WORLD TRADE ORGANIZATION
ORGANISATION MONDIALE DU COMMERCE
ORGANIZACIÓN MUNDIAL DEL COMERCIO

TRADE AND CLIMATE CHANGE

INFORMATION BRIEF N°4

CARBON CONTENT OF INTERNATIONAL TRADE[1]

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 the past decades, the carbon emissions embodied in international trade has increased as a result of globalization and the rise of global value chains. Carbon emissions are transferred from the developed to the developing world, reaching their peak in recent years.
- In cases where production emissions in the exporting country are lower than in the importing country and the difference of production emissions exceeds transportation emissions, international trade reduces total emissions.
- Economic modelling shows that, when compared with a counterfactual scenario without trade, carbon emissions induced by trade may be smaller than the level estimated using conventional carbon accounting.
- Policy initiatives and advancements in green technologies could bring a reduction in emissions linked to trade and transportation in the future. Moreover, trade can play a role in diffusing green technologies.

1 INTRODUCTION

1.1. How does international trade affect climate change? To answer this question, conventional estimates often calculate the amount of greenhouse gas (GHG) emissions embodied in international trade. A number of studies find that about 20-30% of total carbon emissions (which account for most GHG emissions) are associated with international trade (e.g. Peters et al., 2011, Meng et al., 2018, Zhang et al., 2020). Nonetheless, these estimates might be subject to measurement errors and uncertainties due to the different estimation approaches and assumptions

1.2. In this note, we explain that trade has complex effects on GHG emissions, which go beyond emissions from 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 helps countries transition to a low-carbon economy. Hence, trade has a multifaceted impact on carbon emissions. Reductions of emissions associated with trade are possible with technological innovation and international climate cooperation.

1.3. This note is structured as follows. Section 2 defines how carbon emissions embedded in trade are calculated. Section 3 looks at trends and the effects of trade on carbon emissions embedded in

[1] This is an information note which represents research in progress. The opinions expressed in this paper are those of its authors. They are not intended to represent the positions or opinions of the WTO or its members and are without prejudice to members' rights and obligations under the WTO. Any errors are attributable to the authors. The note has been written by Ankai Xu, Enxhi Tresa, Marc Bacchetta, Francesco Bellelli and José-Antonio Monteiro.

international trade. Section 4 discusses the role of policies in reducing trade emission. Section 5 concludes.

