities. The chapter concludes with a discussion of the role of international cooperation, and in particular that of the WTO, in supporting climate-change mitigation efforts.

2. Achieving a low-carbon economy is an imperative but faces challenges

Tackling climate change requires major climate policy actions to steer the economy towards a low-carbon emission path, yet there is no single strategy that can support the transition to a low-carbon economy. In addition, various challenges face the adoption and implementation of carbon mitigation policies, including conflicting economic, energy and political priorities (see Box C.1).

For instance, only 6 per cent of the US$ 13 trillion in COVID-19-related stimulus packages adopted by G20 economies in 2020 and 2021 has been allocated to areas that could also reduce global GHG emissions, including installing renewable energy systems, improving energy efficiency in buildings and electrifying transportation systems. Another 3 per cent of the stimulus packages has been directed at areas that are likely to increase emissions by supporting carbon-intensive activities (Nahm, Miller and Urpelainen, 2022). In comparison, 16 per cent of total global fiscal stimulus spending adopted during the 2008-09 global financial crisis was targeted at activities contributing to environmental protection, including climate change mitigation (Jaeger, Westphal and Park, 2020).

Addressing the distributional consequences of climate change policies is also important to ensure a fair and inclusive transition to a low-carbon economy. Well-functioning financial markets are also essential to support a low-carbon economy.

(a) Different strategies can support the transition to a low-carbon economy

Efforts to reduce and prevent GHG emissions into the atmosphere, commonly referred to as climate change mitigation, are essential to limit global warming and substantially reduce the future effects of climate change (IPCC, 2022b). The urgency to move towards a low-carbon economy requires a significant transformation of the way energy, goods and services are produced, delivered and consumed.

There is, however, no one-size-fits-all strategy to support a low-carbon transition. A low-carbon economy can be achieved in a number of ways, for example by shifting the energy mix away from fossil fuels; promoting alternative sustainable renewable energy sources, such as geothermal, hydro and solar power; improving energy efficiency in buildings, transport, industry and consumption; and reducing production and consumption.[2]

Inducing consumers to make behavioural changes could significantly support a transition to a low-carbon economy if these changes curb energy demand (IEA, 2021). This could involve encouraging consumers to purchase and adopt low-carbon products and technologies, such as solar water heaters and electric vehicles, and encouraging behaviour that is more conscious of the consequences of consumption, such as economical energy use, switching transport modes and consuming less carbon-intensive food (Lonergan and Sawers, 2022).

Box C.1: Implications of the war in Ukraine on climate change

The war in Ukraine is having a devastating impact on the Ukrainian people, infrastructure and economy. It is also having a disastrous impact on the environment, for example through the destruction of forest and marine ecosystems, air and water pollution, and waste. Given the important roles of both Russia and Ukraine in the global commodities and energy markets, cascading impacts of the conflict are being felt worldwide, including through higher food and energy prices and the reduced availability of certain Russian and Ukrainian exports (WTO, 2022b).

The war and its consequences highlight the importance of devising climate change strategies that balance energy and food security with environmental imperatives. It is, however, unclear at this stage, whether the war and its geopolitical consequences will slow down or accelerate the transition to a low-carbon economy.

In response to rising oil and gas prices consequent to the war in Ukraine and as a result of sanctions on many Russian exports, some countries have opted to diversify their energy suppliers, signing contracts for liquefied natural gas (LNG) from Africa, the Middle East and the United States (Dvorak and Hirtenstein, 2022). Some countries are also considering increasing natural gas and oil production, building new natural gas pipelines, and reopening or extending the operation of coal-fired power plants (Tollefson, 2022).

Although these new commercial energy contracts and projects may address the current urgent energy security problems, they could also slow down the transition to a low-carbon economy if, for example, new providers of coal, gas and oil demand long-term supply commitments. The race to secure LNG supplies by some countries could further exacerbate price spikes in LNG, which could drive some developing and least-developed economies to increase or switch their energy consumption to high carbon-intensive fossil fuels, such as coal and oil.

The war could also lead some governments to redirect public spending, initially allocated to tackling climate change, to other priorities, some of which may be carbon-intensive, such as military equipment. More generally, geopolitical tensions could imperil international cooperation on climate change, which is essential to make significant progress in tackling climate change.

At the same time, energy security concerns, in particular energy independence, stemming from the consequences of the war in Ukraine, could also accelerate the transition to a low-carbon economy. In response to the war, some countries have adopted plans to accelerate their clean energy transition by increasing energy efficiency and renewable energy production capacities. Energy price hikes could also lead some consumers to buy more energy-efficient products and smaller or electric vehicles.

An accelerated low-carbon transition would require a diversified and affordable supply of the metals and minerals required to produce renewable energy equipment and energy-efficient products, the availability of which is not currently guaranteed as a result of the war. However, international trade may help to ensure a more diversified and resilient supply of critical materials, and further contribute to the transition to a low-carbon economy.

(b) Ambitious climate change mitigation policies are essential

Every five years, signatories to the Paris Agreement submit roadmaps to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat, known as Nationally Determined Contributions (NDCs), which detail how they plan to achieve their carbon emission-reduction targets.[3] A review of the 164 latest available NDCs reveals that the most frequently listed measures in NDCs are related to the energy sector, including electric power generation from renewable energy and low- or zero-carbon fuels (UNFCCC, 2021). Many NDCs also report measures for enhancing carbon sequestration, the most frequently indicated being afforestation, reforestation and sustainable forest management.

While positive, the level of ambition of these policies is not currently enough to achieve a low-carbon economy consistent with the Paris Agreement's timeline, namely cutting by half GHG emissions by 2030 and reach net zero by 2050 (UNEP, 2021a).

The lack of progress stems in part from the fact that climate change is a market failure because it

has been caused by actors who are not necessarily experiencing the consequences of their acts. For example, firms and consumers may not directly face the climate change-related consequences of the GHG they emit, and, as a result, they continue to emit excessive quantities of GHGs. Measures to tackle climate change can also be characterized by positive externalities, for example all economic actors benefit from increased climate change mitigation efforts, even if they did not contribute to these efforts. However, this can create incentives to free-ride on climate efforts made by others, limiting the global level of climate change mitigation efforts. Climate change mitigation policies are essential to tackle these market failures.

Other market failures may also call for policy interventions. For example, climate-friendly innovations in one country can benefit the innovation activity of all other countries since they increase the global stock of knowledge and support the decarbonization process of the economy. In the presence of such knowledge spillovers, companies that invest in research and development (R&D) into low-carbon technologies are often unable to capture the entire return of their investment. Economies of scale, sunk costs and costs of reorienting research and switching technology also give established, higher-carbon technologies an advantage (Acemoglu et al., 2012).

In addition, the capital required to transition to low-carbon alternatives is often subject to uncertainties, political risks and a lack of short-term return on investment which can often impede the funding of innovative or large-infrastructure projects. Low-carbon infrastructures often require substantive upfront investment in networks, such as electronic grids or charging stations for electric vehicles, which can also be difficult to establish without policy interventions. Finally, information about the energy efficiency or carbon content of a product or production process may not be available, making it difficult for economic agents to make informed decisions (Stern and Stiglitz, 2022).

(c) Climate change mitigation policies are multifaceted

Climate change mitigation policies can support the transition to a low-carbon economy by establishing incentives and requirements to deploy climate-friendly technologies and to facilitate the withdrawal or improve the energy efficiency of carbon-intensive assets.[4] The effectiveness of climate change mitigation policies depends on their design and on the responses of firms and consumers. Firms generally only change their behaviours if they are legally required to do so or it is economically profitable, while people generally only change their behaviours if they are legally obliged to do so, if the alternative is cheaper or better, or if they want to imitate or conform with social norms (Lonergan and Sawers, 2022).

Policy instruments for a low-carbon transition can be grouped according to their underlying mechanisms that aim to achieve climate change mitigation (IPCC, 2007b), namely (i) command-and-control instruments; (ii) market-based instruments; (iii) information instruments; and (iv) voluntary agreements.

(i) Command-and-control instruments

Command-and-control instruments are the most common form of climate mitigation policies (IPCC, 2007b). Command-and-control measures fall broadly into two categories: (1) regulatory measures on processes and production methods and (2) prohibition mandates of certain products and practices.

Reducing the environmental impact of production activities may sometimes involve setting standards and regulation for the way products are produced. These regulatory measures commonly take two forms: (1) performance standards, which dictate specific environmental outcomes to be achieved per unit of production (e.g. number of grammes of CO_2 per kilowatt-hour of electricity generated) and (2) technical standards, which specify various pollution abatement technologies or production methods to be used by producers (WTO and UNEP, 2009).

Prohibition, or phase-out mandates, as well as bans on sales and imports of high-emission equipment and energy-inefficient products, are increasingly common. Such mandates are introduced to eliminate existing fossil-fuel assets, such as coal-fired power plants, and to prevent new investment in high-emissions equipment (Finon, 2019).

(ii) Market-based instruments

In recent years, market-based instruments have become an alternative to traditional command-and-control policies (Peace and Ye, 2020). These instruments have the advantage of providing greater flexibility in how economic agents wish to reduce GHG emissions. Market-based instruments can be categorized into four broad groups: (1) carbon pricing, (2) support measures, (3) fossil fuel subsidy reform and (4) green government procurement.

Carbon pricing, including carbon taxes and emission trading schemes, is often highlighted by economists as an efficient way to reduce emissions (Aldy and Stavins, 2012; Metcalf and Weisbach, 2009; Stavins, 2022) (see Chapter D). Carbon pricing is associated with the idea that polluters should pay for the damage they cause. By putting a price on carbon emissions, the costs of economic agents' GHG-emitting activities are made explicit, thereby giving agents incentives to find ways to reduce emissions. Moreover, by giving agents the flexibility to choose the appropriate course of action to reduce emissions, carbon pricing can also stimulate innovation for new, low-carbon products and production processes.

Governments can also support a low-carbon transition by incentivizing the development, production and adoption of low-carbon products and technologies. R&D subsidies can lower costs and improve the performance of low-carbon technologies, as well as foster innovation in environmental technologies (Acemoglu et al., 2012; Bosetti et al., 2013; Verdolini et al., 2015). Subsidies can also be given to producers of renewable energy. Feed-in tariffs, for instance, allow renewable energy producers to receive a guaranteed price for each unit of electricity generated, guaranteed grid access and long-term contracts with electric grid utilities (Fell and Linn, 2013; Wilke, 2011). Subsidies can also be provided to consumers to encourage the adoption of low-carbon products and technologies, for example LED lighting or electric vehicles (Finon, 2019).

The phasing-out of fossil fuel subsidies also affects the carbon price. Because fossil fuel subsidies essentially function as a negative carbon price, removing these subsidies results in an increase in the price of carbon-based fuels (Jenkins, 2014; van Asselt and Skovgaard, 2021). Subsidy reform therefore enables the incorporation of costs of environmental externalities that were not reflected under the subsidized prices and thereby incentivizes a decreased use of fossil fuels. More generally, reforming support measures targeted at carbon-intensive products and activities, such as some agricultural subsidies, can lead to reduction in GHG emissions (OECD, 2022b; Springmann and Freund, 2022).[5]

Through green government procurement (GGP) policies, governments can influence private sector producers through their purchases of low-carbon goods and services, create markets for new entrants, and stimulate innovative solutions to climate change problems by awarding public R&D contracts. Given the sheer volume of demand for goods and services that government procurement can represent,[6] GPP can create a large and stable demand for new low-carbon solutions before a commercial market is viable.

(iii) Information instruments

Firms and consumers may act inefficiently when they lack the necessary information about the environmental consequences of their actions. Information instruments provide environment- and energy-related information on specific products and activities to allow investors and consumers to make climate-informed choices. The disclosure of environmentally related information includes labelling programmes, rating and certification systems, public awareness campaigns and environmental self-declaration claims.

Eco-labels, including carbon labels, are increasingly being adopted (OECD, 2016). The carbon-related information intended to consumers can be communicated in different ways.[7] A low-carbon label shows that the product's carbon footprint has been reduced without necessarily specifying by how much. A carbon neutral label indicates that the product's carbon footprint has been reduced but any remaining carbon emissions have been compensated via carbon offset projects. A carbon score lists the amount of carbon emitted across the product's lifecycle. A carbon rating shows how the product performs in terms of energy use and efficiency relative to others similar products in its category.

