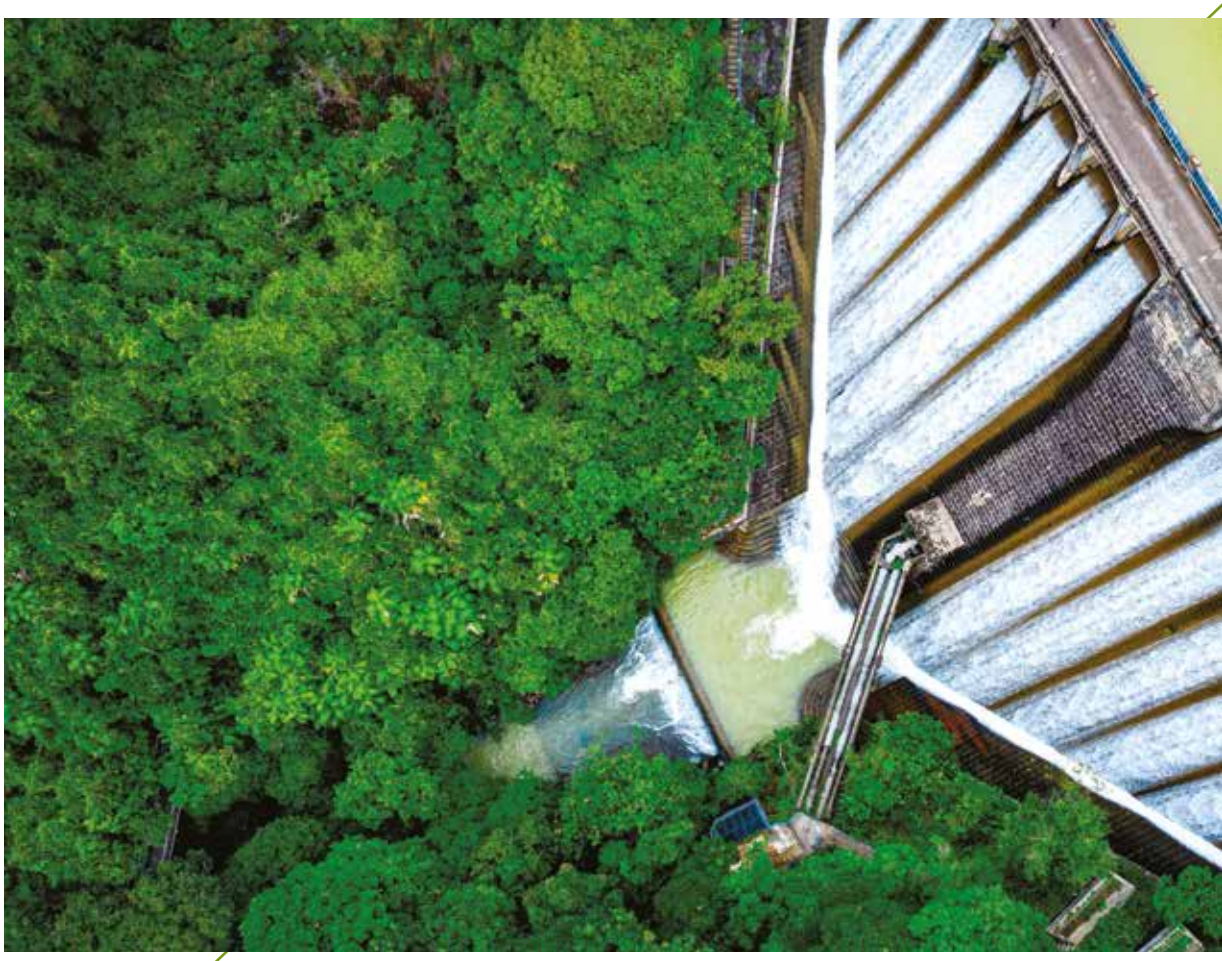
C The trade implications of a low-carbon economy

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

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International Renewable Energy Agency (IRENA)

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]