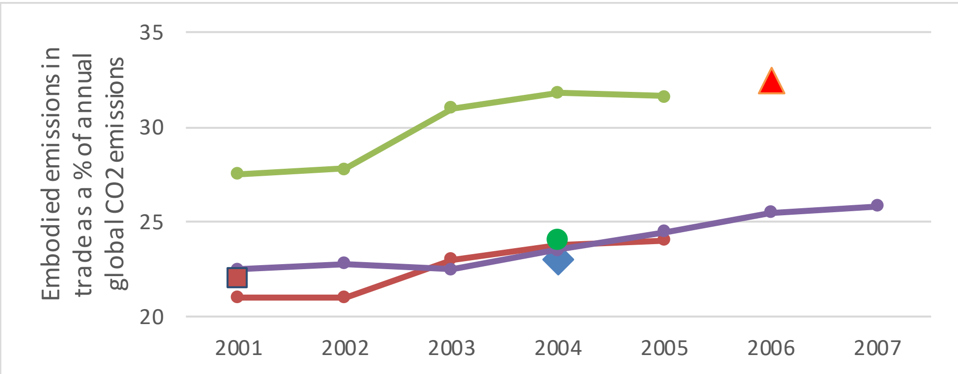
2 CARBON EMISSIONS EMBEDDED IN TRADE

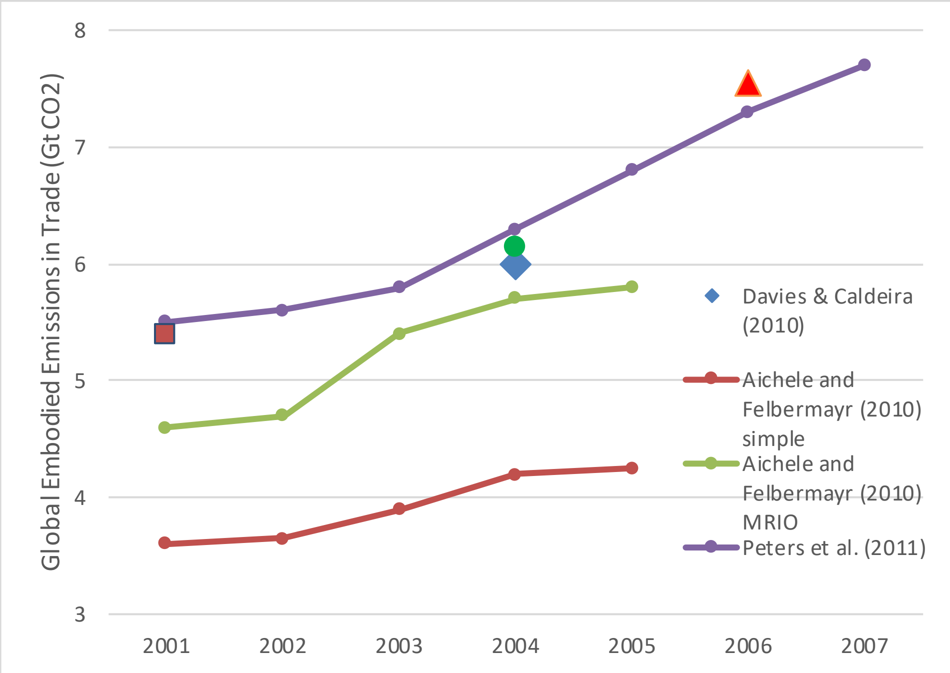
2.1. Carbon accounting is a complex task because production often involves multiple inputs and may be carried out in different places. Emissions embedded in a product include not only the *direct* emissions from its final production, but also all the *indirect* emissions generated by the production and transportation of its inputs. The direct emissions involve the release of GHG in the production process, and the indirect emissions include the GHG emissions from the generation of the electricity used during production as well as the use of intermediate inputs which themselves requires emissions to produce.

2.2. For example, the emissions embedded in a product as simple as chocolate cookies includes emissions from many sources. GHG emissions are released to produce the energy used in the preparation and baking of the cookies. 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. For each of these ingredients we should also account for their inputs' emissions (e.g. fertilisers for wheat, energy for grinding grains and toasting cocoa, etc.). Comprehensive carbon accounting even includes emissions associated with the disposal of the final product.

2.3. This step-by-step analysis of all the emissions released in the production of a product is called a life cycle assessment. However, this is only one of the existing methodologies in measuring carbon content. To measure the aggregated emissions of an economy, researchers often employ a top-down approach by looking at aggregated national emissions and breaking them down by sector and production stages using input-output tables. As a result of data limitations and the numerous assumptions on which these calculations rely, estimates of carbon emissions embodied in trade often vary considerably (Sato, 2013). As illustrated in Figure 1, studies have found some 4 Gt–6 Gt of CO_2 embodied in global trade in 2004 (equivalent to 15–25% of annual GHG emissions) and 7.8 Gt for 2006 (equivalent to around 30% of global emissions).