While information-enhancing initiatives can be owned or managed by governments,[8] environmental information instruments are increasingly adopted by the private sector and non-profit organizations. An increasing number of firms use eco-labelling to establish or foster niche markets for environmentally friendly products. Some firms also voluntarily disclose information about their environmental performance. Recently, collaborations between public and private sectors on environmental information schemes have become common, such as roundtable certification schemes.

(iv) Voluntary agreements

Voluntary agreements are customized contracts between a government authority and one or more private sector parties, that aim to improve environmental performance and resource utilization beyond compliance to regulated obligations (Cornelis, 2019; IPCC, 2007b).[9] There is no legal obligation to participate, and, in most cases, there are no penalties for terminating participation (Karamanos, 2001). Voluntary agreements can, in some cases,

obviate the need to use legislative action. They can also encourage a proactive, cooperative approach between public and private sectors. In addition, they can lead other firms to imitate the environmentally friendlier practices of voluntary agreements-signatory firms.

(d) Addressing the distributional and political implications of ambitious climate change mitigation policies is essential

The adoption and implementation of ambitious carbon mitigation policies can face challenges in some segments of the population and some sectors. This is because the distributional consequences of carbon mitigation policies can include replacing existing sectors, activities and technologies with alternatives that are more efficient or that use low-carbon energy sources, and this can provoke opposition, which may impede implementation (Jenkins, 2014; Nemet et al., 2017; Stern, 2017a). In addition, as discussed in Section C.3., the trade implications of some climate mitigation policies, can affect governments' mitigation policy strategies and level of ambition, such as the risk of relocation of carbon intensive activities to countries with less stringent climate policies.

Carbon mitigation policies which aim to increase fossil fuel prices can, at least in the short term, increase energy prices generally, and negatively impact consumers and producers. Pressures from those who lose out, or who may lose out, because of decarbonization can slow down the transition to a low-carbon economy by hindering the use of more efficient, low-emission technologies. The climate change mitigation policies necessary to establish the transition to a low-carbon economy therefore require public support to ensure they are credible, effective and long-lasting.

For instance, carbon pricing policies often face significant political economy hurdles (Jenkins and Karplus, 2017) and raise concerns about the burden that carbon price increases may impose on low-income groups.[10] At the same time, however, the potential of these policies to raise revenue that can then be redistributed for various purposes (known as "revenue recycling") has been proposed as a possible remedy to distributional concerns (Jakob et al., 2016; Rausch and Yonezawa, 2021).

Similarly, fossil fuel subsidy reforms have been known to incur significant distributional and political implications with, in some cases, extensive strikes and violent public protests that have prompted governments to reverse their reforms.[11] Other structural factors, such as insufficient institutional or governance capacity, may also make it difficult to remove fossil fuel subsidies once they are in place (Lockwood, 2015; Skovgaard and van Asselt, 2019).

Some climate change mitigation policies can benefit certain groups more than others, and can thereby garner greater political support (Jenkins, 2014). For instance, subsidies encouraging households to purchase electric vehicles have been found particularly to favour high-income earners (Sherlock, 2019; Sovacool et al., 2019), while developing and expanding an affordable electrified public transportation network, through GPP, can particularly benefit lower-income and/or minority groups who may not own cars and who rely on public transport to commute to work and to school (Slastanova et al., 2021).

The distributional effects of some climate change mitigation policies may be more salient for producers than consumers, if the former face the direct impacts of the policies and cannot reflect the increased costs that result from these policies in the prices of goods and services (Johnstone and Serret, 2006). For instance, the compliance costs of regulations, including environmental ones, tend to impact micro, small and medium-sized enterprises (MSMEs) disproportionately (Crain and Crain, 2010). Nevertheless, climate change mitigation policies can be designed in such a way as to lessen the burden faced by vulnerable groups, which could help to support and lead a more fair and inclusive transition to a low-carbon economy.

(e) Well-functioning financial markets are essential to support the transition to a low-carbon economy

The transformation across all energy and land-use systems that a low-carbon transition could entail would require a significant expansion in investment (IEA, 2021). McKinsey (2022) estimates that a total investment of US$ 275 trillion would be required in capital spending on physical assets over the period 2021-50 in order to limit global warming to less than 1.5°C; this would represent an average of US$ 9.2 trillion per year. As discussed in Section C.4.1, achieving a low-carbon economy on a global scale also requires offering financial support to developing and least-developed countries (LDCs) to mitigate the adverse impacts of the transition and enable them to invest and take advantage of new opportunities.

Global funding for the energy transition alone is estimated to amount to US$ 131 trillion over the next 30 years (McKinsey, 2022), and annual clean energy investment worldwide would need to more than triple by 2030 to around US$ 5 trillion to reach net zero emissions by 2050. This investment could add an extra 0.4 percentage points to annual global GDP growth (IEA, 2021). The magnitude of the investment requirements implies that contributions from financial institutions and the private sector will be crucial.[12]

Firms finance their activities, such as investing in climate-friendly technology, by using the profits they generate, raising their debt or issuing bonds. The interest rate on debt and the equity cost of capital – two components of the cost of capital – can influence a firm's decision to invest in low-carbon-emission projects. For instance, high interest rates make investment more expensive, and less attractive, for firms and reduces their investment. Conversely, a high ratio of the firm's price to profits (also known as the price/earnings ratio) typically signals that the market considers that the firm in question is high quality and low risk or growing fast, and investors, typically, make money by acquiring equity shares in firms with high profits or high price/earnings ratios.

Financial markets, including central banks, can support the transition to a low-carbon economy by adopting strategies to reduce funding in carbon-intensive projects, enhancing risk management capabilities to identify new low-carbon opportunities, and developing new financial products to support investors in winding down carbon-intensive legacy assets. Total climate finance, comprising funds from corporations, commercial financial institutions and household consumption, has steadily increased over the last decade, reaching an annual average of US$ 632 billion in 2019 and 2020 (Climate Policy Initiative, 2021). Private-sector-led climate-related activities are most common in renewable energy investment, in particular on-shore wind and solar photovoltaic (PV) energy projects, and in energy efficiency investment and waste management. Other climate-related projects include land-fill gas capture and projects in agriculture and forestry and IT applications for process monitoring and control, to support resource efficiency such has smart irrigation and smart cold chain management.

Privately financed climate projects are typically the result of the combined effects of a range of public interventions and of broader enabling conditions (OECD, 2017). Innovative financial instruments such as carbon finance, green stock indices and green bonds raise money from investors to exclusively finance environmental projects. For instance, green bond markets have grown quickly in size and market coverage since the first green bond was issued in 2007 by the European Investment Bank. At the end of 2021, the global green bond market reached a total volume of US$ 517.4 billion, marking a market expansion trend of 10 consecutive years (Climate Policy Initiative, 2021).

Environmental, social and governance (ESG) criteria are increasingly incorporated into investors' analysis processes to identify material risks and growth opportunities in low-carbon investment, among others. While ESG is a promising approach, ESG ratings are not standardized, and unfortunately the ESG approach is also associated with free-riding, greenwashing and mis-selling risks (Lonergan and Sawers, 2022). Free-riding arises when firms are willing to undervalue high-carbon-emission assets and sell them to obtain a higher ESG score. Greenwashing arises when firms with a high ESG continue to hold high carbon emission assets. The risk of mis-selling comes from the investors' high expectation that ESG investment will necessarily deliver high returns, although many ESG investment remain risky.

Harmonizing ESG criteria and measurement tools and improving information disclosure and regulatory control can improve the effectiveness of ESG finance in contributing to a low-carbon economy by reducing the cost of capital of low-carbon projects.

3. A low-carbon economy would change trade patterns and provide new trading opportunities

History has shown that the dramatic opening of the world economy, combined with the rapid pace of technological change, have improved the welfare and living standards of billions of people around the world, including its poorest citizens. This process was necessarily accompanied by economic changes and some disruptions in the jobs market, as economies shifted from lower to higher productivity and from declining industries to rising ones (WTO, 2017).

The transition to a low-carbon economy should be no different, with economies shifting from fossil fuels to renewable energy sources and from high-carbon-intensive activities to low-carbon-intensive ones. This transformation is likely to affect international trade flows by altering comparative advantages. New trading opportunities for renewable energy and low-carbon-intensive products are likely to emerge, although addressing any climate-related trade tensions is essential.

(a) The transition to a low-carbon economy provides opportunities to support a more sustainable and equitable development

A low-carbon economy brings considerable environmental benefits that can contribute to a more sustainable development path. The transition to a low-carbon economy averts and minimizes the severe consequences of climate change, including a rise in global temperatures, sea levels and frequency, duration and intensity of extreme weather-related events, such as floods, cyclones, and droughts. The low-carbon transition also improves air quality, which in turn improves health and living conditions. Decarbonization through sustainable land management, climate-smart agricultural practices and forest protection can also promote biodiversity, improve food security and enhance climate resilience (see Chapter B).

While the transition to a low-carbon economy would entail short-term investment and adjustment costs, it could also provide important economic benefits and opportunities to support a more sustainable and fair development. It is estimated that bold actions in climate mitigation could yield a cumulated economic gain of US$ 26 trillion between 2018 and 2030 (Garrido et al., 2019). This transition would also limit the risks of a changing climate. As noted in Chapter B, without ambitious mitigation measures, climate change could cause 250,000 additional deaths per annum (WHO, 2018) and up to 18 per cent of global GDP loss by 2050 (Swiss Re Institute, 2021).

While the transition to a low-carbon economy is expected to change the way agricultural and manufacturing goods are produced, services are delivered and buildings are heated and cooled, the labour market is also likely to go through a transformation, with job opportunities moving between occupations and sectors. Workers in carbon-intensive industries, such as cement and steel, are likely to be disproportionately affected.

The low-carbon transition could also, however, bring about employment opportunities since the renewable energy sector is more labour-intensive than the fossil fuel sector (Garrett-Peltier, 2017). The renewable energy sector already provided 12.7 million jobs globally in 2021 (IRENA and ILO, 2022), and it is projected that 14 million jobs could be created in clean energy and 16 million additional jobs in energy-related sectors by 2030 (IEA, 2021).[13] Jobs in the renewable energy sector are also more gender-inclusive than jobs in fossil fuels, with women holding 32 per cent of total renewables jobs but only 21 per cent in fossil fuels jobs. The overall magnitude of the labour shift associated with a low-carbon transition could still be relatively limited, given that most jobs are likely to be neither high-carbon-intensive nor low-carbon-intensive (IMF, 2022).

The obstacles and labour mobility frictions experienced by workers who wish to move into sectors with rising employment (e.g., solar panel installation) and out of declining ones (e.g., coal mining) can be high. Mismatches between skills offered and wanted in the labour market impede workers' transition between jobs (ILO and WTO, 2017). In addition, geographical frictions, or barriers, account for a substantial share of the total mobility costs affecting the reallocation of workers between regions, and may be related to physical geography, social networks, family ties, cultural barriers, language and housing. Labour mobility costs tend to be higher in developing countries (WTO, 2017).

Supporting the labour market adjustment for workers displaced by the closure of carbon-intensive industries is essential to ensure a fair transition to a low-carbon-emission economy. Labour market adjustment policies can take different forms, including job-search assistance, skills development and training programmes (Bacchetta, Milet and Monteiro, 2019; WTO, 2017). Environmental and low-carbon-intensive jobs tend to be higher-skilled and better-paid jobs (ILO, 2018), which could attract some workers, including displaced workers, to these job opportunities. The wage premium in environmental jobs could thus also contribute to facilitating the labour market adjustment (IMF, 2022).

(b) International trade in low-carbon technologies and in renewable energy can support a low-carbon transition

Although international trade emits GHG, it can play an essential role in supporting and promoting the development, access and deployment of low-carbon technologies. Trade in renewable energy and electricity can also help to make production processes cleaner by providing access to affordable sustainable and renewable energy sources.

International trade can support a low-carbon transition by helping to share out the fixed and sunk investment costs of new environmental technologies, as high investment costs are often associated with the development of new technologies, including environmental ones. This can come about in supply chains when coordination between upstream and downstream firms can lead to cost allocation, shared

decision-making and long-term commitment (Ghosh and Shah, 2015; Mattingly, 2017; Qin et al., 2021; Xu and Xie, 2016). Often, only a small number of countries have specific technological expertise in the manufacturing of specific environmental technology, such as renewable energy components and equipment, trade in environmental products thus provides access to technologies with a level of efficiency that cannot be replicated domestically in importing countries (Garsous and Worack, 2021).