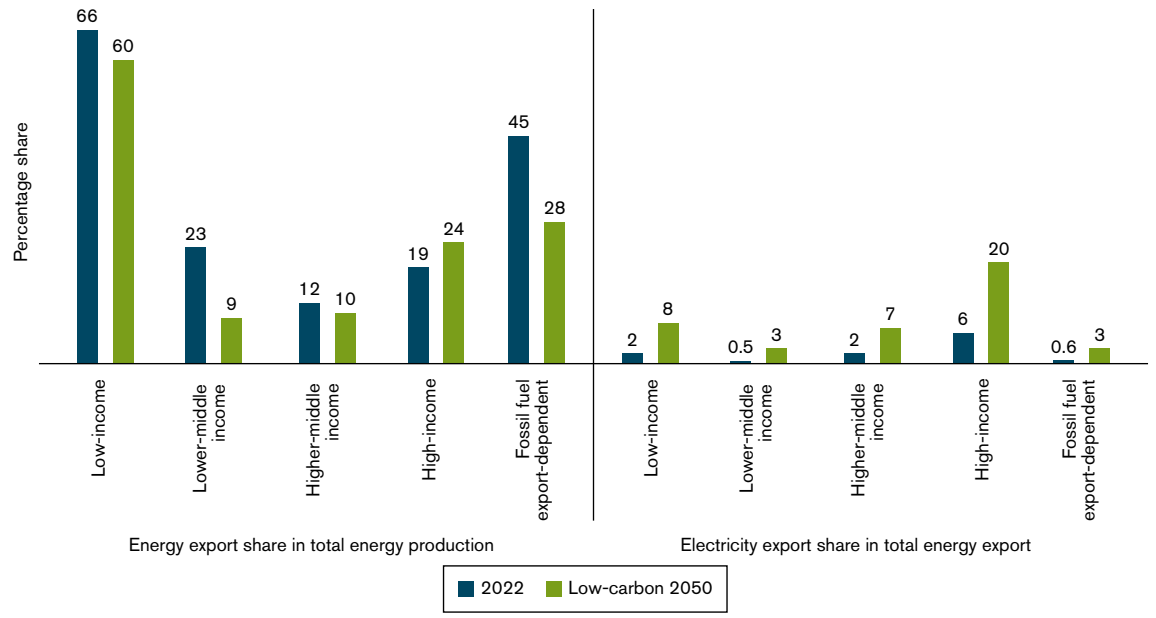
However, a low-carbon transition would lead to a 38 per cent reduction in energy trade from 2022 to 2050 (left panel of Figure C.1). Two forces may explain this result: a reduction in fossil fuel exports and an increase in trade in renewable energy. The latter is, however, not large enough to offset 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.

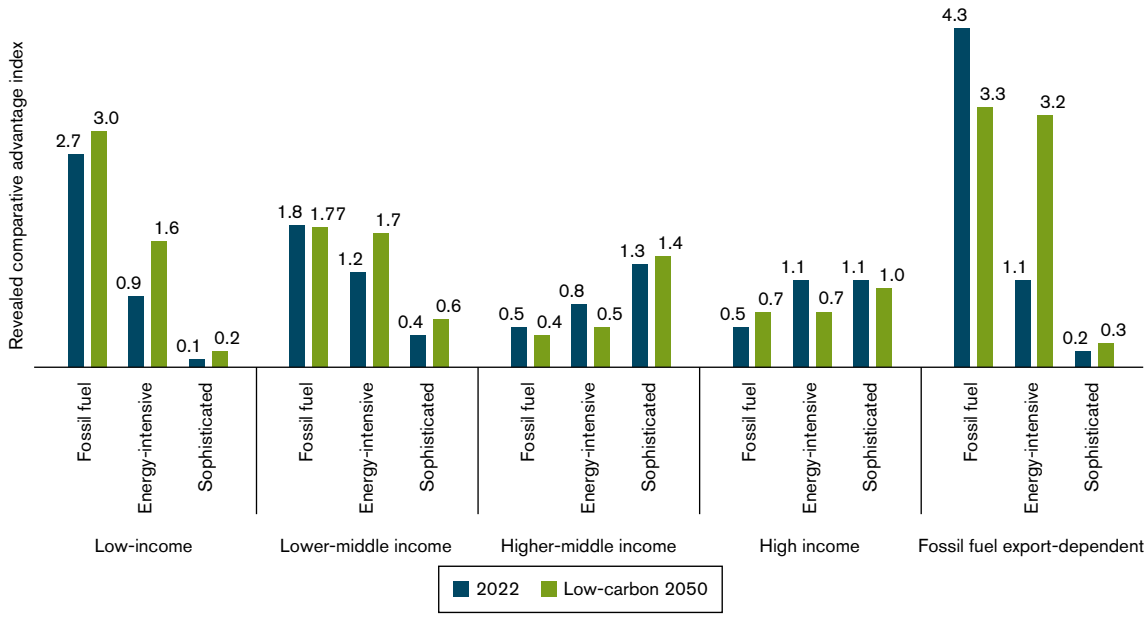
reduction in the real output of coal, oil, gas and refined petroleum products in all regions, ranging from between 50 per cent in fossil fuel export-dependent countries (FFEDCs)[17] to more than 60 per cent and 70 per cent in low- and higher middle-income countries. At the same time, capital and labour 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.

