



WORLD TRADE  
ORGANIZATION

# TRADE AND CLIMATE CHANGE

## Information brief n° 4



The carbon content of  
international trade



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# THE CARBON CONTENT OF INTERNATIONAL TRADE<sup>1</sup>

*Revised 09/11/2021*

## Information brief n° 4

### KEY POINTS

- Trade affects greenhouse gas (GHG) emissions in multiple ways, and therefore the overall impact of trade on carbon emissions is complex to measure.
- In past decades, GHG emissions generated by the production and transport of exported and imported goods and services have increased and represent, on average, 20-30 per cent of global GHG emissions.
- The amount of GHG emissions embedded in an economy's international trade is determined by a broad range of factors, including the size of the economy, the sectoral composition of its foreign trade, its level of participation in global value chains (GVCs), the modes of transportation used for its imports and exports, and the energy efficiency of its production system, which depends in part on environmental and energy policies.
- A few sectors, including energy and transportation, account for more than 75 per cent of the GHG emissions embedded in international trade. The international transport sector generates 12 per cent of global GHG emissions. For several sectors and economies, the share of transportation-related emissions in total GHG emissions embedded in trade exceeds the share of production-related emissions.
- While developed economies tend to be net importers of GHG emissions, developing economies and commodity-dependent economies tend to be net exporters of GHG emissions. International carbon emissions transfer from developed to developing has, however, declined in recent years thanks in part to improvements in energy efficiency.
- Although international trade, like any economic activity, generates GHG emissions, for some products and services trade can reduce total GHG emissions, e.g., when production-related GHG emissions in the exporting country are lower than in the importing country, and this difference in production-related GHG emissions exceeds transportation-related GHG emissions.
- Policy initiatives and advancements in environmental and energy efficiency technologies can reduce GHG emissions associated with the production and transportation of international trade. In this context, trade can play a role in diffusing green technologies and improving carbon efficiency.

## 1. INTRODUCTION

How does international trade affect climate change? To answer this question, different methods have been proposed. One popular approach, known as carbon emission accounting, estimates the amount of GHG emissions embedded in international trade by assessing the level of GHGs emitted during production, transport and consumption along supply chains in and between countries.

Trade has complex effects on GHG emissions, which go beyond emissions from production and international transportation. Trade affects where production is taking place and, if the carbon intensity of production is not the same everywhere, this also affects the level of emissions. Importantly, trade also plays a critical role in diffusing green technology and can help countries transition to lower-carbon economic activities. Hence, trade has a multifaceted impact on carbon emissions. Reducing the emissions associated with trade is possible with the help of technological innovation and international climate cooperation.

This note is structured as follows. Section 2 describes how GHG emissions embedded in trade are calculated and provides an overview of the latest trends. Section 3 looks at the determinants of GHG emissions embedded in international trade. Section 4 discusses the role of policies and international cooperation in reducing the GHG emissions embedded in trade.

## 2. CARBON EMISSIONS EMBEDDED IN TRADE

International trade, like any economic activity, generates GHG emissions. Tracking and measuring the GHGs emitted during the production and consumption of goods and services is, however, a complex task because production often involves multiple inputs and may be carried out in different places. Carbon emission accounting measures the amount of GHG emissions embedded in economic activities, including international trade, by estimating the level of GHGs emitted during production, transport and consumption along supply chains in and between countries.

Carbon emissions embedded in a product or service include the *direct* GHG emissions from its final production, assembly, packaging and shipping to the market (consumers). Embedded carbon emissions also account for all the *indirect* GHG emissions generated by the production and transportation of the inputs used to produce the final product or service, including the GHG emissions from the generation of the electricity used during production.