International trade can also contribute to a low-carbon transition by promoting the diffusion of environmental technologies, as it increases the dissemination of knowledge across borders (see Chapter F). The diffusion of knowledge and ideas can also improve productivity. An increase in innovation in cleaner energy technologies, often measured by the number of relevant patents, has been found to reduce energy intensity and improve environmental performance (Chakraborty and Mazzanti, 2020; Ghisetti and Quatraro, 2017; Wurlod and Noailly, 2018). In addition, knowledge diffusion across countries and sectors can enable economies to exploit differences in comparative advantages more effectively, thanks to differences between countries in their access to and absorptive capacity of knowledge in environmental technologies (Bretschger et al., 2017).

International trade in renewable energy and electricity could also help to compensate for the uneven geographical distribution of clean energy sources, such as solar irradiation and wind power density. For example, the potential for solar energy production is particularly high in many countries in Africa, Asia, Latin America and the Middle East, while the potential for wind power tends to be very high along coastlines above the northern tropic and below the southern tropic. For instance, the world's largest solar power station was built in Morocco, while the largest offshore wind farm is located in the United Kingdom.

Trade and investment in goods and services related to sustainable renewable energy can contribute to increasing the global production of renewable energy at low cost. For instance, the capacity of solar panels globally traded in 2017 was estimated at almost 80 gigawatts, the equivalent of more than 9 per cent of the global electricity generation in 2017 (Wang et al., 2021).

However, the full potential of international trade in renewable energy and electricity requires addressing the structural challenges on existing power-generation, transmission, and distribution infrastructure created by new renewable electricity flows as well as the inherent variability of renewables, including potential imbalances in supply and demand and limited storage capacity (McKinsey & Company, 2021). Despite rapid and significant advances in high-voltage direct current power transmission (Patel, 2022), cross-border electricity transmission via high-voltage lines over long distances remains relatively costly. Renewable energy could alternatively be exported via pipeline or ship by using energy carriers, namely gases or liquids produced using renewable energy (van der Zwaan, Lamboo and Dalla Longa, 2021).[14] In recent years, the potential of green hydrogen as a versatile carbon-free energy carrier is being increasingly recognized, as discussed by Gauri Singh in her opinion piece.

The transfer of environmental technologies could also help to overcome the mismatch between the regional location of renewable energy resources and the availability of low-carbon technology. Recent analysis of patenting activity suggests that the trajectory of the climate change mitigation knowledge flow increased (especially from developed to developing countries) after the Kyoto Protocol and especially the Paris Agreement (Torrance, West and Friedman, 2022). Developing countries frequently lack significant legacy, carbon-heavy energy systems; which, with the relevant energy and environmental policies, could enable them to leapfrog directly to low-cost and reliable renewable energy technologies that are well-suited to serving dispersed rural populations with limited or no access to electricity or other sources of energy (Arndt et al., 2019).

The transition to a low-carbon economy is likely to take place in a world of increasing geopolitical tensions and supply chain disruptions (see Chapter B). In this context, it is essential that the supply of energy and key mineral resources needed to produce some low-carbon technologies, such as renewable energy equipment and energy efficient products, is diversified and resilient. In order to assemble a risk-based supply strategy, future energy needs need to be evaluated in light of energy security concerns, and transparency and coordination among trading partners must be supported (WTO, 2021c).

(c) A low-carbon economy would impact trade patterns

While climate change may alter countries' comparative advantages (see Chapter B), a low-carbon transition is also likely to lead to shifts in trade patterns. The impact of the low-carbon transition is likely to be stronger on those countries whose comparative advantage stems from fossil fuel energy and high-carbon intensive activities. While a growing literature on climate change and trade looks at the future consequences of climate change, in particular

OPINION PIECE

By Gauri Singh
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Green hydrogen requires an appetite for action

The International Renewable Energy Agency (IRENA)'s *World Energy Transitions Outlook 2022*, which sets out in precise detail the route to achieving 1.5°C by 2030, argues in favour of using hydrogen to achieve full decarbonization (IRENA, 2022). This means raising global production to five times the current production, or 614 megatonnes of hydrogen per year, to reach 12 per cent of the final energy demand by 2050. Green hydrogen is expected to make up the vast bulk of this production.

Discussion of green hydrogen arrives at the right time. Renewable power generation costs have plunged over the past decade, driven by rapidly improving technologies, economies of scale, competitive supply chains and an ever-improving developer experience. To use just one example, electricity costs from utility-scale solar photovoltaics fell by 85 per cent between 2010 and 2020.

Unlike fossil fuels, renewable energy can potentially be produced by every nation. It is energy-fair. The same can be said of green hydrogen, which is a process of conversion, using water and electrolysis technology powered by renewable energy. The method could radically transform the way global energy is traded.

Green hydrogen can also be economical in locations with the optimal combination of abundant renewable resources, space for solar or wind farms, and access to water, matched with the capability to export to large demand centres. New power centres could be built in places that exploit these factors to become hydrogen hubs for its production and use.

Until recently, however, there has been no cost-effective way of transporting renewable electricity over long distances to link low-cost production sites with demand. Suitable transmission lines are rare and extremely expensive to construct. The use of hydrogen as an energy carrier could provide the answer, enabling renewable energy to be traded across borders in the form of molecules or commodities such as ammonia.

To make trade cost-effective, production of green hydrogen must be sufficiently less expensive in the exporting region than in the importing region to compensate for transport costs. This cost differential will loom large as the scale of projects increases and technology develops to reduce transport costs. Hydrogen trade can lower energy supply cost energy since cheaper energy is tapped into. It can also lead to a more robust energy system with more alternatives to cope with exploding crises.

We still have much to do. For the hydrogen trade to truly flourish globally, a market needs to be created to generate demand, promote transparency, and connect suppliers and end users. Underpinning the market, nations need to produce a market regulatory framework containing the flexibility to promote growth. And there must be an internationally accepted certification scheme accepted by all. Finally, innovation must dramatically improve the available technologies that reinforce the integrated value chain.

Green hydrogen is not going to leap on to the world's energy stage fully formed and ready to salvage efforts to achieve 1.5°C by 2030. It is going to require decisive action and dynamic innovation to create new production centres and stimulate demand. Above everything else, it will take ambition and clear-sightedness about our future prospects. The world must be prepared to extend its reach to grasp every opportunity for energy transition. Taking the first step is simple: we just have to reach out.

global warming, on some trade patterns, the trade implications of the transition to a low-carbon economy have been less discussed.

The WTO Global Trade Model (WTO GTM) was used to fill part of this gap and analyse how moving towards a low-carbon economy by 2050 could impact the economy and trade patterns.[15] It is important, however, to emphasize that the simulation scenarios are not forecasts or predictions for the future but representations of what could happen in the future under a set of assumptions. In this analysis, the low-carbon transition is assumed to be achieved thanks to international cooperation and the adoption of global carbon pricing, which is based on a combination of global emissions reductions with announced NDCs until 2030. Under this scenario, fossil fuels extraction and use are phased out by 2050, while electrification and renewable energy use increase to achieve low-carbon emissions by 2050.

(i) A low-carbon economy could spur regional trade in renewable electricity

Assuming a successful transition to a low-carbon economy, this transition is likely to change the structure of domestic energy production and the composition of energy trade. The simulation results suggest that the global share of fossil fuel exports in total energy exports would decrease, while the global share of trade in renewable energy in total energy trade is projected to increase with the level of decarbonization ambition (right panel of Figure C.1).[16]

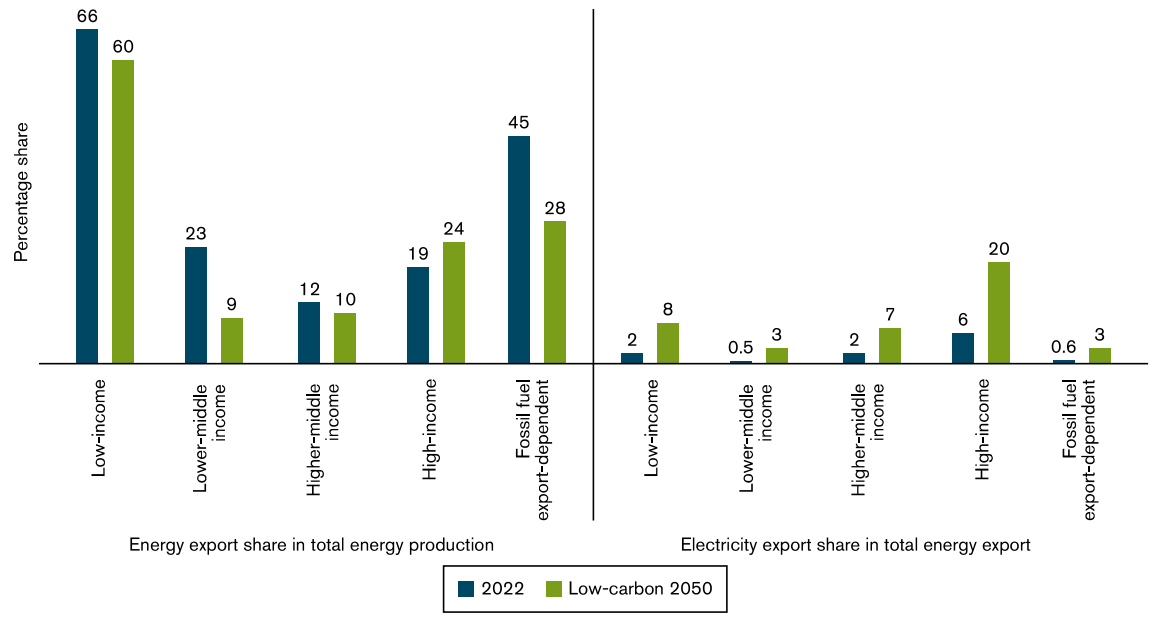
However, a low-carbon transition would lead to a 38 per cent reduction in energy trade from 2022 to 2050 (left panel of Figure C.1). Two forces may explain this result: a reduction in fossil fuel exports and an increase in trade in renewable energy. The latter is, however, not large enough to offset the former because fossil fuel energy (i.e., natural gas, coal, oil) is assumed to remain much more tradeable than trade in electricity, including from renewable energy sources, due to high costs to transport electricity.

(ii) The low-carbon transition would shift production and trade patterns, affecting regions differently

The economic impacts of a low-carbon transition are likely to be unevenly distributed, with those highly dependent on fossil fuel energy exports more severely impacted. In addition, a broad range of policies and a well-functioning financial and labour markets can contribute to mitigating the adjustment costs to a low-carbon economy and opening up new economic opportunities.

The simulation results suggest that a low-carbon economy would necessarily lead to a substantial

Figure C.1: Trade in electricity could increase in a low-carbon economy



Source: Bekkers et al. (2022).

Note: Simulation results based on the WTO GTM. The "low-carbon 2050" scenario assumes countries cooperate to achieve almost net zero emissions by 2050.

