IATRC

INTERNATIONAL AGRICULTURAL TRADE RESEARCH CONSORTIUM

Commissioned Paper

Achieving Climate Change and Environment Goals without Protectionist Measures: Mission (Im)possible?

Fabio G. Santeramo, Emanuele Ferrari, Andrea Toreti

March 2024

IATRC Commissioned Paper CP-31

International Agricultural Trade Research Consortium

Commissioned Paper No. 31

Achieving Climate Change and Environment Goals without Protectionist Measures: Mission (Im)possible?

This Commissioned Paper was co-authored by a working group which responded to a call for Commissioned Papers from the Executive Committee of the IATRC. The members of the group were:

Fabio G. Santeramo
University of Foggia and European University Institute – Foggia, Italy
Fabio.santeramo@unifg.it

Emanuele Ferrari
Joint Research Center of the EU Commission, Sevilla, Spain

Andrea Toreti
Joint Research Center of the EU Commission, Ispra, Italy

The views expressed should not be taken to represent those of the institutions to which the authors are attached, nor to the IATRC and its funding agencies. Correspondence regarding the content of the paper should be directed to the authors.

The International Agricultural Trade Research Consortium (IATRC) is an organization of approximately 220 economists from 28 different countries, interested in research, policy analysis, and current developments in international agricultural trade. It is supported by the United States Department of Agriculture (ERS, FAS, and OCE), Agriculture and Agri-Food Canada, and the participating organizations. Funding for this commissioned paper comes from the USDA Foreign Agricultural Service.

Achieving Climate Change and Environment Goals without Protectionist Measures: Mission (Im)possible?

St. Paul, Minnesota: University of Minnesota, Department of Applied Economics, International Agricultural Trade Research Consortium

Copies of this paper and other IATRC Publications are available on the website
www.iatrcweb.org

This volume contains information which was presented at an
International Agricultural Trade Research Consortium Annual Meeting,
which was held December 11-13, 2022 in Clearwater Beach, Florida, USA.

Achieving climate change and environment goals without protectionist measures: Mission (im)possible?

Fabio G. Santeramo[a], Emanuele Ferrari[b], Andrea Toreti[c]

[a] University of Foggia and European University Institute, Italy
[b] Joint Research Center of the EU Commission, Sevilla, Spain
[c] Joint Research Center of the EU Commission, Ispra, Italy

COMMISSIONED PAPER

International Agricultural Trade Research Consortium (IATRC)

March 2024

Contact Information

Prof. Fabio Gaetano Santeramo, PhD
University of Foggia
Via Napoli 22, Foggia, Italy
Email: fabio.santeramo@unifg.it
Phone: +39 0881 589447

Achieving climate change and environment goals without protectionist measures: Mission (im)possible?

1. Introduction

Trade and environment are interconnected, with trade being part of the problem (via emissions) as well as part of the solution (moving goods from areas of surplus to deficit areas). Trade and policies have direct and unintended consequences that need to be analyzed in a combined way.

International regulations are capable of shaping trade routes, altering comparative advantages and export/import incentives, co-determining transaction costs as well as extensive and intensive trade margins. . The trade regime is very impactful on trade of agricultural goods, where regulatory interventions are substantial and distortive (Anderson et al., 2013). Moreover,

We review several issues that are necessary to understand how trade policies may help achieving climate change and environmental goals, without distorting or fractioning trade. While the focus is necessarily on the agricultural sector, this piece is of broader interest as it shed lights on characteristics of the climate-trade-policies nexus that go beyond the primary sector. The remainder of the manuscript is as follows: first we examine the economics of the climate-trade nexus to level the playing field and set foundational concepts for economic analyses; second, we delve into the climate-trade -policies nexus, pointing at major unintended consequences (e.g. leakage and competitiveness loss); third, we provide anecdotal empirical evidence on trade, policies and the global value chain. We conclude with policy reflections.