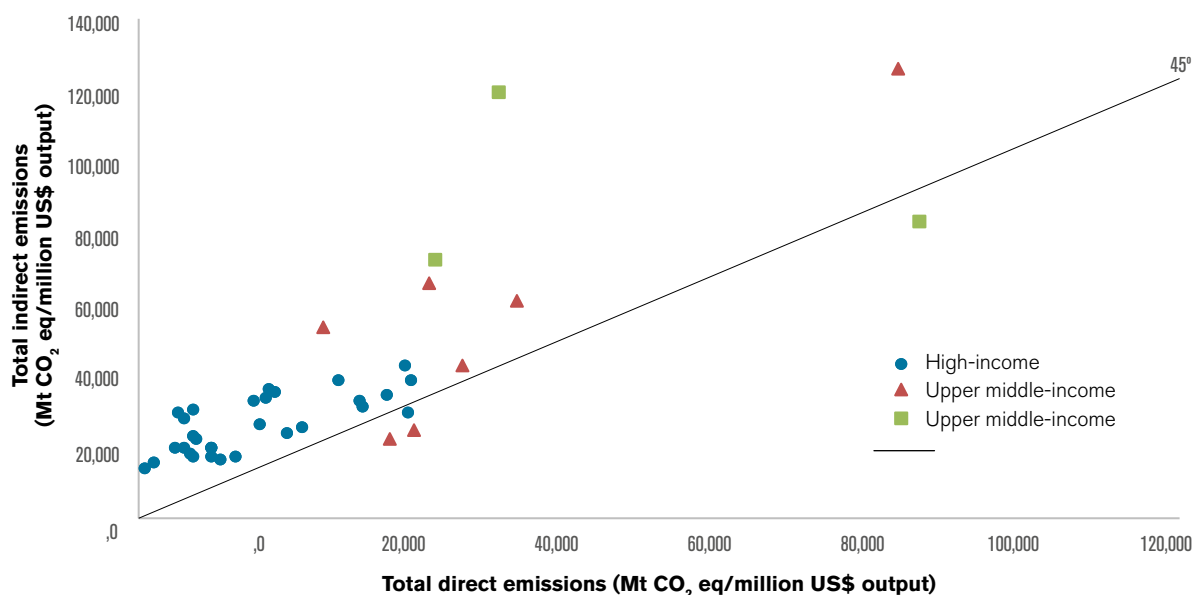
For example, the emissions embedded in a product as simple as chocolate cookies originate from many sources. GHG emissions are released to produce the energy used in the preparation, baking and packaging of the cookies, as well as their transportation to the customers. Emissions are also associated with the cookies' ingredients (e.g., chocolate, flour, sugar). Each of these ingredients is responsible for emissions during their production and transportation. Similarly, the inputs used to manufacture these ingredients (e.g., land use change to cultivate crops, fertilizers to grow wheat, energy to grind grains and toast cocoa, etc.) generate GHG emissions.

This step-by-step analysis of all the emissions released in the production, transportation and distribution of a product or service is known as life cycle assessment. Carbon emission accounting based on such life cycle assessment can even include GHG emissions associated with the disposal of the product. Given its complexity and intensive data requirements, life cycle assessment is mostly used for product-, firm- or industry-specific carbon footprint analysis.

An alternative approach to estimating the carbon emissions embedded in countries' economic activities, including international trade, consists in breaking down aggregated national GHG emissions by sector and production stages using product-specific and/or sector-specific GHG emission intensity factors and input-output tables. Input-output tables describe how much of an industry's output is used by other industries and consumed by households and government within an economy. Measuring the carbon content of trade further requires cross-country input-output tables that estimate the value, in a given country, of a sector's input or output that is exported to or imported from a specific sector in another country.<sup>2</sup>

GHG emissions embedded in production differ considerably across economies. Developing economies tend to emit more GHG emissions per unit of output than developed economies. With a few exceptions, *indirect* GHG emissions embedded in production tend to be greater than *direct* GHG emissions embedded in production, as highlighted in Figure 1. The amount of *indirect* GHG emissions embedded in production tends to be higher in economies particularly active in downstream supply chains. Conversely, economies active in upstream supply chains tend to have lower indirect GHG emissions embedded in production.

Figure 1: Indirect GHG emissions tend to be greater than direct GHG emissions



Source: Authors' computation, using the WIOD database for 2009.