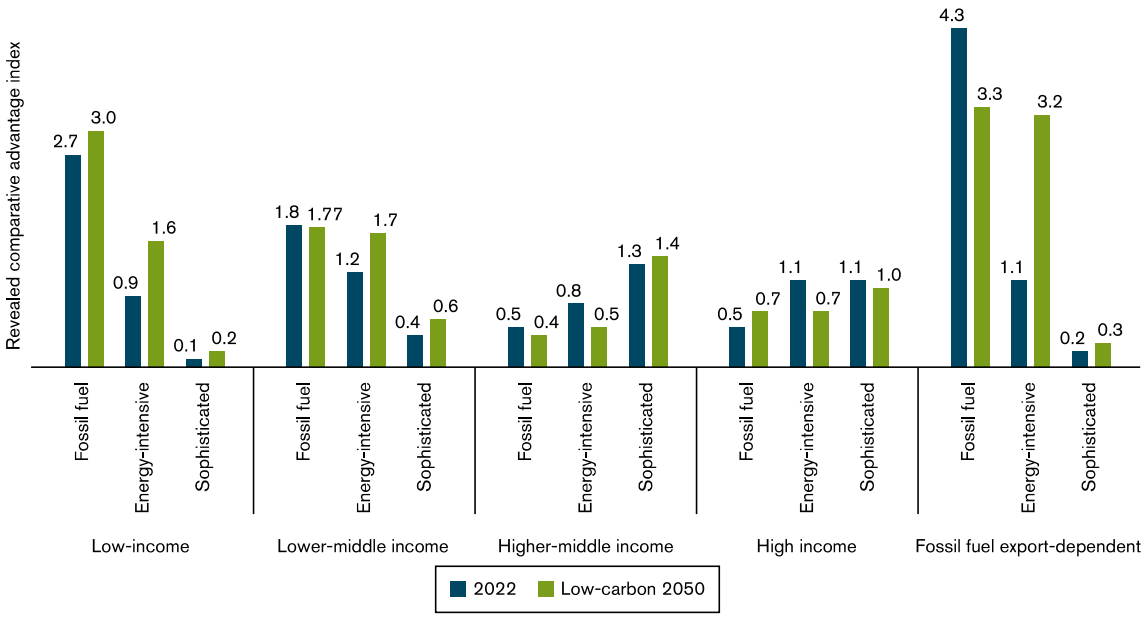
reduction in the real output of coal, oil, gas and refined petroleum products in all regions, ranging from between 50 per cent in fossil fuel export-dependent countries (FFEDCs)[17] to more than 60 per cent and 70 per cent in low- and higher middle-income countries. At the same time, capital and labour would likely be reallocated to different activities to ensure a low-carbon transition. Countries could thus shift their production and comparative advantages from fossil fuels sectors to energy-intensive industrial sectors, such as iron and steel, and to knowledge-based sophisticated sectors, such as computer electronic equipment and motor vehicles.

The change in trade patterns as a result of decarbonization is reflected in the relative ability of a country to produce a good vis-à-vis its trading partners, commonly known as revealed comparative advantage (RCA). The increase in the RCA of FFEDCs in energy-intensive sectors could be larger than in sophisticated sectors, because a reduction of fossil fuel prices as a result of decarbonization makes regions with large reserves of fossil fuels more competitive in energy-intensive sectors (see Figure C.2). This trend, though smaller in magnitude, could also be observed in low-income countries. Due to the shift of energy-intensive sectors and sophisticated sectors to other regions, high-income countries could experience a small reduction of their RCA in sophisticated sectors and energy-intensive sectors, although they would maintain their comparative advantage in sophisticated sectors.

At the same time, FFEDCs and low-income regions could benefit from a low-carbon transition. As mentioned in the previous section, decarbonization could help FFEDCs and low-income regions to diversify their economies away from volatile fossil fuel sectors towards more sophisticated sectors with more growth potential, offering new economic opportunities. Furthermore, FFEDCs and low-income countries with significant renewable energy source potentials could also shift towards production and exports of renewable energies. However, the current export revenues from fossil fuels would not be fully replaced with revenues from exporting renewable electricity, because unlike fossil energy, electricity, including from renewable sources, is less tradeable over long distances.[18] Production and export opportunities may also be explored in goods and services produced with renewable energy.

The materialization of these new economic opportunities hinges to a large extent on the adoption of complementary policies to facilitate access to and diffusion of environmental technologies, and shift

Figure C.2: A low-carbon economy could lead economies to shift their comparative advantages



Source: Bekkers et al. (2022).

Note: Results based on the WTO GTM. Revealed comparative advantage (RCA) is an index defined as the share of an economy's exports in that economy's total exports, relative to the share of the world's exports in that sector in total world exports. A RCA higher than one indicates a country has a revealed comparative advantage for a given sector. The higher the value of a country's RCA for a sector, the higher its export strength.

investment from fossil fuel-based physical capital to human capital (Peszko et al., 2020). Policies to tackle climate change, promote education and energy infrastructure are also essential to ensure that countries have the appropriate enabling conditions to support the environmental industry (see Chapter F). As discussed in Section C.4, financial and technical support are also important to mitigate the adverse impacts of the transition and enable countries, in particular low-income economies, to take advantage of new low-carbon economic opportunities.

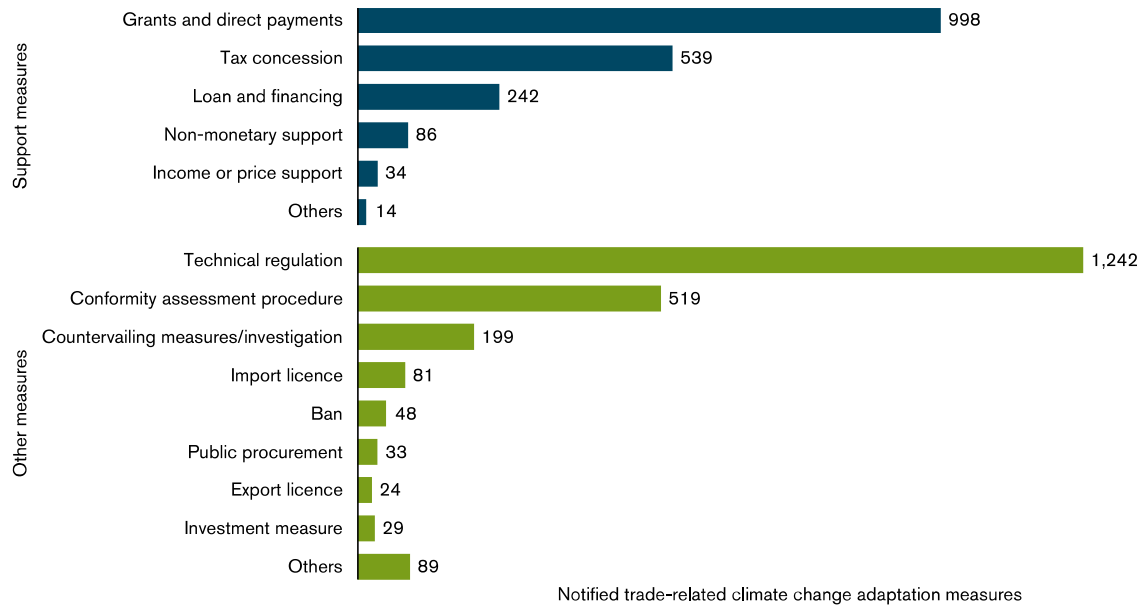
(d) Some climate change mitigation policies may have trade implications

The transition to a low-carbon economy requires ambitious climate change mitigation policies. Some of these policies can have trade impacts and generate cross-border spillovers, which may affect governments' mitigation policy strategies and levels of ambition. One key problem is that the effectiveness of certain mitigation policies, when adopted unilaterally, may be undermined by the lack of ambition in other countries and a loss of competitiveness (see also Chapter D).

While not all climate change mitigation policies have trade implications, trade-related climate change mitigation measures are often notified to the WTO. Between 2009 and 2020, WTO members notified 3,460 measures explicitly addressing climate change mitigation, but also energy conservation and efficiency, and alternative and renewable energy.[19] Most of these notified trade-related climate change mitigation measures are support measures and technical regulations and conformity assessment procedures (see Figure C.3). For example, notified measures include new regulatory requirements to reduce the use of fluorocarbons and promote alternative chemicals with low global warming potential,[20] preferential tax treatment for energy-saving and new energy vehicles and vessels,[21] and the use of import licences to regulate lighting with minimum energy performance standards.[22]

Depending on their design and implementation, trade-related climate change mitigation policies can raise concerns among trading partners on the grounds that these measures can discriminate among different trading partners or between imports and similar domestic goods, or can unnecessarily restrict trade. For instance, prohibition and phase-out mandates can have negative impacts on trade by forcing foreign suppliers that previously served a given market to redirect their exports or terminate them entirely.[23]

Figure C.3: Support measures and technical regulations are the most common trade-related climate change mitigation measures



Source: Authors' calculations, based on the WTO Environmental Database.

Note: The figure reports climate change mitigation measures notified to the WTO between 2009 and 2020 by types of policies. One notified measure can cover more than one type of policy.

Carbon pricing can also have trade implications, as discussed in detail in Chapter D.[24] Some types of support measures can also create trade tensions, such as support measures that attribute exclusive rights to the use of research output by domestic firms (WTO, 2020a) or that are provided to shield domestic producers from foreign competition, or strategically for industrial policy purposes (UNEP and DIE, 2017). For instance, subsidies with local content requirements can spur investment in homegrown climate-friendly infrastructure and technology, but at the same time be trade-restricting.

Fossil fuel subsidy reform can also affect trade competitiveness by increasing the prices of intermediates for energy-intensive industries (Burniaux, Château and Sauvage, 2011), thus increasing the production costs and reduce the competitiveness of carbon-intensive industries such as steelmaking, petrochemicals and aluminium (Cockburn, Robichaud and Tiberti, 2018; Ellis, 2010; Jensen and Tarr, 2003). The removal of support for fossil fuel consumption and production worldwide also impacts FFEDCs. However, ultimately, the trade impacts of fossil fuel subsidy reform depend on firms' response measures (Moerenhout and Irschlinger, 2020). Firms can, for example, substitute certain energy inputs for alternative sources, improve resource efficiency or pass directly the compliance costs on to consumers, although if firms decide to respond by increasing prices, this can harm their competitiveness in the international market (Rentschler, Kornejew and Bazilian, 2017).

The use and proliferation of informational instruments, such as environmental labels, has important trade implications. Few mandatory labelling requirements are currently in place, but prominent voluntary labels can ultimately become a market entry requirement (OECD, 2016). The multiplication of informational schemes may negatively impact the international competitiveness of producers by increasing compliance costs, including the costs of information-seeking, of switching to more expensive environmentally-friendly production methods, and of adopting complex certification and audit procedures. The latter are particularly burdensome for producers in developing countries and MSMEs, who often lack the infrastructure required for certification and traceability requirements (UNEP, 2005) (see Box C.2).

At the same time, some trade policies can incentivize higher levels of environmental protection. For instance, government support, such as R&D investments, can propagate knowledge diffusion across borders (Fadly and Fontes, 2019; Shahnazi and Shabani, 2019), and trade can play an important role in enhancing this effect. Similarly, GGP policies can be combined with more open government procurement markets to increase the number of suppliers participating in

Box C.2: The role of MSMEs in a low-carbon transition

MSMEs account for roughly 90 per cent of global businesses and an estimated 50 and 35 per cent of GDP in developed and developing economies, respectively (WTO, 2016). Many MSMEs are owned and led by women (World Bank and WTO, 2020).

Although MSMEs can play a large role in achieving global decarbonization targets, only a fraction of them have plans to decarbonize their activities (BCG-HSBC, 2021), despite the fact that the transition to a low-carbon economy offers them a number of opportunities and benefits, from new environmental products and services, to increased production efficiency and lower business costs (ITC, 2021). For instance, 25 per cent of total expected investment across 15 clean energy sectors in developing countries could be accessible to MSMEs (World Bank, 2014). Internationalization can further drive MSME sustainability practices, through exposure to new technologies, new compliance requirements in foreign markets, and demand for sustainability by foreign consumers (Hojnik, Ruzzier and Manolova, 2018).

Nevertheless, significant challenges inhibit further carbon mitigation initiatives by MSMEs. Capital-constrained businesses may be unable to invest without support in more sustainable production and energy-efficient techniques, despite their long-term payoffs (IEA, 2021). MSMEs may also struggle to comply with, or benefit from, climate change mitigation policies, particularly when national and international standards diverge (WTO, 2022c).

Often designed in developed economies, environmental standards and other non-tariff measures to support environmental products, including testing and conformity assessments, can be especially challenging for MSMEs from developing economies to comply with (Pesko et al., 2020). Clear climate change mitigation policies designed with MSME considerations in mind can both promote inclusivity and provide new environmentally sustainable business opportunities for all enterprises.

tenders, and potentially give government purchasers access to more climate-friendly goods, services and technological solutions.

Trade can also raise ambitions with regard to environmental standards and regulations, since firms that wish to export to highly regulated countries have an incentive to develop or adopt higher standards. Analyses of the car industry, for instance, have found that markets that have high emission standards for vehicles tend to put pressure on countries that do not, thereby inducing a ratcheting-up of regulations in these countries (Crippa et al., 2016; Perkins and Neumayer, 2012). As discussed in the next section, international cooperation plays an important role in mitigating potential negative trade impacts and in leveraging synergies through concerted, coordinated and transparent actions.