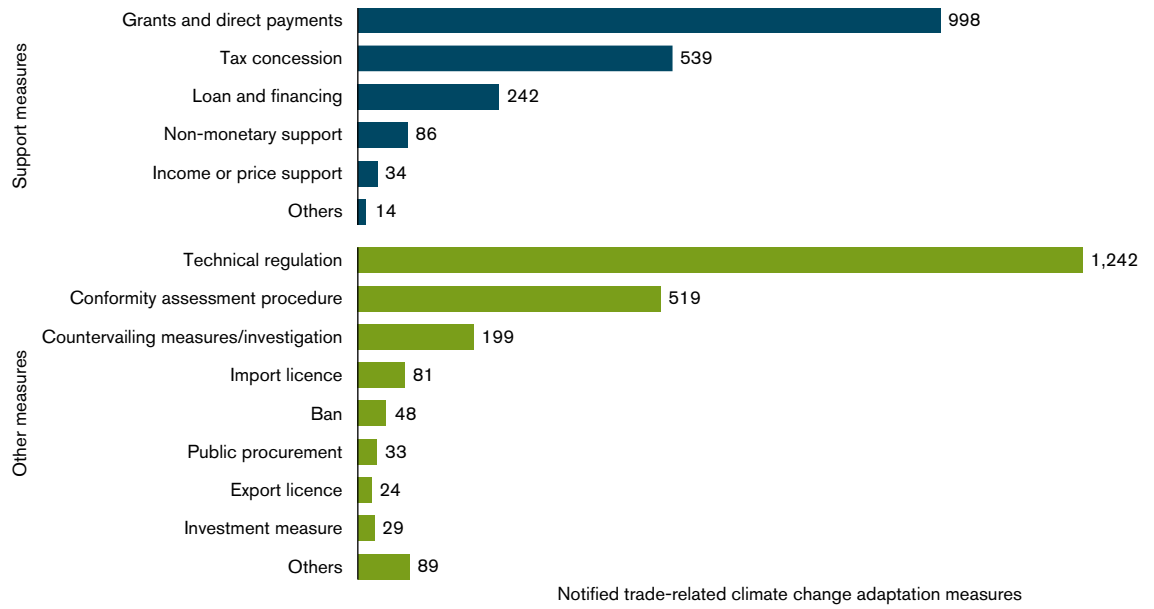
(d) Some climate change mitigation policies may have trade implications

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).

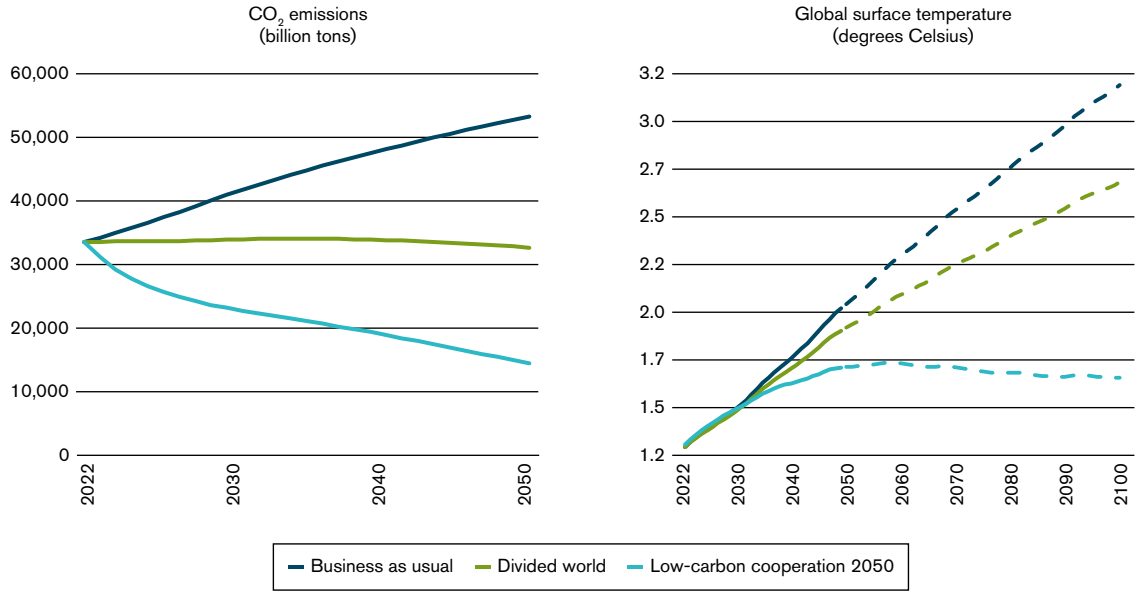
To keep the increase in global temperatures below 1.5°C, the aspirational goal of the Paris Agreement, the world needs to halve annual GHG emissions in the next eight years. This requires additional cooperation among countries. To illustrate the importance of international cooperation, the WTO GTM was 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.