Note: The analysis considers the production of both goods and services, including transport. The total rate of emissions is computed by multiplying the emissions per output diagonal matrix with the Leontief inverse matrix, i.e., the matrix that considers direct and indirect intermediate goods used in final output production. The GHG emissions include CH<sub>4</sub>, N<sub>2</sub>O and CO<sub>2</sub>, all expressed in CO<sub>2</sub> equivalence. Emissions are expressed in megatons (Mt) per million US dollars of output.

GHG emissions embedded in international trade only consider the *direct* and *indirect* GHG emissions associated with the production and transport of goods and services that are exported and imported. GHGs emitted during the production and transport of goods and services produced domestically (without any foreign inputs) and consumed domestically are excluded from the calculation of carbon emissions embedded in trade.

Carbon emission accounting studies suggest that about 20-30 per cent of total carbon dioxide (CO<sub>2</sub>) emissions, which account for most GHG emissions, are associated with international trade (Peters et al., 2011; Meng et al., 2018; Zhang et al., 2020). For instance, the latest available estimates suggest that the production and transport of traded goods and services emitted 8 billion tonnes of CO<sub>2</sub> in 2015, representing 25 per cent of total CO<sub>2</sub> emissions. While the value of international trade has increased by 60 per cent since 2005, carbon emissions embodied in trade increased by 10 per cent between 2005 and 2015 (Cezar and Polge, 2020).

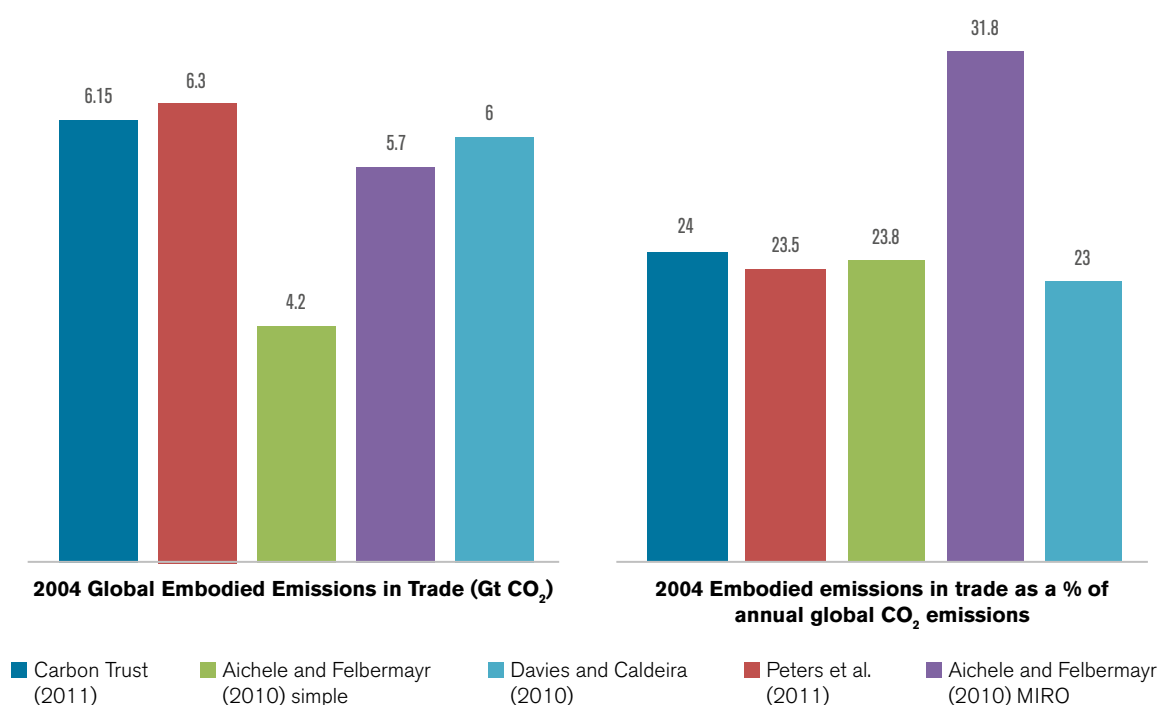
**About 20-30 per cent of total CO<sub>2</sub> emissions, which account for most GHG emissions, are estimated to be associated with international trade.**

Carbon emissions embedded in trade tend to fluctuate over the years. Prior to the global financial crisis, carbon emissions embedded in trade increased relatively steadily and reached their peak in 2008. They declined significantly during the global financial crisis, rebounded in 2010 and 2011, and have been decreasing slightly since 2012 (Wood et al., 2020).