4. International cooperation is essential to achieve a low-carbon economy

Climate change is a problem of the global commons. In the absence of global coordination, the adoption of individual climate change mitigation strategies is likely to be less than optimal (Akimoto, Sano and Tehrani, 2017; Thube, Delzeit and Henning, 2022). In addition, economic agents may avoid reducing their GHG emission by free-riding on the mitigation efforts of others, while governments' concerns over losing competitiveness could lead to "race to the bottom" or "regulatory chill" situations in which they lower or fail to implement their climate policies, or refrain from adopting ambitious climate policies (Copeland and Taylor, 2004; Dechezleprêtre and Sato, 2017).

International cooperation can help to overcome these challenges and to scale up action on climate change mitigation. It helps to avoid unproductive frictions or obstacles and to address cross-border spillovers, both negative and positive, generated by unilateral climate policies (Kruse-Andersen and Sørensen, 2022). International cooperation ultimately can help allow for the reduction of GHG emissions at the lowest possible cost for growth and is essential for a just transition to a global low-carbon economy.

(a) Greater international cooperation is needed to support a just low-carbon transition

Despite the UNFCCC's 30-year history, progress on climate action has been too slow and uneven to fully contain global temperature increase. The current GHG emission reduction pledges that countries made under the Paris Agreement and other climate mitigation measures adopted would only reduce global carbon emissions by 7.5 per cent by 2030, more than six times less than what would be necessary to keep the global temperature increase below 1.5°C by 2100. In the absence of more ambitious climate change policies and initiatives, the world is projected to hit global warming of about 2.7°C by the end of the century (UNEP, 2021a).

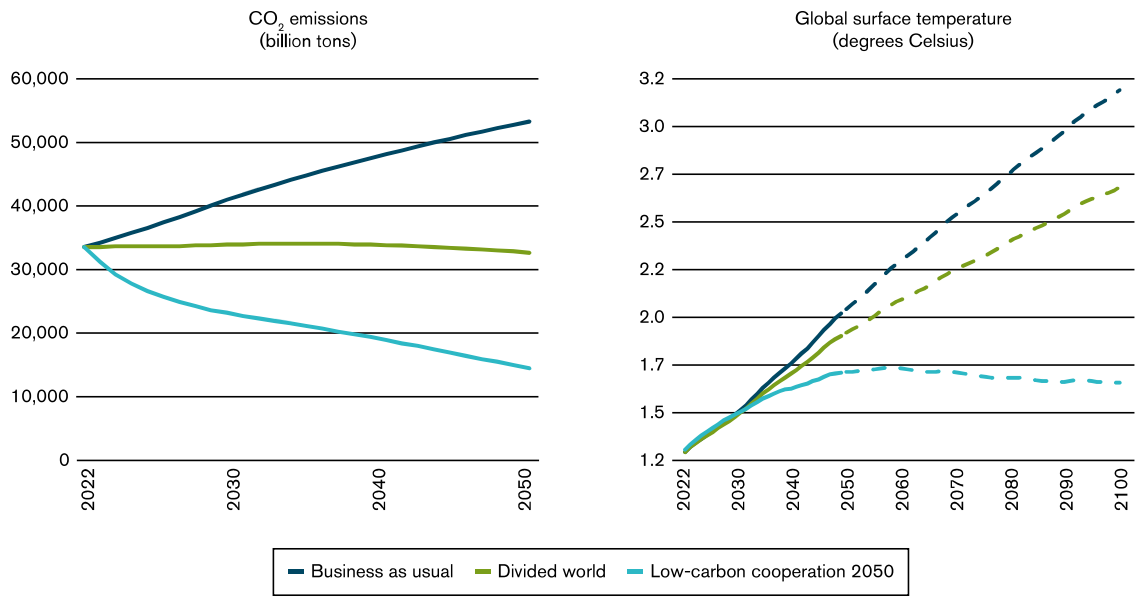
To keep the increase in global temperatures below 1.5°C, the aspirational goal of the Paris Agreement, the world needs to halve annual GHG emissions in the next eight years. This requires additional cooperation among countries. To illustrate the importance of international cooperation, the WTO GTM was used to assess the CO_2 emission and global temperature trajectories of three scenarios (Bekkers et al., 2022).[25]

The baseline "business-as-usual" scenario assumes countries continue to implement their climate change mitigation policies at their respective 2021 levels, without taking further action to implement their NDC pledges. The simulation results suggest that, in the absence of more ambitious global climate change mitigation actions, global annual carbon emissions could reach over 50 gigatonnes of CO_2 (Gt CO_2) in 2050, while the average global temperature could rise by 2°C warming and by over 3°C by the end of the century (see Figure C.4).

Under the "divided world" scenario, countries are assumed to take unilateral climate change mitigation policies, including national carbon pricing, in line with their NDC pledges until 2030.[26] After 2030, carbon prices are assumed to follow a linear growth pattern, resulting in a wide gap between unilaterally imposed carbon prices, which lead countries with high carbon prices to impose border carbon adjustments on imports from countries with less stringent mitigation policies (see Chapter D). Electrification and renewable shares would keep increasing in an uneven manner until 2050, while coal phase-out would be achieved only by countries which have pledged to do so by 2050. The lack of international cooperation could lead to relatively constant global carbon emissions and an average global temperature rise of 1.9°C by 2050 and 2.6°C by the end of the century, well above the Paris Agreement's objective to mitigate climate change.

The "low-carbon cooperation" scenario, described in Section C.3, assumes countries cooperate to tackle climate change by adopting ambitious climate changes policies, including a global carbon pricing system. In contrast to a situation marked by

Figure C.4: International cooperation is needed to reduce carbon emissions and limit global warming to less than 2°C



Source: Bekkers et al. (2022).

Note: Results based on the WTO GTM. The "business as usual" scenario assumes countries continue to apply their climate change policies at their 2021 levels. The "divided world" scenario assumes countries adopt unilaterally climate change policies. The "low-carbon cooperation 2050" scenario assumes countries cooperate by adopting a global carbon pricing system.

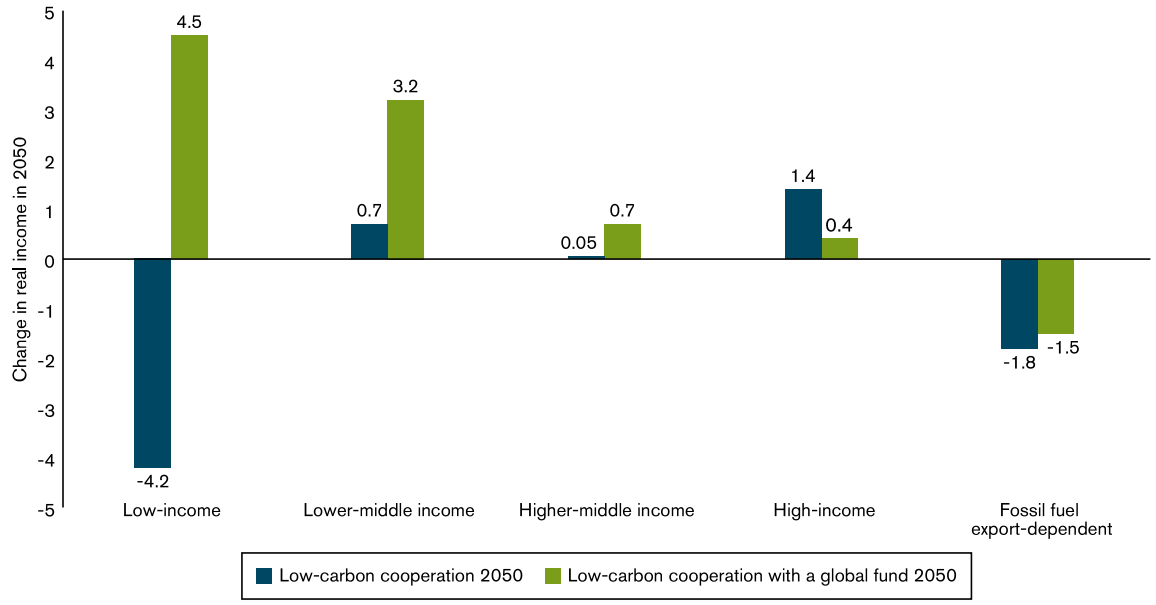
unilateral and uncoordinated climate change policies, international cooperation and coordinated actions could lead to annual global carbon emissions to fall to 14.4 Gt CO_2 and the global average temperature to rise by approximately 1.7°C by 2050, below the Paris Agreement's objective to limit global warming to well below 2°C above pre-industrial levels.

In addition to achieving carbon mitigation objectives, greater international cooperation is also needed to ensure a just low-carbon transition. As discussed in Section C.3, the impacts of decarbonization are unevenly distributed between high-income and low-income regions. Low-income economies could experience a slow-down in economic growth in the absence of complementary and adjustment policies because their economy is less diversified and relatively more reliant on fossil fuel than middle- and high-income economies (except FFEDCs). In addition, low-income economies tend to face a relatively high cost of capital and a limited access to international financial markets which hinder governments and firms in those countries to finance the transition towards a low-carbon economy.

Several options, including additional financial mechanisms, have been discussed in the literature to enable developing countries, and in particular LDCs, to offset the economic costs associated with the transition from an economy based on relatively cheap fossil fuels to an economy based on low-carbon technologies. For example, the so-called Global Carbon Incentive (GCI) would establish a global fund into which regions emitting more than the global average would contribute to the fund, while regions emitting less than the average would receive revenues from the fund (Cramton et al., 2017; Rajan, 2021).

The WTO GTM was used to explore how such a global fund could contribute to a just low-carbon transition. The simulations suggest that implementing an additional financing mechanism to distribute the low-carbon transition burden between high- and low-income countries could increase low and lower-middle income countries' real income by 4.5 per cent and 3.2 per cent, respectively, thus turning the initial negative impact of decarbonization for low-income countries into a positive impact on economic growth (see Figure C.5). Additional financing mechanisms can therefore play an important role in rebalancing the decarbonization impacts with a relatively minimal cost and contribute to a just low-carbon transition.

Figure C.5: Greater cooperation with additional financing mechanism would support a just low-carbon transition



Source: Bekkers et al. (2022).

Note: Results based on the WTO GTM. The figure displays the change in real income in 2050 relative to "business as usual" scenario. The "business as usual" scenario assumes countries continue to apply their climate change policies at their 2021 levels. The "low-carbon cooperation 2050" scenario assumes countries cooperate by adopting a global carbon pricing system. The "low-carbon cooperation 2050 with global fund" scenario assumes that countries cooperation by adopting a global fund to compensate adversely affected countries. Each country's net payment to the global fund is calculated on the basis of the difference between the country's per capita carbon emissions and the global average per capita emissions, multiplied by its population and a reference global price for carbon emissions.

(b) International cooperation on climate adaptation is broad and diverse

International cooperation on climate change mitigation is cross-cutting and involves a broad range of actors at the national, regional, plurilateral and multilateral level. The UNFCCC is the central multilateral framework for tackling climate change, providing an international forum for global negotiations on climate change, while also coordinating the implementation of climate policies. Such coordination can play an important role in the development of national GHG reduction policies, as it can provide assurance to domestic policymakers that commensurate efforts are being taken internationally by key trading partners. A number of countries also pursue bilateral and regional agreements on climate change mitigation in parallel to and in support of the commitments established under the UNFCCC (OECD, 2015).

Other international cooperation efforts, including through other multilateral environmental agreements, have also increasingly looked at how enhanced coordination under their own frameworks could support climate action. For example, the parties to the Montreal Protocol on Substances that Deplete the Ozone Layer adopted the Kigali Amendment to reduce the production and trade of hydrofluorocarbons (HFCs), a refrigerant with high global-warming potential. Its full implementation is expected to prevent up to 0.4°C of global warming by the end of the century. Some sectoral cooperation efforts are directly related to climate mitigation, such as sustainable forestry efforts under the International Tropical Timber Organization (ITTO), support for low-carbon energy transition at the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA), and efforts to decarbonize transportation under the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) (see also Chapter E).

Cooperation and coordination among non-governmental organizations (NGOs), and between them and governments, are also on the rise.[27] The private sector has also intensified its engagement in international cooperation on climate change mitigation.