Figure 1: Embodied Emissions in Global Trade: Estimates from the Literature

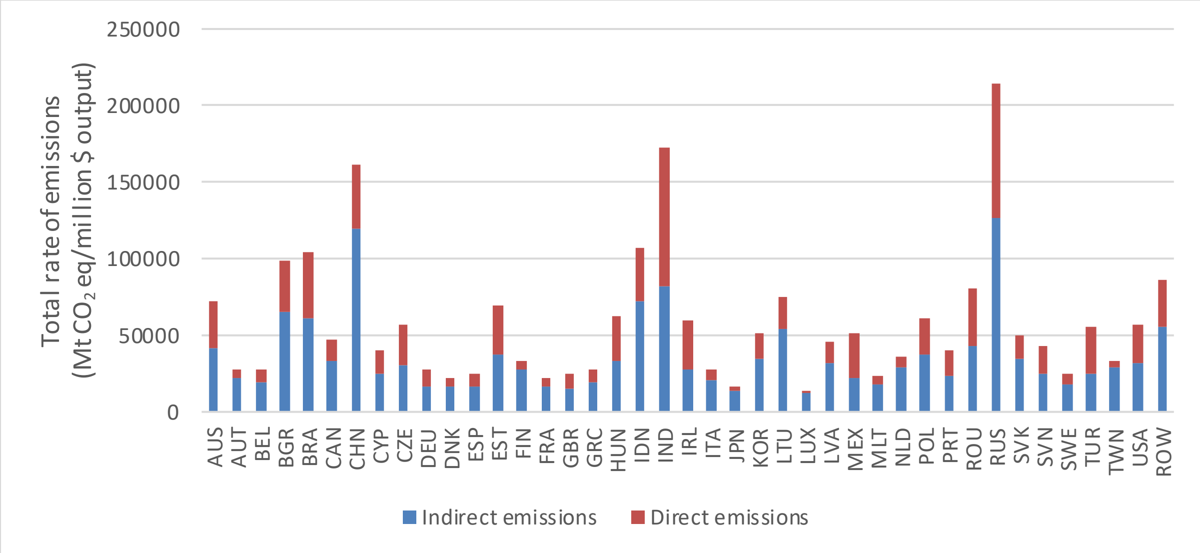




Source: Sato (2013)
Notes: The bottom graph plots the estimated global emissions embedded in trade by study, expressed in absolute volume. The top graph plots the corresponding share relative to global annual CO2 emissions (right, secondary axis).

2.4. A final complication of emission accounting is that modern GVCs integrate production taking place in different parts of the world. A product consumed in the United States may be produced in South Korea using inputs from China, Malaysia and Japan. Therefore, the consumption of the final product embeds emissions from different locations in the world. In other words, international trade *transfers* part of the emissions associated with a product to a country different from the country in which the product is finally produced. As a result, it is often found that international trade is responsible for an important share of global emissions (e.g. Meng et al., 2018, Zhang et al., 2020). Figure 2 depicts both the domestic and foreign GHG emissions embedded in production for different countries. The foreign embedded emissions that result from trade are quite important in developed economies. In contrast, domestic emissions represent a rather higher share in developing economies, possibly due to a relocation of carbon-intensive activities in these countries and more carbon intensive production techniques.

Figure 2. Direct and indirect GHG emissions embedded in production



Source: Authors' computation using the WIOD database for year 2009.
Note: 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_4, N_2O and CO_2, all expressed in CO_2 equivalence. Emissions are expressed in megatons (Mt) per million dollars of output.

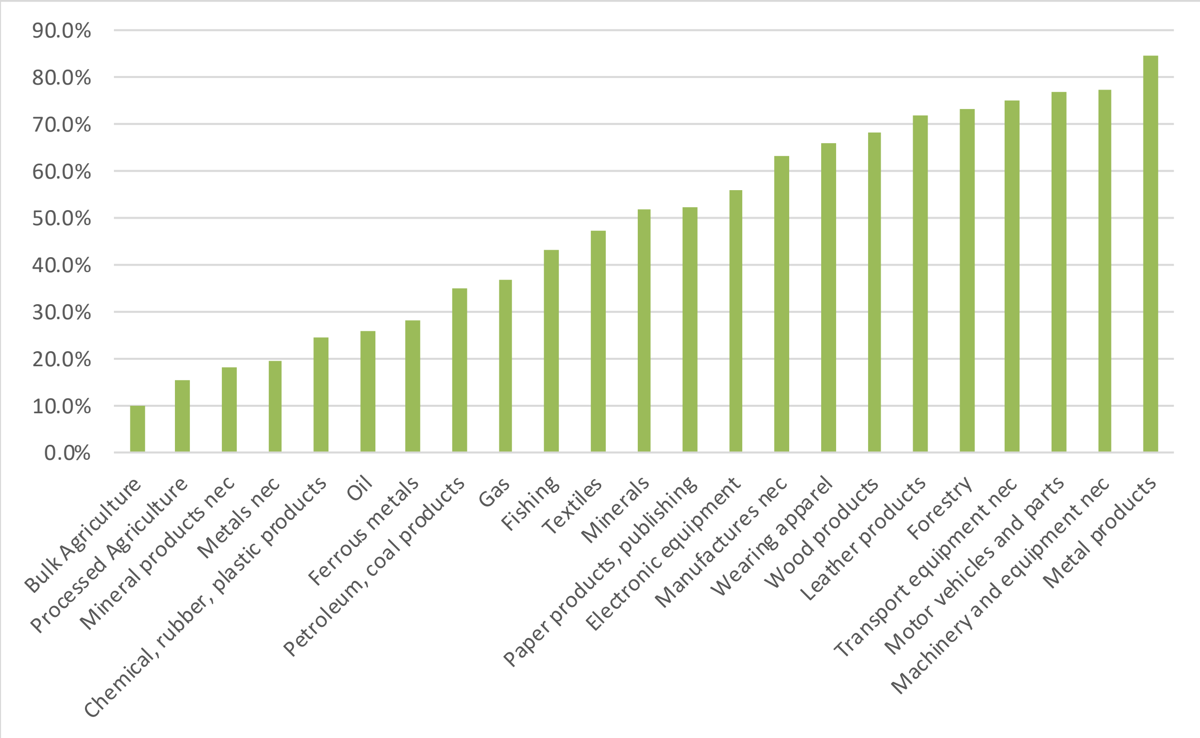
3 THE EFFECTS OF TRADE ON CARBON EMISSIONS