The accuracy of these carbon content estimates remains, however, unclear because of data limitations, measurement errors and uncertainties due to different estimation approaches and numerous assumptions (including regarding emission intensity factors). As illustrated in Figure 2, the estimated level of carbon embedded in trade ranges from low to high by a factor of almost 1.5 depending on the different estimation approaches and assumptions (Sato, 2013).



Figure 2: Estimates of embedded GHG emissions in trade vary across studies



Source: Sato (2013).

Notes: The left panel plots the estimated global emissions embedded in trade by study, expressed in absolute volume. The right panel plots the corresponding share relative to global annual CO<sub>2</sub> emissions.

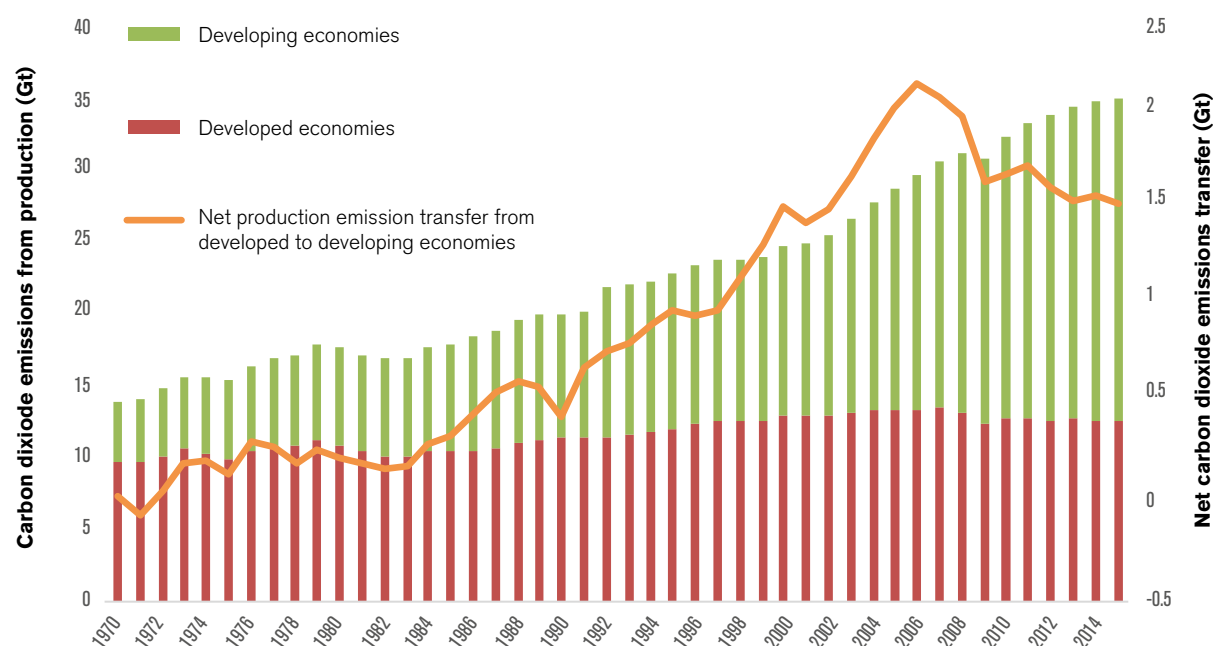
Given that trade separates production and consumption across space, carbon emission accounting can be analysed from either a production or a consumption perspective. From a production perspective, GHG emissions embedded in the economy correspond to the quantity of GHG emitted by the domestic supply, namely the production of goods and services consumed domestically and exported. Conversely, from a consumption perspective, GHG emissions embedded in the economy correspond to the GHG emissions generated by the domestic demand, which encompasses the consumption of goods and services produced domestically and imported. The difference between the production and consumption perspectives determines the trade balance in GHG emissions, namely whether economies are net importers or exporters of GHG emissions. A trade deficit or surplus in GHG emissions is sometimes referred to as international GHG emission transfer.<sup>3</sup>