(c) International cooperation on trade can support and enhance climate change mitigation actions

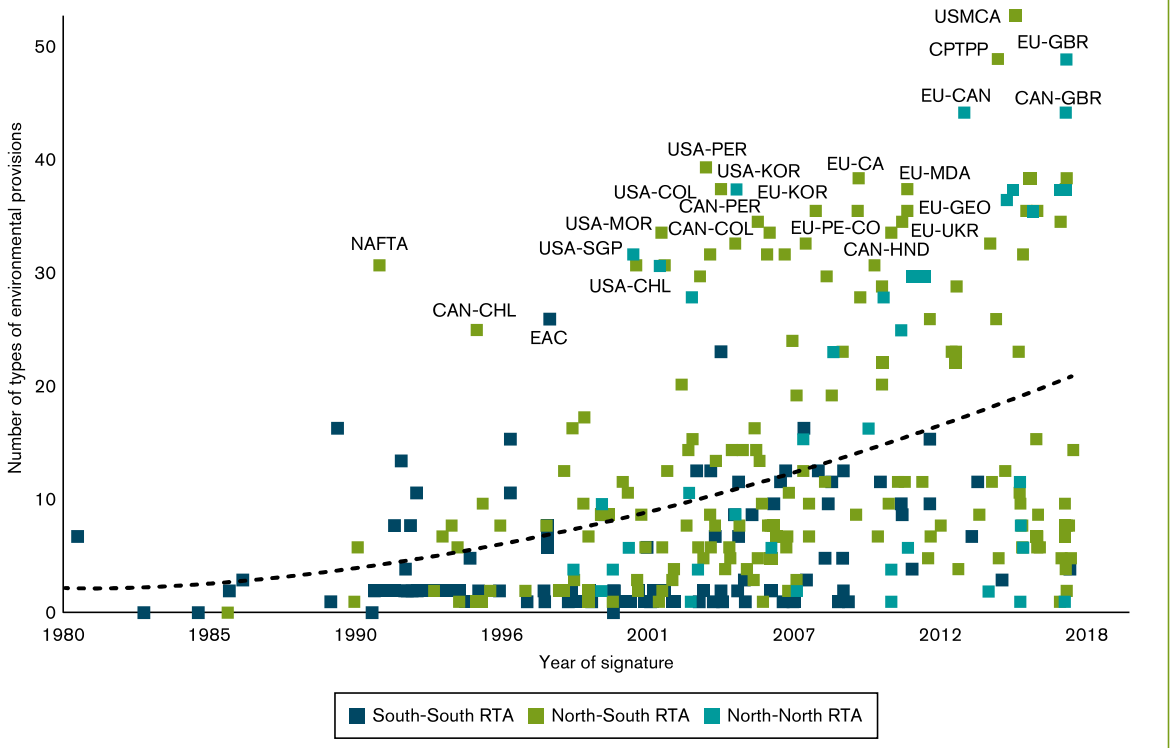
Although the term "international trade" does not feature in the Paris Agreement, its parties have discussed numerous trade-related elements to support climate efforts as part of their cooperation under several technical bodies, including the Forum on Response Measures, the Katowice Committee of Experts (KCI) and the Koronivia Joint Work on Agriculture. In such discussions, the potential role of trade to support parties in their climate efforts has often been highlighted, including the role of trade in helping countries to diversify economically away from their reliance on carbon-intensive sectors and with the just transition of workforces to new low-carbon sectors (UNFCCC, 2016b).[28]

International trade is also an integral part of a limited but increasing number of countries' NDCs to achieve their climate mitigation goals (WTO, 2021f). A review of the NDCs announced in the run-up to the 21st Conference of the Parties or Paris Climate Conference (COP21) of 2015 reveals that, while 45 per cent of NDCs included a direct reference to trade, only around 22 per cent of all NDCs referred to specific trade-related measures geared towards fostering emission mitigation (Brandi, 2017). The trade implication of some of these explicit measures listed in NDCs may, however, not necessarily materialize depending on the instruments and measures ultimately adopted at the domestic level to implement them.

The last 30 years have seen a rapid proliferation of regional trade agreements (RTAs). While RTAs traditionally aimed at lowering tariff and non-tariff trade barriers, an increasing number of RTAs explicitly address sustainable development and environmental issues. The number and level of detail of environmental provisions in RTAs has also increased significantly over the years (see Figure C.6), with the most detailed provisions often found within chapters dedicated to environment or sustainable development or within environmental cooperation agreements (Monteiro, 2016).

Provisions that explicitly address climate change in RTAs have similarly increased over the years, although these tend to be less frequent (namely, 64 RTAs notified to the WTO) and detailed than other types of environmental provisions (WTO, 2021b).

Figure C.6: Environmental provisions in RTAs continue to expand



Source: Authors' calculations, based on updated data from Monteiro (2016).

Note: Analysis based on RTAs notified to the WTO. "North" is defined as high-income countries, whereas "South" is defined as middle- and low-income countries according to the World Bank's country classification.

Provisions on climate change can take many forms. Some provisions underscore the importance of addressing climate change, including through trade in environmental goods and services and reducing subsidies for fossil fuels, while others require the parties to effectively implementing the Paris Agreement and adopt climate change policies.[29] The most common type of provisions identifies climate change mitigation as a cooperation area, covering different issues including alternative energy and energy conservation, sustainable forestry management, and activities related to aspects of the international climate change regime with relevance for trade.[30]

Explicit provisions on climate change are often complemented by other environmental provisions. For instance, provisions establishing level-playing-field commitments to ensure environmental policies are effectively applied. RTAs may also establish institutional arrangements as tools for ensuring implementation. These can entail, for example, setting up committees to ensure dialogue on implementation, implementing public accountability mechanisms, and carrying out *ex post* reviews of commitment implementation (Monteiro, 2016; Monteiro and Trachtman, 2020).

In addition to regional trade initiatives, the multilateral trading system provides an enabling framework that contributes to can support climate mitigation efforts. As discussed below in greater detail, WTO rules, the WTO monitoring and transparency functions, and the Aid for Trade initiative provide important mechanisms to foster a coherent linkage between trade and climate policies.

(d) WTO rules help to prevent protectionism and to promote efficient and effective trade-related climate policies

Measures adopted by WTO members in pursuit of climate goals may, by their very nature, restrict trade and thereby affect the rights, under WTO rules, of other members. The WTO Agreements expressly recognize the rights of WTO members to adopt measures to protect the environment so long as they are not applied arbitrarily and are not more restrictive than necessary. WTO members have also reaffirmed, at the political level, that WTO rules do not override environmental protection (WTO and UNEP, 2009, 2018).[31]

The preamble of the Marrakesh Agreement Establishing the World Trade Organization (WTO Agreement)[32] states that sustainable development and the protection of the environment are central objectives of the multilateral trading system. According to WTO jurisprudence, the preamble to the WTO Agreement "informs" the reading of all WTO covered agreements and "shows that the signatories to that Agreement were, in 1994, fully aware of the importance and legitimacy of environmental protection as a goal of national and international policy."[33]

The common understanding on the urgent need to act on climate, as enshrined, for example, in the Paris Agreement, is important since WTO law should not "be read in clinical isolation from public international law."[34] A deeper understanding by the trade community of the content and rationale of the multilateral climate framework can be key to enhancing the mutual supportiveness between the two systems. This requires enhanced domestic coordination between ministries and domestic agencies involved in trade and climate policies and diplomacy, but it is also carried out by the regular work of the Committee on Trade and Environment (CTE), as discussed below.

While WTO rules do not prevent members from adopting a wide range of ambitious climate measures, they do impose a series of requirements to ensure that measures are tailored to their objectives.[35] In particular, members seeking to adopt trade-related climate measures must respect a series of key WTO principles, such as non-discrimination between domestic and foreign products (national treatment) and among trading partners (most-favoured nation treatment), transparency in designing and implementing the measure, avoiding creating unnecessary barriers to trade, and the prohibition on quantitative restrictions to trade.

However, even if certain climate measures might, at first, appear to be contrary to one or more of such principles as defined in WTO Agreements (e.g., because they impose restrictions on trade in certain particularly carbon-intensive goods), WTO rules contain important flexibilities that allow for the accommodation of legitimate policies. Article XX of the General Agreement on Tariffs and Trade (GATT) introduces the "general exceptions" to obligations under this agreement, one of the main examples of such flexibility. However, several other WTO Agreements contain similar flexibilities, such as the General Agreement on Trade in Services (GATS), the Technical Barriers to Trade (TBT) Agreements, and the Agreement on Trade-Related Investment Measures (TRIMs Agreement). WTO adjudicators have reaffirmed time and again the rights of WTO

members to determine their own environmental and climate policies, as well as the degree of protection they choose, even if that significantly restricts trade.[36]

Environment-related disputes at the WTO have helped to clarify that there are several useful checks to ensure that trade-related measures to fight climate change are not misused for protectionist purposes. These checks include:

- Coherence: The trade restriction or difference in treatment between domestic and imported products can be explained by the legitimate objective pursued rather than by the granting of protection to domestic sectors.
- Fit-for-purpose: The measure can efficiently contribute to the legitimate objective in a balanced way or is part of a domestic conservation policy also restricting domestic production or consumption.
- Mindful and holistic: The measure forms part of a holistic climate policy and considers the impact on other countries, as well as on other national, regional and international efforts on the same topic.
- Flexible: The measure is result-oriented and takes into account alternative measures to address the same challenge as effectively.

Environmental measures modified in light of these principles following WTO disputes have resulted in more coherent and effective measures to protect the environment, even if they have also led to more significant trade effects. That is because once the unjustifiable or arbitrary discriminatory elements of these measures were corrected or eliminated, the environmental policies were often applied to a wider and more coherent number of goods, more effectively, and more in line with the legitimate objective (WTO, 2020b).

Several other WTO disciplines also seek the same objective of ensuring better, more effective and less distorting trade policies aimed at legitimate objectives. A number of WTO agreements address specific types of trade-related measures, which can be applied to address climate change, as discussed in Section C.2.

The TBT Agreement covers mandatory technical regulations, voluntary standards and conformity assessment procedures in respect of all products (including industrial and agricultural products). It recommends that technical regulations should, to the extent possible, be based on performance, rather than on design and descriptive features. This principle helps to ensure that producers and innovators anywhere — including from developing countries and LDCs — can find the most effective and efficient way of fulfilling the requirements of the technical regulation. It can also avoid "locking-in" certain technological solutions that might no longer be the most environmentally efficient in the future. The TBT Agreement also recognizes the need to support developing-country producers to comply with such requirements.

The WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement) establishes a balanced framework for the innovation and dissemination of climate technologies for the mutual benefit of innovators and technology users, in particular through a range of tailored domestic measures concerning the governance of the intellectual property (IP) system for social and economic welfare. The IP system works in conjunction with international trade to facilitate knowledge transfers and diffusion of critical mitigation technologies, including through the effect of GVCs and knowledge spillovers, and trade in knowledge-intensive goods (Delgado and Kyle, 2022).

Under Article 66.2 of the TRIPS Agreement developed-country members are required to provide incentives for enterprises and institutions in their territories to encourage technology transfer to LDCs. Since 2003, developed-country members have been required to submit annual reports on actions taken or planned in this area. A review of the annual reports submitted by nine developed-country members between 2018-20 reveals that some 754 technology transfer programmes, of which 152 covered environmental and climate change technologies transferred to 41 LDC recipients.[37] Around 82 per cent of these programmes focused on various climate-related issues, including renewable energy, energy efficiency, climate adaptation and sustainable water and forest management (see Figure C.7).