3.1. Trade affects carbon emissions in multiple ways. Firstly, it is directly responsible for the expansion of economic activity, including international transportation (the *scale* effect). Secondly, trade openness alters the nations' production mix, which can be negative or positive depending on whether a country has a comparative advantage in emission-intensive sectors (the *composition* effect). Third, trade allows the incorporation of green technologies into the production process and rising environmental awareness among consumers as well as higher regulatory stringency, which generates positive impacts on the environment (the *technique* effect).

3.2. Economic literature shows that trade is likely to increase GHG emissions by stimulating growth. This effect is called the *scale* effect (Copeland and Taylor, 2004). Increases in economic activity are associated with a growth in production and transportation, which increase the level of GHGs. The magnitude of the scale effect varies and depends on the carbon-intensity of the production increase. Transportation emissions are more directly measurable. Global transport emissions have been growing steadily over the last thirty years (ITF, 2021). Since 1990, global transport emissions have grown at an average annual rate of 1.9%. However, not all these emissions are linked to international merchandise trade, in fact passenger transportation accounts for more than two thirds of global transport emissions (ITF, 2021). Emissions associated with international trade represent about 30% of all transport emissions (ITF, 2015).

3.3. Traded merchandise can be transported by air, road, rail and water, or via pipelines in the case of oil. Transport emissions largely depend on the distance between countries and the modes of transport. Over half of international trade-related carbon emissions are from maritime shipping (ITF, 2021). Among the different modes of transport, shipping is also the most efficient in terms of carbon emissions per volume of goods transported. Nonetheless, transportation accounts for a large portion of the emissions in many sectors (Figure 3).

Figure 3: Share of transport emissions over total emissions, by sector



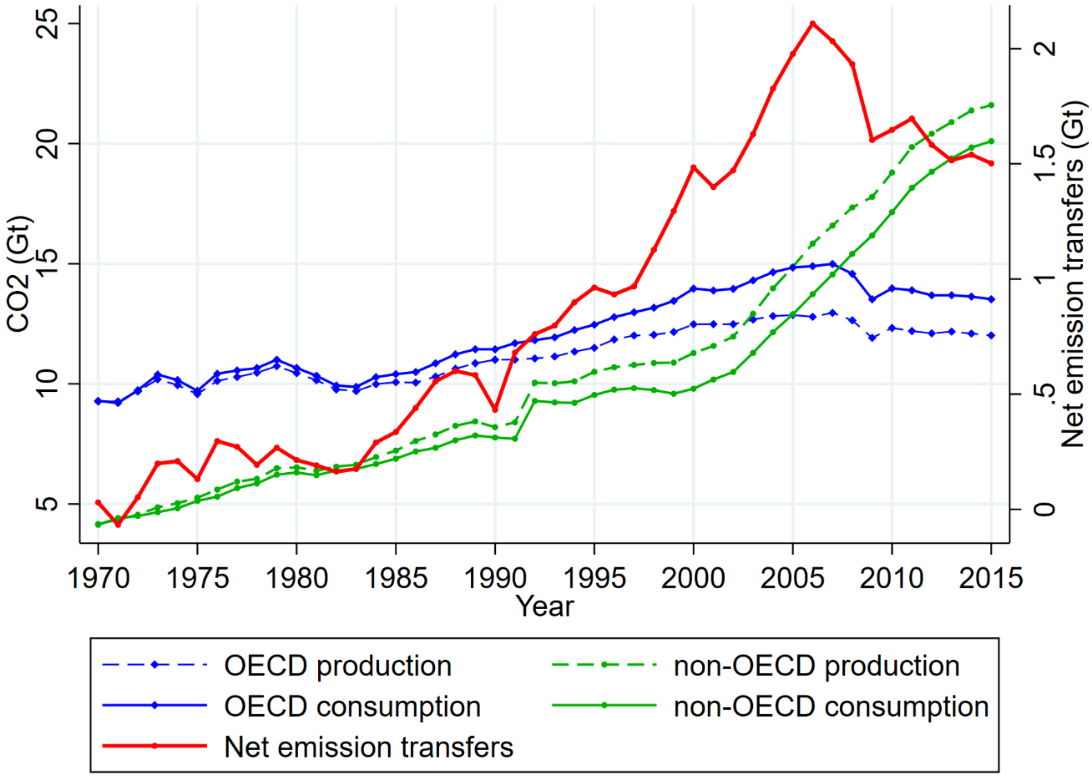
Source: Transport emission intensity from Cristea et al (2013), bilateral trade flows for year 2017 from GTAP.
Note: This figure shows the share of transport emissions over total trade-related emissions (transportation emissions and production emissions) per sector. The transport and trade-related emissions in 2017 are calculated by multiplying the intensity of emissions in 2004 (in million grams of CO2 emissions per million USD 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.