2. Economics of the Climate-Trade nexus

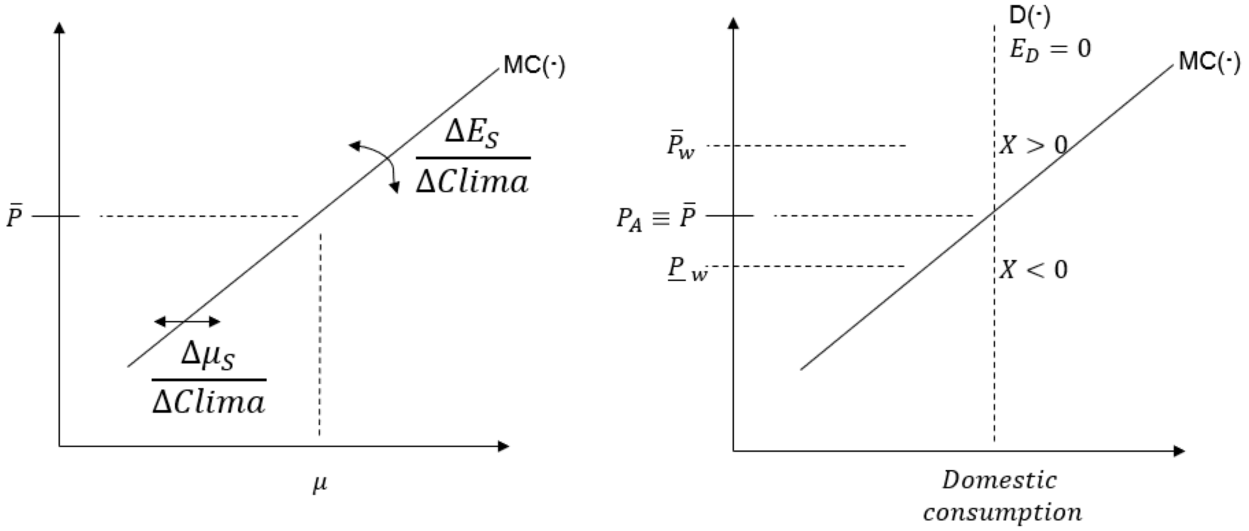
Climate-trade nexus

The theory of comparative advantages explains trade dynamics and policies (Maneschi, 1998; Costinot et al., 2015). Exports is incentivized by low(er) opportunity costs of production.

The changes in climate alter comparative advantages insofar productions may become relatively cheaper when climate is more favorable. These changes induce (costly) adaptation adjustments, via migration and trade (Desmet and Rossi-Hansberg, 2024)[1], and have (potentially disruptive) effects on the environment insofar the externalities are generally not internalized in price signals[2].

The effects of climate change on the primary sector can be stylized with (admittedly simple) economic models, insofar the climate conditions enter the production function of agricultural products (Mendelsohn et al., 1994). Figure 1a summaries the mechanisms through which climate conditions may alter the agricultural production, export capacity and trade. The left panel shows how climate conditions may shift leftward or rightward the supply curve, as they may increase or decrease the (average) production costs (μ). Moreover, the figure shows that the effect of climate may be also on the slope of the supply curve (i.e. on the elasticity of the supply, E_s). The rationale behind this mechanism is that climate conditions may influence the degree of substitutability of the inputs. For instance, precipitations may allow the substitution of irrigation with water-saving agronomic practices. In short, climate conditions alter the whole production function.

Figure 1a – Climate – Production – Trade nexus



The left panel shows the potential effects of climate changes on the marginal costs (MC), thus on the supply function. Climate conditions impact on elasticity of the supply (E_s) and on (average) production costs (μ). The right panel shows how the effects may result in excess (or deficit) of supply, and thus on changes in trade. The picture shows how, assuming rigid demand (with