The Agreement on Subsidies and Countervailing Measures (SCM Agreement) disciplines the use of subsidies, and regulates the actions WTO members can take to counter the effects of subsidies. While not all climate support measures are covered by the SCM Agreement (as it only covers financial contributions, income or price supports that confer a benefit), subsidies that are specific to certain enterprises and cause adverse effects can be "actioned" by affected WTO members by applying domestic measures (countervailing duties) or through the WTO Dispute Settlement System (WTO, 2020b). In addition,

Figure C.7: Most environmental technology transfer programmes reported under TRIPS Article 66.2 relate to climate change

Source: Authors' calculations, based on the reports submitted by developed-country members under TRIPS Article 66.2

Note: The numbers in parenthesis report the number of environmental technology transfer programmes by type of environmental objective reported under TRIPS Article 66.2 between 2018 and 2020.

subsidies contingent upon the use of domestic goods or export performance are considered to be particularly harmful to trade and prohibited.[38]

The SCM Agreement used to include a list of certain "non-actionable" subsidies, including those for R&D, regional development and the adaptation of existing facilities to new environmental requirements. However, this provision applied only during the first five years that the SCM Agreement was in force. A revival of the category of non-actionable subsidies is often discussed within the context of government support for climate change mitigation (Howse, 2010).[39]

In recent years, a few disputes concerning support provided for renewable energy generation and conditioned upon the use of domestic content (i.e., local content requirement) were brought before the WTO Dispute Settlement System.[40] In none of these disputes was the goal of promoting renewable energy put into question. However, the aspects that were found to be contrary to WTO disciplines were the requirements for energy producers to use local components and products. In addition, the Appellate Body indicated that, when assessing the benefit from a support measure for renewable energy, due consideration of a country's sustainable energy production objectives should be given, and that an appropriate benchmark should be used that could take into consideration the differences in costs and environmental externalities involved in fossil fuel-based energy and renewable energy production.[41]

In effect, these trade disputes raise the question of whether local content requirements are effective and appropriate means of promoting renewable energy production. Some evidence suggests that local content requirements have hindered global international investment flows in solar PV and wind energy, reducing the potential benefits from international trade and investment (OECD, 2015; Stephenson, 2013) and ultimately can hamper or slow down climate change mitigation efforts (WTO and IRENA, 2021).

The increasing use of trade defence measures, namely antidumping, countervailing duties and safeguards, against imports of renewable energy goods and other products required for the low-carbon energy transition has also raised concerns about their impact on climate mitigation efforts (see Chapter F) (Horlick, 2014; Kampel, 2017; Kasteng, 2014; UNCTAD, 2014).

While WTO members have the right to decide whether to initiate investigations and apply trade defence measures (including based on public interest considerations, such as climate change), WTO rules seek to ensure that such measures and processes are not abused.

The Agreement on Agriculture (AoA) aims to reduce trade restrictions on agricultural products caused by barriers to market access, exports subsidies and subsidies that directly stimulate production and distort agricultural trade. The AoA contains, however, a category of permissible subsidies, known as "Green Box" support measures, which include certain flexibilities for domestic support afforded for environmental purposes. This, together with certain conditions and other flexibilities for limited distortive programmes, can provide members with opportunities to pursue climate-related measures in the area of agriculture (see Chapter B).

The plurilateral WTO Agreement on Government Procurement (GPA 2012) commits its signatories to opening their government procurement markets to each other's suppliers in a reciprocal manner.[42] The GPA 2012 can help governments to obtain better value for money for climate-friendly goods and services through GPP (See Section C.2). The agreement notably allows parties to apply technical specifications aimed at promoting natural resource conservation or protecting the environment, as well as to use the environmental characteristics of a good or service as an award criterion in evaluating tenders.

As the low-carbon transition entails a change in the composition of energy trade as well as trade in manufactured inputs and complementary products necessary to generate renewable energy, governments may increasingly resort to trade policies to adjust to and support this transition. Greater cooperation on trade policies, such as trade remedies, subsidies, IP protection and local content requirements, would be necessary to discuss further, and potentially clarify, strengthen and update WTO rules to ensure the low-carbon transition can be achieved as smoothly as possible.

(d) Transparency and dialogue support coherent and fit-for-purpose climate change policies

Transparency is an important feature of decision-making and regulatory action to address transboundary problems, such as climate change (Gupta and Mason, 2014). It contributes to build trust, enhance accountability, and potentially improve the effectiveness of climate change policies.

Several WTO agreements require WTO members to inform each other about new or forthcoming trade-related measures, including those related to climate change. The notification process is an essential tool to facilitate access to information about trade-related climate measures contemplated by members.

Under the Trade Policy Review Mechanism, WTO members also carry out periodic collective assessments of each member's trade policies and practices. These exercises promote greater transparency in, and understanding of, members' trade policies, including those that relate directly to climate change.

The WTO Environmental Database (EDB) compiles in one single interface the environment-related measures notified by members, as well as the environment-related information contained in members' trade policy review reports.

For transparency to be effective, it is essential to go beyond the simple exchange of trade-related information, and understand what is being notified and their implications on other members. Through its committees and other bodies, the WTO provides a forum that give members the opportunity to share experiences and best practices and address trade concerns and avoid trade disputes.[43]

Climate-related trade measures are discussed in most WTO bodies. For instance, the Council for Trade in Goods has recently discussed the European Union's plans for a carbon border adjustment mechanism.[44] Market access issues related to environmental services were addressed in the Council for Trade in Services.[45] The TRIPS Council discussed a wide array of policies and initiatives addressing the interplay of IP, climate change and development.[46] The TBT Committee considered several specific trade concerns related to technical regulations and conformity assessment procedures related to energy efficiency.[47]

A more focused discussion on trade and climate policies takes place in the CTE, where members specifically meet to discuss how trade and environmental measures could work better together to promote sustainable development. These discussions and information exchange also cover issues related to the low-carbon transition, such as environmental taxes and labelling schemes, sustainable natural resource management, environmental goods and services, and the environmental footprint of products and organizations. The CTE also serves as a forum

where the secretariats of multilateral environmental agreements, such as the UNFCCC, and other institutions, such as the International Civil Aviation Organization, regularly brief WTO members on their trade-related environmental work.

At the same time, more could be done to ensure that the work in the WTO leads to solutions and concrete actions supporting the transition to a low-carbon economy. Three new environmental initiatives – the Trade and Environmental Sustainability Structured Discussions (TESSD) and the Informal Dialogue on Plastics Pollution and Environmentally Sustainable Plastics Trade (IDP) (both launched in November 2020), and the Fossil Fuel Subsidy Reform initiative (FFSR) (launched in December 2021), share the common goal of ensuring that trade and the WTO form part of the solution to climate change and environmental degradation.[48] These initiatives, which are open to all WTO members, also actively involve external stakeholders, such as NGOs, businesses, academia and other international organizations, each of which provide technical expertise and experience.

Climate change is one of the main themes of the TESSD, which aim to complement discussions in the CTE. Participants in the TESSD have been discussing how trade-related climate change measures can best contribute to climate and environmental goals and commitments, while remaining consistent with WTO rules. They are working towards identifying solutions and concrete actions to contribute to the transition to a low-carbon economy, including environmental goods and services, the circular economy, sustainable supply chains and the trade and environmental effects of subsidies.

The IDP is concerned with the rising environmental, health and economic costs of plastics pollution, since 99 per cent of plastics are fossil fuel-based, and can release emissions throughout their lifecycle (CIEL, 2019). Plastics currently generate 1.8 gigatonnes of CO_2-equivalent, and this could more than double by 2060 in the absence of significantly more stringent and coordinated action (OECD, 2022c). Participants in the IDP have been discussing how the WTO can contribute to strengthening policy coherence, exploring collective approaches among WTO members, and improving technical assistance to developing countries in support of global efforts to reduce plastic waste and move towards a circular plastics economy.

The FFSR initiative encourages the rationalization and phasing-out of inefficient fossil fuel subsidies that lead to wasteful consumption. Globally, countries subsidized fossil fuel production and consumption to the tune of over US$ 440 billion in 2021 (IEA, 2022d). The initiative foresees exploring the trade relevance of discussing FFSR in the multilateral trading system, including by taking stock of international efforts and members' priorities, discussing the development and social aspects of FFSR, and providing updates on members' actions with regard to transparency and reforms.

In addition to dedicated environmental initiatives, the WTO could further strengthen its role as a forum for coordination and dialogue on trade and climate change, as well as for cooperation with other international organizations to develop recommendations regarding the trade-related policies and instruments needed for the transition to a low-carbon economy (see, for example, Chapter D on carbon pricing). In addition, the WTO could also advance dialogue with the private sector to address trade-related challenges for decarbonizing supply chains (see also Chapter E).[49]

(e) Aid for Trade can play an important role in supporting a just transition to a low-carbon economy

As discussed in Section C.2, climate finance is vital for a just transition to a low-carbon economy. Yet, climate finance levels remain far below what is needed to prevent global temperature from rising above 1.5°C. Available estimates suggest that although total climate finance has increased, on average, by almost 15 per cent between 2011 and 2020, the increase in annual climate finance flows has slowed in recent years. Projections suggest that annual climate finance flows would need to increase by 590 per cent in order to reduce GHG emissions by 45 per cent by 2030 and avoid the most dangerous consequences of climate change (Climate Policy Initiative, 2021).

The Aid for Trade initiative can help to assist developing countries and LDCs in mobilizing some of the financial support required to meet their trade integration objectives while pursuing the transition to a low-carbon economy.

While Aid for Trade mainly tracks concessional financing (official development assistance flows), climate finance also includes non-concessional financing (other official flows), export credits and private finance mobilized through public climate finance. In 2020, climate-related Aid for Trade represented more than 50 per cent of climate-related official development assistance flows, illustrating the rising complementarities in trade, development and climate agendas (OECD and WTO, 2022).

Over the period 2013 to 2020, US$ 80 billion were disbursed to Aid for Trade projects with a climate-mitigation objective; disbursements almost doubled between 2013 (US$ 6.5 billion) and 2020 (US$ 12.3 billion) (see Figure C.8). In 2020, 43 per cent of mitigation-related Aid for Trade targeted renewable power generation, distribution and energy conservation, while 23 per cent went to climate-friendly infrastructure, and 17 per cent went to agriculture, forestry and fishing.

With more developing countries and their financing partners prioritizing climate mitigation in their development programming, the share of Aid for Trade dedicated to the transition to a low-carbon economy is set to grow. However, more could be done to exploit the synergies between climate finance and Aid for Trade by mainstreaming trade considerations into climate strategies – and climate considerations into trade cooperation strategies.

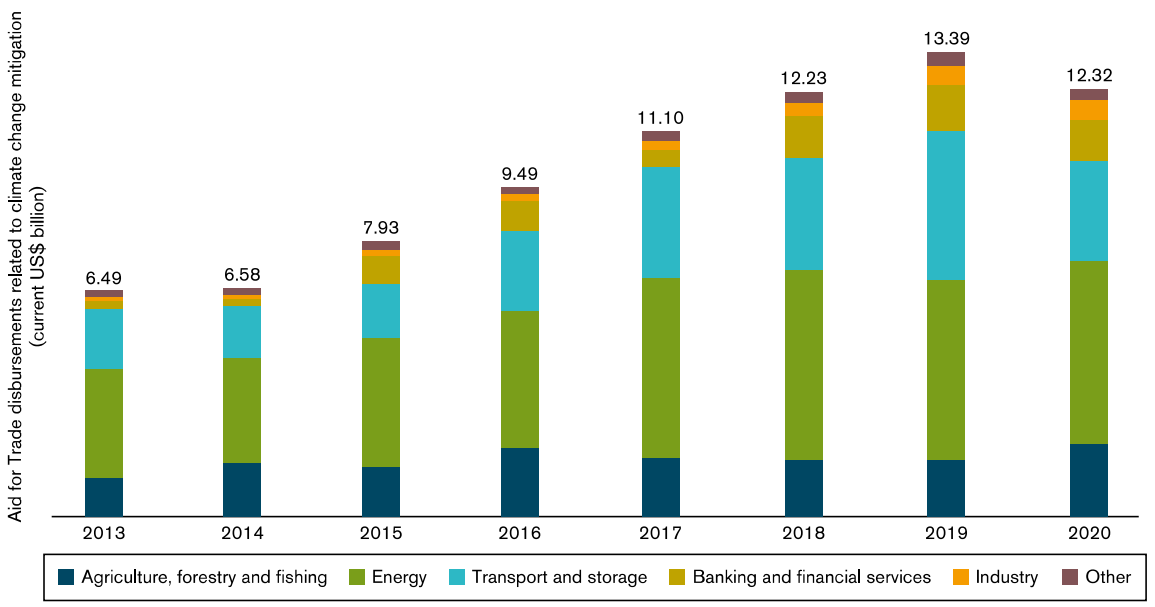
5. Conclusion

The transition to a low-carbon economy would require a substantial transformation of energy, production, transport and land-use systems. This transformation is unlikely to be achieved without ambitious climate change policies that may comprise a broad range of different measures, including market-based measures, command-and-control regulations, information-based instruments and voluntary agreements.

Trade can contribute to supporting the low-carbon transition by incentivizing environmental innovation, leveraging comparative advantages in the production of low-carbon technologies and renewable energy, and expanding access to and deployment of critical low-carbon goods and services. A transition towards a low-carbon economy is also likely to change what, with whom and how trade is conducted. Trade in renewable energy and electricity and trade in goods and services produced and delivered with clean energy could expand significantly.