Carbon emission accounting studies suggest that high-income economies consume more GHGs than they emit, making them net importers of GHG emissions. Conversely, developing economies and commodity-dependent economies tend to be net exporter of GHG emissions (Peters et al., 2011; Cezar and Polge, 2020; Wood et al., 2020). As highlighted in Figure 3, since the mid-1980s, with the rise of globalization, developing economies have seen a rapid increase in production-related carbon emissions, in part due to production for export and to domestic investment in productive capacity. Conversely, the production-related carbon emissions in developed economies have, on average, declined. Although international carbon emission transfer (from developed to developing economies) increased significantly faster than international trade and gross domestic product in the 1990s and early 2000s (Peters et al., 2011), it has been declining since 2006.

**High-income economies consume more GHGs than they emit, making them net importers of GHG emissions.**



Figure 3: Trade imbalances in GHG emissions have decreased in recent years



Source: Wood et al. (2020).

Note: Net emission transfers refer to the international carbon emission transfer, defined as the difference between the carbon emission embodied in production (including exports) and the carbon emission embodied in consumption (including imports).

### 3. THE DETERMINANTS OF CARBON EMISSIONS EMBEDDED IN TRADE

While carbon emission accounting provides interesting insights on the amount and evolution of GHG emissions embedded in trade, it is a purely descriptive analysis that is silent on the determinants of GHG emissions embedded in trade and more broadly on the impact of trade on GHG emissions. The amount of GHG emissions embedded in trade is determined by a broad range of factors, some of which might be unrelated to trade. The main determinants of GHG emissions embedded in trade include (1) the size of the economy; (2) the sectoral composition of trade flows; (3) the emergence of GVCs; (4) transportation; and (5) the energy efficiency of the production systems. Although they are discussed individually hereafter, these factors interact with each other.

**The main determinants of GHG emissions embedded in trade include the size of the economy, the sectoral composition of trade flows, the emergence of GVCs, transportation and the energy efficiency of the production systems.**

#### 3.1 Size of the economy

GHG emissions embedded in trade differ across economies reflecting, in part, differences in the sizes of the economies in question. The largest exporters and importers of GHG emissions are large economies. This is because the monetary value of exports and imports determines, in part, the quantity of GHG emissions embedded. GHG emissions embedded in trade also depend on the size of the population because larger countries produce and consume more.

### 3.2 Sectoral composition of trade flows

Different industries are characterized by different carbon emission intensities. According to carbon emission accounting studies, a few sectors, including energy, basic metals, transportation, coal and petroleum products, computers, electronic and electrical equipment, and chemicals and pharmaceuticals, account, on average, for more than 75 per cent of the total carbon emissions embedded in trade (Cezar and Polge, 2020; Yamano and Guilhoto, 2020). Recent analysis further suggests that carbon emissions embedded in services trade are increasing faster than merchandise trade (Huo et al., 2021). Besides transportation, tourism and professional services are found to be the main contributors of GHG embedded in services trade.

Economies which specialize in these GHG-intensive sectors, or which use these goods and services intensively as inputs for domestic production, release larger quantities of GHG. Trade openness can further impact GHG emissions by shifting the production of these GHG-intensive activities to locations with different carbon emission intensities.