3.4. The second way trade can impact emissions is by shifting production to locations with different carbon emission intensities or modifying the production mix (*composition effect*). The amount of carbon emissions transferred through international trade has evolved over time. Notably, the rise of global value chains has resulted in rapid increases in emission transfers from the developed to the developing world (Wood et al., 2020). Following the rise in outsourcing activities, developed countries have been able to decarbonize domestically, while developing countries have witnessed an increase in their carbon emissions.

3.5. Figure 4 depicts the carbon emissions embedded in the production and final consumption in OECD (mostly high-income) countries and non-OECD (mostly middle and low-income) countries. The gap between production and consumption emissions in OECD countries represents the net transfer to non-OECD countries, which we plot in red in Figure 4. Since the mid-1980s, with the rise of globalisation, non-OECD countries have seen a rapid increase in production-related CO_2 emissions, in part due to production for export and domestic investment in productive capacity. In contrast, OECD countries on average saw their production-related emissions decline (at least in per capita terms), whilst emissions embedded in imports grew rapidly. International emission transfers grew significantly faster than global trade and gross domestic product in the 1990s and early 2000s (Peters et al., 2011). The cross-country trade of embedded emissions as a percentage of total global GHG emissions rose from 19% in 1995 to 24% in 2011 (Wood, Stadler et al., 2018). In particular, as shown in Figure 4, emission transfers from OECD to non-OECD countries peaked in 2006 and have been declining since. This is principally due to the reduction in the emissions intensity of traded goods, rather than the volume of trade (Wood et al., 2020).

3.6. The development of emissions transfers between OECD and non-OECD countries is mirrored in the broader development of all emissions embodied in trade. The global emissions embedded in all international trade flows peaked in 2008, pointing to the fact that improvements in emissions intensity (measured as CO_2 emissions per unit of traded value in constant prices) outpaced the growth in trade volumes from around 2005-6. After a rapid decline of trade volumes during the financial crisis in 2008-9, both trade and emissions transfers rebounded in 2010 and 2011. However, the percentage of emissions embedded in trade has declined since 2012, due to accelerated decrease in emissions intensity of trade (Wood et al., 2020).