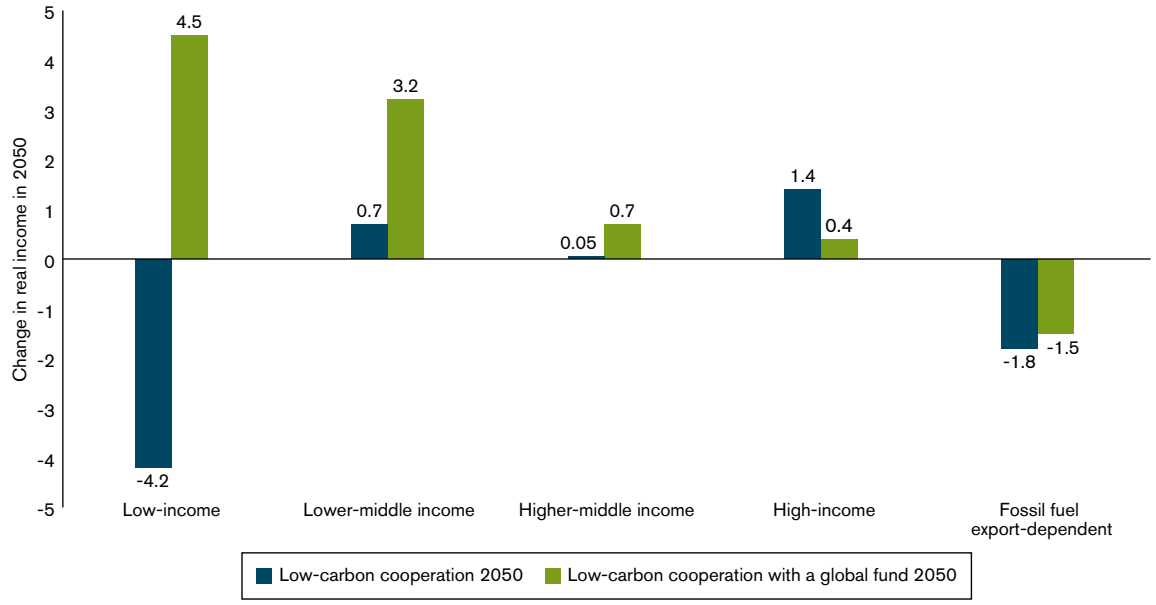
unilateral and uncoordinated climate change policies, international cooperation and coordinated actions could lead to annual global carbon emissions to fall to 14.4 Gt CO_2 and the global average temperature to rise by approximately 1.7°C by 2050, below the Paris Agreement's objective to limit global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