### 3.3 The emergence of GVCs

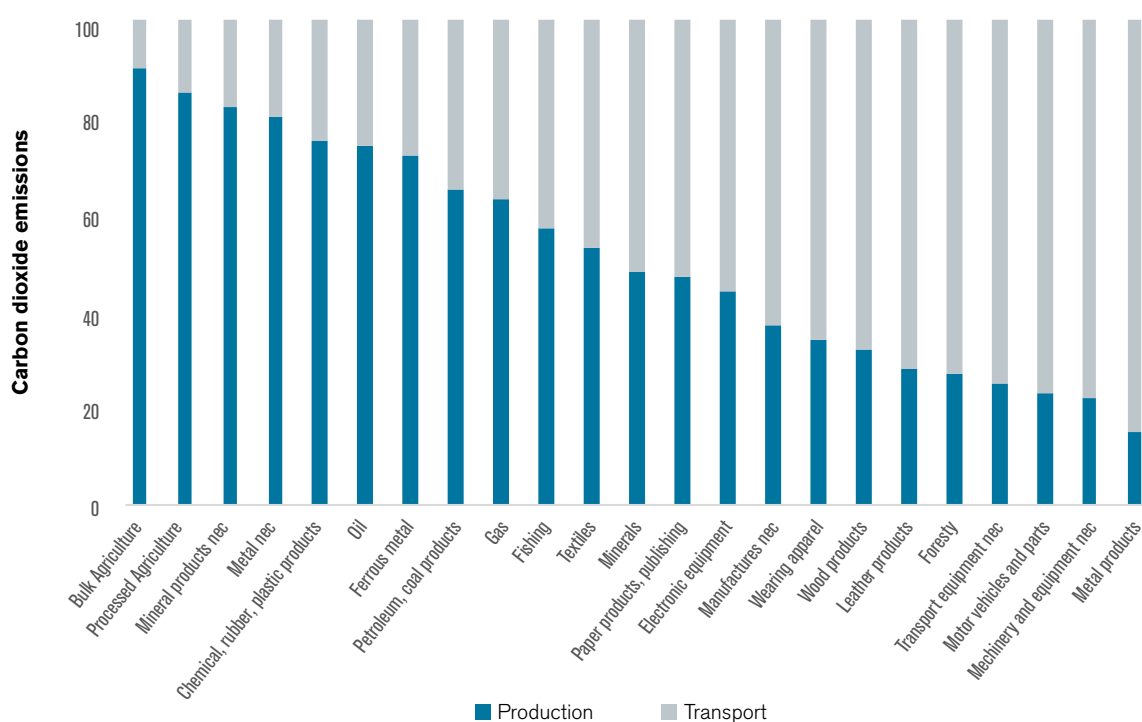
The emergence of GVCs has increased the fragmentation of production processes and the offshoring of some tasks. As a result, economies more integrated in GVCs have increased their imports of intermediate inputs and, thus, have also increased the amount of GHG emissions embedded in those imports. Conversely, the share of imported GHG emissions in exports is relatively lower for economies with lower GVC participation and with large GHG emissions embedded in their domestic production (Cezar and Polge, 2020; Wood et al., 2020).

### 3.4 Transportation

The amount of GHG emissions embedded in trade also depends on the mode of transportation used, which itself depends on the type of goods and services being traded and the geographical locations of the trading partners. As discussed above, transportation is one of the sectors that contributes the most to GHG emissions embedded in international trade. While the domestic and international transport sector accounts for over 24 per cent of global GHG emissions, emissions from international transport represent 12 per cent of these global emissions (Ritchie, 2020). International transport emissions have been growing steadily at an average annual rate of 1.9 per cent since 1990 (ITF, 2021). While passenger transportation accounts for more than two-thirds of international transport emissions, the remaining transport emissions are associated with international freight transport (ITF, 2021). GHG emissions associated with international freight transport represent about 30 per cent of all transport emissions and more than 7 per cent of global GHG emissions (ITF, 2015).

International freight transport is also estimated to represent, on average, 33 per cent of the carbon emissions generated by trade during the production and transport of goods traded internationally (Cristea et al., 2013). This average, however, masks large differences in the contribution of different economic sectors and economies to trade-related merchandise transport. Traded merchandise can be transported by air, road, rail and water, or via pipelines in the case, for example, of oil, gas and water. The most important mode of transport used for merchandise trade is sea transportation, which is the most efficient mode of transportation in terms of GHG emissions per volume of goods transported. Over half of international trade-related carbon emissions, on average, are produced by maritime shipping (ITF, 2021). However, unlike agricultural goods, fuels and mining products, manufactured goods are increasingly transported by air, the most GHG-intensive mode of transportation. At the same time, road and rail transport are of particular importance for trade with neighbouring countries or within regional clusters. As a result, transportation accounts for a large share of the carbon emissions in many sectors, as highlighted in Figure 4.