Figure 4. Evolution of carbon intensity in production and trade

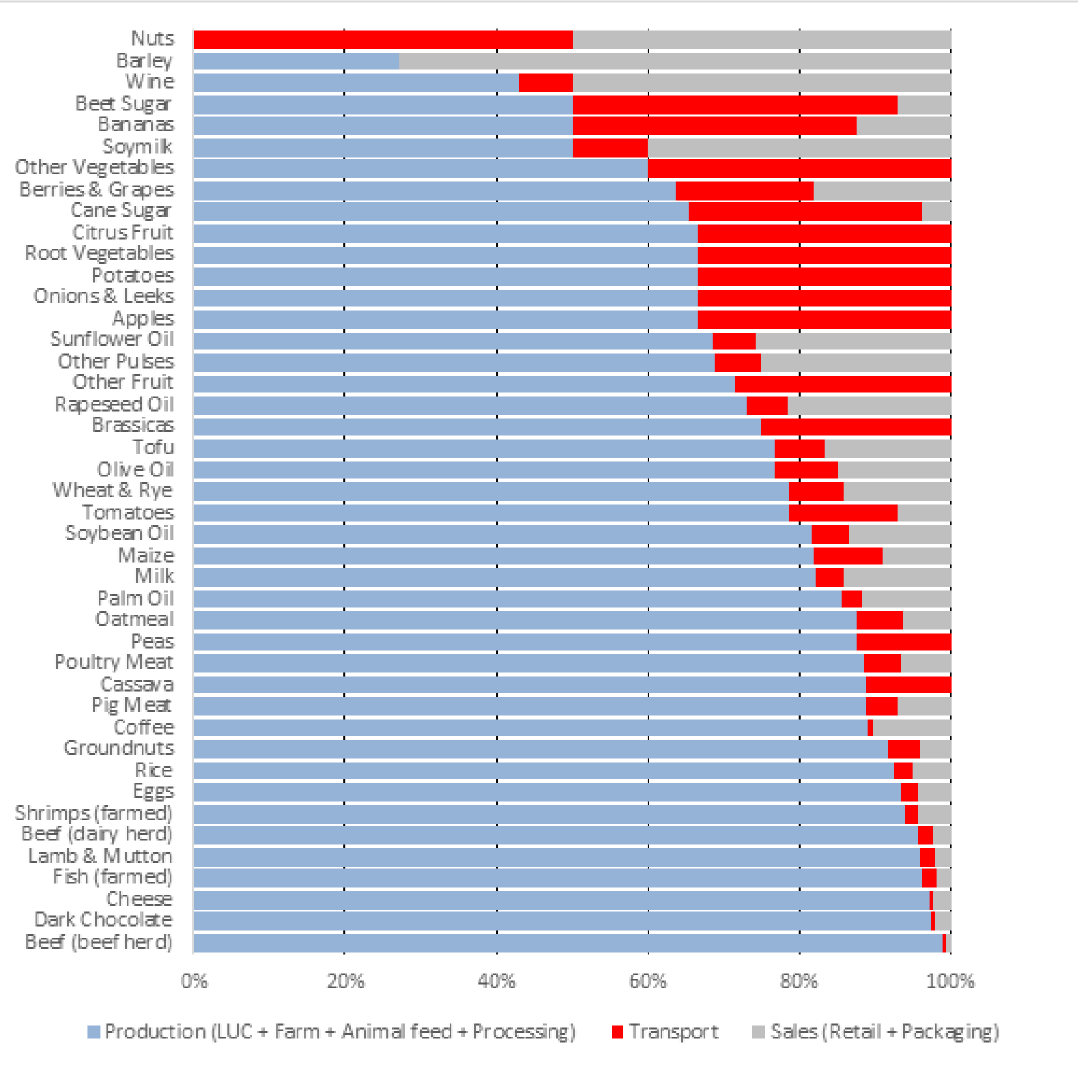


Source: Wood et al. (2020).
Note: Net emission transfers refer to the difference between production and consumption-based countries.

3.7. The net effect of trade on GHG emissions depends, among others, on how much transportation accounts for the total emissions through a product's life cycle. Figure 5 provides the share of GHG emissions released in different phases of the supply chain of some food products. For some agricultural commodities, transportation emissions account for only a small share of total emissions in a food supply chain.

3.8. In cases where production emissions in the exporting country are lower than in the importing country and the difference of production emissions exceeds transportation emissions, international trade reduces total emissions. Cristea et al. (2013) report that roughly 31% of trade by value, despite transportation emissions, can lead to a net reduction in carbon emissions compared to domestic production, and that in many cases this net reduction is substantial. However, the remaining cases represent significant increases in emissions. In the aggregate, this corresponds to an increase in emissions equal to 1274 million tons of CO_2, of which 1178 million tons is due to transport emissions. For these cases, improvements in carbon-efficiency in production and transportation is necessary.

Figure 5: Greenhouse gas emissions across the food supply chain



Source: Nemecek and Poore (2018)
Note: GHG emissions are measured in kilograms of carbon dioxide equivalents (kgCO_2eq) per kilogram of food.