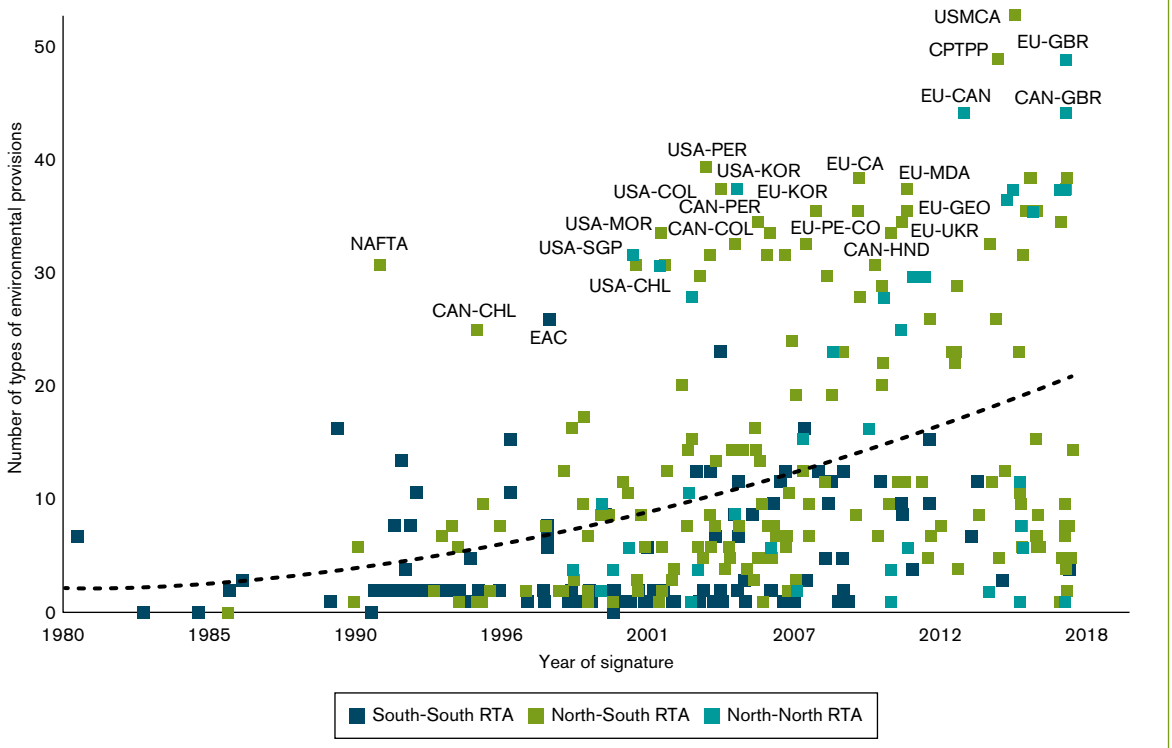
Although the term "international trade" does not feature in the Paris Agreement, its parties have discussed numerous trade-related elements to support climate efforts as part of their cooperation under several technical bodies, including the Forum on Response Measures, the Katowice Committee of Experts (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.

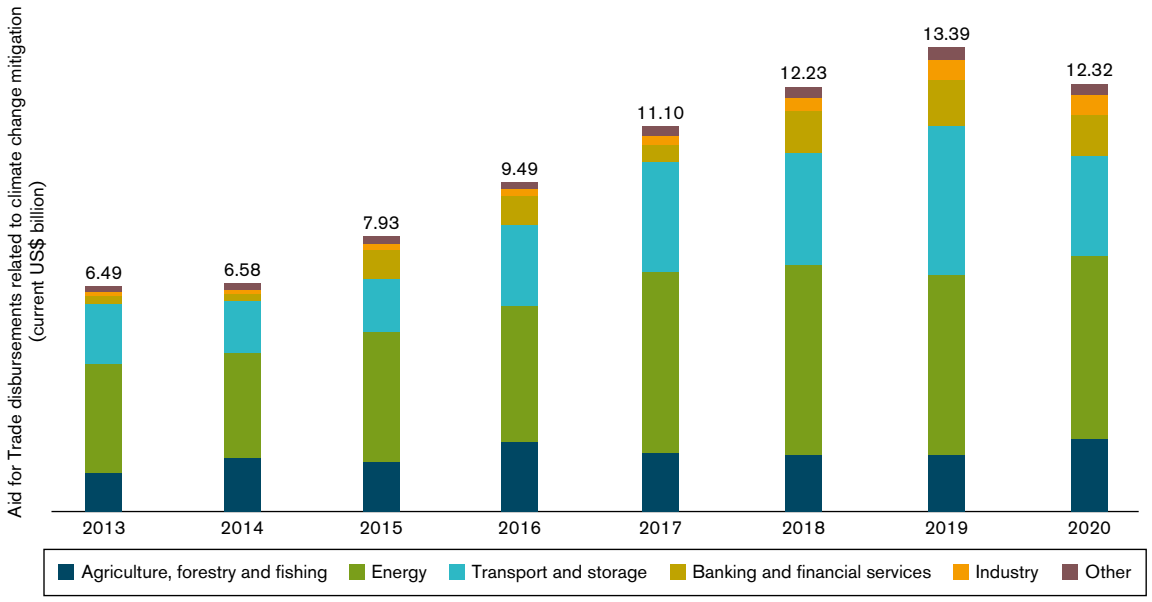
5. Conclusion

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