**Figure 4: The share of transport-related carbon emissions differs significantly across sectors**



Source: Transport emission intensity from Cristea et al (2013); bilateral trade flows for year 2017 from the Global Trade Analysis Project (GTAP).

Note: This figure shows the share of transport emissions over total trade-related emissions (transportation emissions and production emissions) per sector. The transport and trade-related emissions in 2017 are calculated by multiplying the intensity of emissions in 2004 (in million grams of CO<sub>2</sub> emissions per million US\$ of value of trade) with the value of trade in 2017 per bilateral trade flow, and aggregated by sector. This method does not capture the change in emissions intensity of transport from 2004 to 2017. "nec" is "not elsewhere classified".

## 4. HOW COULD TRADE-RELATED CARBON EMISSIONS BE REDUCED?

Given that trade contributes to GHG emissions, there have been calls to reduce international trade by producing and consuming "locally". Such calls raise the question of what the level of GHG emissions would be if economies only produced and consumed locally while ensuring a high level of welfare. Although international trade leads to GHG emissions, it can also contribute to improving welfare by supporting economic growth, lowering prices, and increasing consumer choice and product variety, as well as by tackling climate change through more trade in climate-friendly goods, services and technologies. In addition, international trade can reduce carbon emissions when production-related carbon emission intensity in the exporting country is lower than in the importing country and the difference of production-related carbon emissions between the two countries exceeds transportation-related emissions from one to the other.

**Although international trade leads to GHG emissions, it can also contribute to improving welfare by supporting economic growth, lowering prices, and increasing consumer choice and product variety, as well as by tackling climate change through more trade in climate-friendly goods, services and technologies.**

Although a situation of autarky is not observable, economists have used economic models to examine the question as a thought experiment. In a scenario where countries close borders to trade, domestic production of intermediate and final goods would need to rise to meet the demand for products that were previously imported. Compared with a hypothetical situation of autarky, international trade would increase global CO<sub>2</sub> emissions by 5 per cent or 1.7 gigatons of CO<sub>2</sub> annually (Shapiro, 2016). This trade-related carbon effect would be almost equally driven by production and transportation. However, the gains from international trade, measured as the benefits for producers and consumers, exceed the environmental costs from carbon emissions by 2 orders of magnitude.

Furthermore, a quarter of all international trade flows, representing roughly 31 per cent of trade in monetary value, could lead to a net reduction in carbon emissions compared to autarky despite transportation-related carbon emissions (Cristea et al., 2013). In many industries, such as bulk agriculture, this net carbon emission reduction could be substantial. However, for the remaining sectors, trade is associated with an increase in carbon emissions. In the aggregate, this corresponds to an increase in emissions equal to 1,274 million tons of CO<sub>2</sub>, of which 1,178 million tons are due to transport emissions. For these cases, improvements in carbon efficiency in production and transportation are necessary to reduce trade-related GHG emissions.

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**Trade-related GHG emission abatement could be achieved by curbing the GHG emissions released by international transportation.**

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Trade-related GHG emission abatement could be achieved by curbing the GHG emissions released by international transportation. Developing new efficient transport technologies, using sustainable and alternative fuels, improving transport infrastructure, and promoting alternative, more carbon-efficient, means of transportation (e.g., rail instead of road) are some of the strategies that can reduce trade-related GHG emissions. Different policy initiatives at the country and regional levels have been adopted to reduce GHG emissions.

For example, the European Union aims to reduce its carbon emissions by at least 60 per cent compared to 1990 by, among other things, switching to more efficient modes of transportation and promoting electrification, as well as by investing in research in hydrogen fuel, advanced biofuels and renewable synthetic fuels (European Commission, 2016). Similarly, the Republic of Korea's pandemic recovery fund supports the electrification of transportation. China and Japan also aim to reduce their transport-related carbon emissions as part of their carbon-neutrality pledge (ITF, 2021). Some governments have also planned to stop the sale or registration of internal combustion engine cars and trucks by dates between 2030 and 2050.