3.9. Finally, trade is also a channel through which environment-friendly technologies diffuse across borders, which influences the carbon-intensity of production (*technique effect*). Trade and the globalization of the solar photovoltaic (PV) market have been major factors driving the decrease in the prices of solar energy production technology and solar energy as manufacturers are better able to source goods and services from competitive suppliers (WTO-IRENA, 2021). Since only a small number of companies, located in a few countries, have specific technological expertise in the manufacturing of goods related to renewable energy, trade provides access to technologies with a level of efficiency that cannot be replicated domestically in importing countries (Garsous and Worack, 2021).

3.10. We have seen that trade has multiple contrasting effects on carbon emissions, but what is the overall effect of trade? In other words, what would be the amount of GHG emissions in a counterfactual situation without trade? We cannot observe the amounts of emissions in the data, but 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 final and intermediate goods would need to rise to meet the demand for products that were previously imported. Shapiro (2016) shows that, compared with a counterfactual of autarky, international trade increases global CO2 emissions by 5% (1.7 gigatons of CO_2 annually). Furthermore, the gains from international trade – measured as the benefits for producers and consumers - exceed the environmental costs from CO_2 emissions by 2 orders of magnitude.

4 HOW COULD TRADE EMISSIONS BE REDUCED?

4.1. Obviously, autarky would not be a viable nor a desirable solution. More realistically, emission abatement could start from curbing the emissions released by transportation activity. Substitution of more carbon-efficient means of transportation (e.g. rail instead of road), could result in a reduction of emissions. IPCC (2014) estimates that 14% of global GHG derive from transportation, mostly because of its reliance on fossil fuels. This estimate includes both international and intra-national transportation of passengers and goods. Policy initiatives and technological innovation are being deployed to reduce these emissions. For example, the European Union aims to reduce by at least 60% its carbon emissions compared to 1990 by, among other things, switching to more efficient modes of transportation, promoting electrification, as well as pushing research in hydrogen, advanced biofuels and renewable synthetic fuels (European Commission, 2016). Similar policies are being implemented in other areas of the world. For instance, Korea's pandemic recovery fund supports electrification of transportation and large countries such as China and Japan aim to reduce their transport emissions as part of their pledge to reach carbon neutrality (ITF, 2021). The International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) launched strategies to decarbonize international shipping by 2100 and improve fuel efficiency and reach carbon neutral growth in aviation.

4.2. International cooperation will be required for a successful climate action. GHG emissions are global externalities. Therefore, successful climate policy requires the engagement of all countries to address concerns over carbon leakage – i.e. a situation in which carbon-intensive industries relocate to places with laxer environmental regulation. Deployment of technological innovation will also be required to meaningfully reduce emissions released during production. In this respect, the WTO also has a role to play in facilitating trade of environmental goods and the diffusion of green technologies. Reducing trade barriers to green technologies will facilitate access and increase adoption of these technologies to help accelerating the transition towards a more sustainable economic model.

5 CONCLUSIONS

5.1. Trade affects emissions in three different ways. First, merchandises need to be transported and transportation generates emissions. Trade also increases emissions by stimulating economic activity. Second, trade modifies the production mix and allows the production and consumption of goods to take place in different regions. Production in the exporting country may differ in terms of carbon intensity compared to the importing country. In instances where the emissions from production and transportation are lower than those from production in the exporting country, trade can result in less carbon emissions. Third, trade also plays an important role in disseminating green technology, leading to a positive impact on decarbonisation.

5.2. Although trade contributes to GHG emissions, the magnitude of such effect may be smaller than suggested by conventional estimates. This is because, if countries closed borders to trade, carbon emissions from domestic production would need to increase to meet domestic consumption. Shapiro (2016) estimates that GHG emissions would only be 5% lower in the absence of trade. And only half of this decrease would be ascribed to reduction in emissions in transportation, because such a scenario would require an increase in internal transportation, which typically uses less carbon-efficient means of transportation than international shipping.

5.3. Policy measures are important to align the private cost of carbon emission with its social cost and reduce carbon emissions associated with both production and transportation of trade. International cooperation has an important role to play in helping to reduce the carbon content of transportation, in contributing to address carbon leakage and in facilitating the diffusion and adoption of green technologies.

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