While decarbonization offers new trading opportunities for many economies, including developing countries, a just low-carbon transition may require complementary policies to help affected regions and vulnerable groups, including MSMEs, to decarbonize and adjust production and consumption patterns more smoothly. Well-functioning labour and financial markets are

Figure C.8: Most Aid for Trade disbursement related to climate change mitigation covers energy and transport



Source: Authors' calculations, based on Organisation for Economic Co-operation and Development (OECD) DAC-CRS (Development Assistance Committee Creditor Reporting System) Aid Activities Database.

Note: Only projects with an explicit objective of mitigating climate change and projects identifying climate change mitigation as important but secondary objective are considered as adaptation-related official development assistance.

essential to support the economic changes needed to move to a low-carbon future.

International cooperation is essential to achieve a low-carbon economy. The WTO contributes to supporting climate change mitigation actions in several ways. WTO rules support members in pursuing their climate objectives by helping to prevent unproductive frictions and obstacles, and ensuring efficient and effective trade-related climate policies. By fostering transparency and providing a forum for policy dialogue, the WTO can contribute to coherent and fit-for-purpose climate policies. In addition, the Aid for Trade initiative can support a just transition to a low-carbon economy.

The progress on global climate actions, however, has been insufficient to fully contain global temperature increase. Greater international cooperation on climate change mitigation is essential to promote a just low-carbon transition. The WTO can further contribute to strengthening the interlinkages between trade and climate objectives by advancing solutions for trade-related climate action.

Endnotes

1 GHGs comprise carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (SF_6). Although discussions on climate change tend to focus on CO_2 because it is the main contributor to climate change, accounting for about three-quarters (74.1 per cent) of total emissions, it is estimated that methane contributes 17.3 per cent, nitrous oxide 6.2 per cent, and other emissions 2.4 per cent (WRI, 2022).

2 Reducing production and consumption to mitigate GHG emissions is commonly known as "degrowth". Although controversial, this strategy has been proposed by some scholars as an alternative means of achieving a low-carbon economy which would allow to minimize unfeasibility and unsustainability risks associated with strategies aimed at decoupling GDP and GHG emissions (Keysser and Lenzen, 2021; Lenzen, Keysser and Hickel, 2022).

3 Unlike the previous framework for climate action under the UNFCCC – the Kyoto Protocol – the Paris Agreement requires all parties, whether developed or developing countries, to take action and contribute to climate change mitigation and adaptation.

4 Nevertheless, several challenges to the transition to a low-carbon economy have been identified in the literature. For instance, the so-called "green paradox" could arise if fossil fuel owners chose to extract and monetize fossil fuel more quickly in reaction to an anticipated phase-out of fossil fuel assets, thereby causing more carbon emissions to be released more quickly (Sinn, 2012).

5 For instance, 87 per cent of global annual farm support (approximately US$ 470 billion) are estimated to be price-distorting, as well as being environmentally and socially harmful, with the vast majority of support provided for the most emission-intensive products. The removal of fiscal subsidies could decrease global GHG emissions from agricultural production in 2030 by 11.3 million tonnes of CO_2-equivalent (CO_2e), while the removal of all border measures could further reduce GHG emissions by 67.1 million tonnes CO_2e (FAO, UNDP and UNEP, 2021).

6 Government procurement amounts to approximatively US$ 11 trillion per year, accounting for about 12 per cent of world GDP (Bosio and Djankov, 2020).

7 So-called food miles labels indicate that the product is locally grown. As discussed in chapter E, although international transportation, especially by air and road, releases GHGs, it is not always the main contributor to a product's carbon footprint.

8 Eco-labels mandated by government agencies may also be considered as environmental regulations.

9 Like GGP, voluntary agreements are voluntary in nature. However, whereas GPP requires commitments on the part of the government to use environmentally friendly goods and services in the public procurement process, voluntary agreements require commitments and action from private-sector firms, with a view to reducing emissions.

10 In high-income countries, carbon pricing has a larger percentage impact on the cost of living for poorer households since they tend to spend a larger proportion of their income on fuels (Goulder et al., 2019). Conversely, in developing countries carbon pricing policies tend to have a larger negative impact on the cost of living of the rich households compared to the poor (Dorband et al., 2019).

11 The distributional impacts of removing fossil fuel subsidies tends to be more progressive in developing countries than in developed ones (Goulder et al., 2019). The removal of fossil fuel subsidies impacts equity through several channels. It impacts the cost of consumption directly, by raising the price of fuels, and indirectly, by raising the prices of fuel intensive products. Raising the price of fuels tends also to cause an increase in the labour intensity of production. This in turn raises employment opportunities and the greater scarcity of labour raises the wage rate in relation to the rental rate on capital (Malerba and Wiebe, 2021).

12 An accelerated delivery of international public finance will be critical to a low-carbon transition, and the private sector will need to finance most of the extra investment required. Indeed, of the amount required for the energy transition pathway aligned with the ambition to limit global warming to less than 1.5°C, around US$ 3.4 trillion (59 per cent) and US$ 2.2 trillion (60 per cent) are expected to come from private-sector equity and lending, in the periods from 2021 to 2030 and from 2031 to 2050, respectively (IRENA, 2021).

13 Learning effects, economies of scale and technological innovations, such as drones and artificial intelligence, could reduce the labour intensity of the renewable energy sectors in the long run (IRENA, 2021).

14 However, energy carriers are a less efficient mode of energy transport compared to fossil fuel energy because of the energy required for their production and potential reconversion processes (Brändle, Schönfisch and Schulte, 2021).

15 The WTO GTM is a computable general equilibrium model, focused on the real side of the global economy, modelling global trade relations See Aguiar et al. (2019) for a technical description of the WTO GTM.

16 For modelling purposes, renewable energy includes solar and wind power. It does not include hydrogen, which is included, for the purpose of the simulation, in the non-electricity nest of the production structure. Switching to renewable energy could lead to higher trade in that energy, but also to higher trade in other minerals.

17 In these simulations, fossil fuel export-dependent countries and regions are Russia, the Middle East and Northern Africa.

18 Although green hydrogen offers an opportunity for energy trade, the scale of trade in hydrogen is projected to be smaller than the current scale of fossil fuels. The share of trade in green hydrogen is projected to reach 17.6 per cent of total energy trade by 2050 compared to 72.9 per cent for fossil fuels exports in 2021.

19 Notified trade measures with the following objectives are considered to be related to climate change, namely: afforestation or reforestation; air pollution reduction; alternative and renewable energy; climate change mitigation and adaptation; energy conservation and efficiency; and ozone layer protection. For more information, see WTO (2021d).

20 See TBT Notification – Japan G/TBT/N/JPN/628.

21 See SCM Notification – China G/SCM/N/343/CHN.

22 See LIC Notification – Australia G/LIC/N/3/AUS/12.

23 See CMA Meeting, Japan-India, G/MA/M/74.

24 See also CMA Meeting Minutes G/MA/M/74; G/MA/M/73; G/MA/M/72.

25 The average global temperature levels implied by different paths of carbon emissions are obtained using the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) based on the projected CO_2 emissions by the WTO GTM Model. For the "business-as-usual" and "divided world" scenarios, it is assumed that CO_2 emissions post-2050 remain constant at 2050 levels. Non-CO_2 emissions follow the Shared Socioeconomic Pathway (SSP) 2-4.5 scenario of the IPCC, which assumes a "middle of the road" world where trends broadly follow their historical patterns resulting in a global warming of 2.5-2.7°C by 2100. For the "cooperation towards net zero" scenario, it is assumed that CO_2 emissions will reach net zero after 2050 and remain this way until 2100. Non-CO_2 emissions follow the SSP1-2.6 scenario of the IPCC, which assumes a world of sustainability-focused growth and equality resulting in a global warming of 1.7-1.8°C by 2100.

26 For modelling purposes, the different climate change policy instruments are not distinguished. These policies are implemented in the simulations as cost-neutral shifts in production methods.

27 Examples of initiatives include the "We Mean Business Coalition", the Science Based Targets initiative, the UN Alliance for Sustainable Fashion, the Global Cement and Concrete Association (GCCA) 2050 Net Zero Global Industry Roadmap, and the COP26 declaration on accelerating the transition to 100 per cent zero emission cars and vans.

28 Trade will also play a role in the implementation of Article 6 of the Paris Agreement, which establishes rules for internationally transferred mitigation outcomes (ITMOs), i.e., cooperative approaches to facilitate the exchange of emissions reductions above those pledged under NDCs. It has been estimated that, by 2030, carbon trading (i.e., the government-authorized buying and selling of credits corresponding to emissions of a certain amount of GHGs) under ITMOs could save US$ 250 billion a year in climate mitigation costs in the energy sector alone (Edmonds et al., 2019).

29 See for instance Colombia-Ecuador-European Union-Peru RTA and European Union-United Kingdom RTA.

30 Although there is limited empirical evidence on the effectiveness of provisions on climate change in RTAs, environmental provisions in RTAs have been found to reduce the emissions of certain pollutants, including CO_2 emissions (Martinez-Zarzoso and Oueslati, 2018) and deforestation (Abman, Lundberg and Ruta, 2021).

31 At the Doha Ministerial Conference, in 2001, WTO members recognized that, under WTO rules, no WTO member should be prevented from taking measures for the protection of the environment at the levels it considers appropriate, as long as these measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade. See ttps://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_e.htm.

32 See https://www.wto.org/english/docs_e/legal_e/04-wto_e.htm.

33 Appellate Body Report, US – Shrimp (1998), para. 129.

34 Appellate Body Report, US – Gasoline (1996), p. 17.

35 Appellate Body Report, US – Gasoline (1996), p. 25.

36 Appellate Body Reports, US – Gasoline, US – Shrimp; EC – Asbestos, Brazil – Retreated Tyres; and US – Tuna II (Mexico).

37 The nine developed-country members are the European Union (with 55 technology transfer programmes), the United States (35), Norway (24), Japan (10), Switzerland (10), the United Kingdom (8), Australia (6), Canada (3) and New Zealand (1). The main LDC beneficiaries of the technology transfer programmes are Bangladesh, Cambodia, Mozambique, Rwanda, Senegal, Tanzania, Uganda and Zambia.

38 Although not directly focused on climate mitigation, the Agreement on Fisheries Subsidies adopted at the 12th WTO Ministerial Conference in June 2022 could also help to contribute to climate mitigation strategies by improving the energy efficiency of vessels (Kristofersson, Gunnlaugsson and Valtysson, 2021) and supporting more sustainable diets (Gephart et al., 2021) (see Box B.5).

39 Some WTO members have, in the past, formally proposed the reintroduction of the non-actionable subsidies category, including that adopted for environmental purposes, specifically in favour of developing-country members. No decision on this matter has been adopted so far. See WTO official documents number WT/MIN(01)/17, TN/RL/W/41 and WT/GC/W/773, which can be accessed at https://docs.wto.org/.

40 See, for example, Canada – Feed in Tariff; India – Solar Cells; and US — Renewable Energy.

41 See Canada – Feed in Tariff, at paragraphs 5.174-190.

42 The GPA 2012 has 21 parties covering 48 WTO members. More information is available at: https://www.wto.org/english/tratop_e/gproc_e/gproc_e.htm.

43 It has been estimated, for instance, that through the work of the TBT Committee on specific trade concerns, € 80 billion worth of unnecessary trade costs affecting EU exports were avoided over a 10-year period (Cernat and Boucher, 2021).

44 See https://www.wto.org/english/news_e/news20_e/good_11jun20_e.htm

45 See https://www.wto.org/english/news_e/news20_e/serv_23oct20_e.htm

46 See https://www.wto.org/english/news_e/news21_e/trip_11mar21_e.htm

47 See, for instance, https://www.wto.org/english/news_e/news22_e/tbt_15jul22_e.htm

48 Three separate ministerial statements were launched at a joint event on 15 December 2021: TESSD Ministerial Statement (WT/MIN(21)/6/Rev.2); IDP Ministerial Statement (WT/MIN(21)/8/Rev.2); and FFSR Ministerial Statement (WT/MIN(21)/9/Rev.1).

49 For example, a virtual "Trade 4 Climate" Dialogue was hosted by the WTO and the International Chamber of Commerce (ICC) on 26 October 2021: https://www.wto.org/english/tratop_e/envir_e/trade4climate_e.htm