At the international level, different initiatives have also been launched to reduce the GHG emissions from the transport sector. Members of the International Maritime Organization (IMO) have committed to reduce emissions by at least 50 per cent by 2050 compared to 2008 levels, while pursuing complete decarbonization as soon as possible in this century. Part of this strategy builds upon already-adopted mandatory energy-efficiency requirements for ships. Similarly, members of the International Civil Aviation Organization (ICAO) agreed in 2019 to aim to improve fuel efficiency by 2 per cent annually through 2050 and to reach carbon neutral growth from 2020 onwards. The International Air Transport Association (IATA) also recently agreed on a plan to reach net zero carbon emissions by 2050 by means of sustainable aviation fuels, new aircraft technology, more efficient operations and infrastructure, and new zero-emissions energy sources, such as electric and hydrogen power.

International cooperation is required for a successful climate action. GHG emissions are global externalities. In the absence of international cooperation, the adoption of climate policies by individual countries is likely to be less than optimal from a global perspective. This is because climate policies in one country can have positive or negative spillovers in other countries, including the risk of carbon leakage (i.e., a situation in which carbon-intensive industries relocate to places with laxer climate regulation). Deployment of technological innovation is also required to meaningfully reduce GHG emissions released during trade-related production. In this respect, the WTO also has a role to play in facilitating trade of environmental goods and the diffusion of climate-friendly technologies. Reducing trade barriers to climate-friendly technologies will facilitate access and increase the adoption of these technologies to help accelerate the transition towards a more sustainable economic model.

## 5. CONCLUSIONS

In past decades, GHG emissions released by the production and transport of exported and imported goods and services have increased, representing, on average, 20 to 30 per cent of global GHG emissions. While advanced economies tend to be net importers of GHG emissions, developing and commodity dependent economies tend to be net exporters of GHG emissions. The evolution of GHG emissions embedded in trade is, however, dynamic, reflecting changes in economic size, the sectoral composition of trade, participation in GVCs, modes of transportation and the energy efficiency of production systems, among others.

Although carbon emission accounting can be used to estimate the amount of GHG emissions embedded in trade and to determine whether economies are net importers or exporters of GHG emissions, the methodology faces some limitations. In particular, estimates can be subject to measurement errors and uncertainties due to different estimation approaches and assumptions. In addition, the methodology is purely descriptive and does not explain how trade actually impacts GHG emissions.

In fact, international trade affects GHG emissions in different ways. Trade generates GHG emissions through the production, transportation, distribution and consumption of traded goods and services. Trade also increases emissions by stimulating economic activity through increased income. In addition, trade modifies the sectoral composition of the economy by allowing the production and consumption of goods to take place in different regions. Economies specialized in the production of GHG-intensive goods and/or services will likely be net exporters of GHG emissions for these goods and/or services. Conversely, economies intensively using these goods and/or services as inputs for domestic production will likely be net importers of GHG emissions for these goods and/or services. The amount of trade-related GHG emissions of some of these goods and services can still be relatively lower compared to a situation where the importing economy would have produced these goods and/or services domestically, when the GHG emissions from production and transportation in the exporting economy are lower than those that the importing economy would have released by producing them.

Trade also plays an important role in the adoption and dissemination of green technologies, including carbon-efficient technologies, which can have a positive impact on decarbonization. The amount of GHG emissions embedded in trade can be reduced by improving energy efficiency and promoting alternative and renewable energy. In that context, public policies are important to incentivize firms and consumers towards more sustainable decisions and behaviours. International cooperation has also an important role to play in maximizing synergies in efforts to reduce the carbon content of international trade, including through the adoption and diffusion of green technologies.

## ENDNOTES

- 1 This document has been prepared under the WTO Secretariat's own responsibility and is without prejudice to the positions of WTO members or to their rights and obligations under the WTO. The note has been written by Ankai Xu, Enxhi Tresa, Marc Bacchetta, Francesco Bellelli and José-Antonio Monteiro.
- 2 Most carbon emission accounting studies do not account directly for the GHG emissions of international transport of each sector individually. Instead, they consider the transport sector as a standalone sector.
- 3 An alternative approach, known as pollution terms of trade, computes the ratio of export GHG intensity to import GHG intensity (Antweiler, 1996).

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