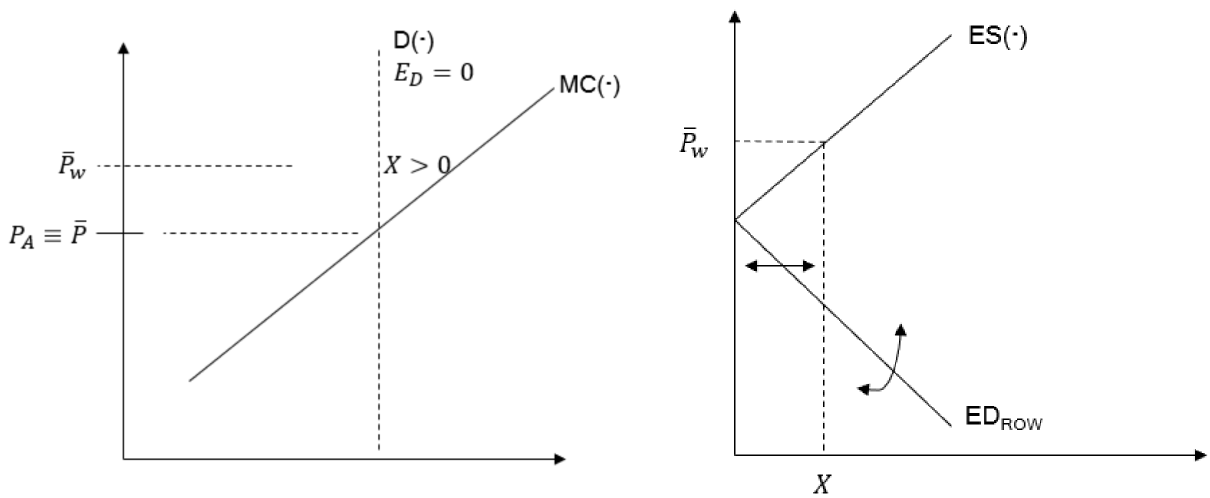
[1] Climate conditions influence, shape, and alter the agri-food supplies, because climate factors are key in the biological production of agricultural goods (Reilly and Hohmann, 1993). The correlation of changes in climate conditions and countries' export capacities as well as terms of trade is now well established (Bozzola et al., 2023; Lamonaca et al., 2024).

[2] Since the Stern report (Stern, 2008), the quantification of economics effects of climate change has been long debated. An interesting piece to appreciate the controversial aspects of the quantification is provided by Tol (2009).

elasticity of demand, E_D, equals to 0) autarky price (P_A) compares to world price (P_W) determining positive or negative trade flows (X).

The right panel (assuming a rigid domestic demand) shows that climate conditions, by shifting or rotating the supply function may result in higher (or lower) export, if the autarky price is below the international price, or in higher (or lower) import, if the autarky price is above the international price[3]. Climate conditions may alter the comparative advantage and therefore make it more (or less) profitable to market the agricultural products on the international market. Changes in comparative advantages (Figure 1.b) are also important to understand bilateral trade: partners that are characterized by different climatic conditions may specialize in the production of different commodities (Conte et al., 2021), which result in larger bilateral trade (Burke and Emerick, 2016). Differently, Dallman (2019) and Heerman (2020) use the same logic to conclude that countries with similar climatic characteristics tend to specialize in similar agri-food productions, which increase their competition in the international market. In short, via production, climate conditions alter export capacity and modify trading relationships.

Figure 1b – Climate – Production – Trade nexus



The left panel reports the effects of climate changes on the excess of supply. The right panel shows that the effects of the climate changes may be indirect, from trading partners. In particular, in the right panel we show the excess of supply (E_S) and the excess of demand (E_D), with respect to the world price (P_W). For simplicity, we assume a rigid demand (elasticity of demand, E_D, equals to 0).

3. Climate – trade – policies nexus

[3] We need to make the disclaimer that the model is admittedly simple. For instance, it does not consider other factors, and it does not consider internal demand that in some cases cannot be satisfied by internal production.

The relationship between climate and trade is bidirectional[4]: on one hand climatic conditions influence production and trade; on the other hand, production, and trade impact the environment through emissions (and other pollutants). Trade policies may help shifting the role of trade from being a potential problem to become part of the solution, and (in fact) we observe that environmental standards are not routinely included in trade agreements (Hoekman et al., 2023). The current policy debate focuses on the interventions devoted to mitigate the impacts of production and trade on the environment and on climate.

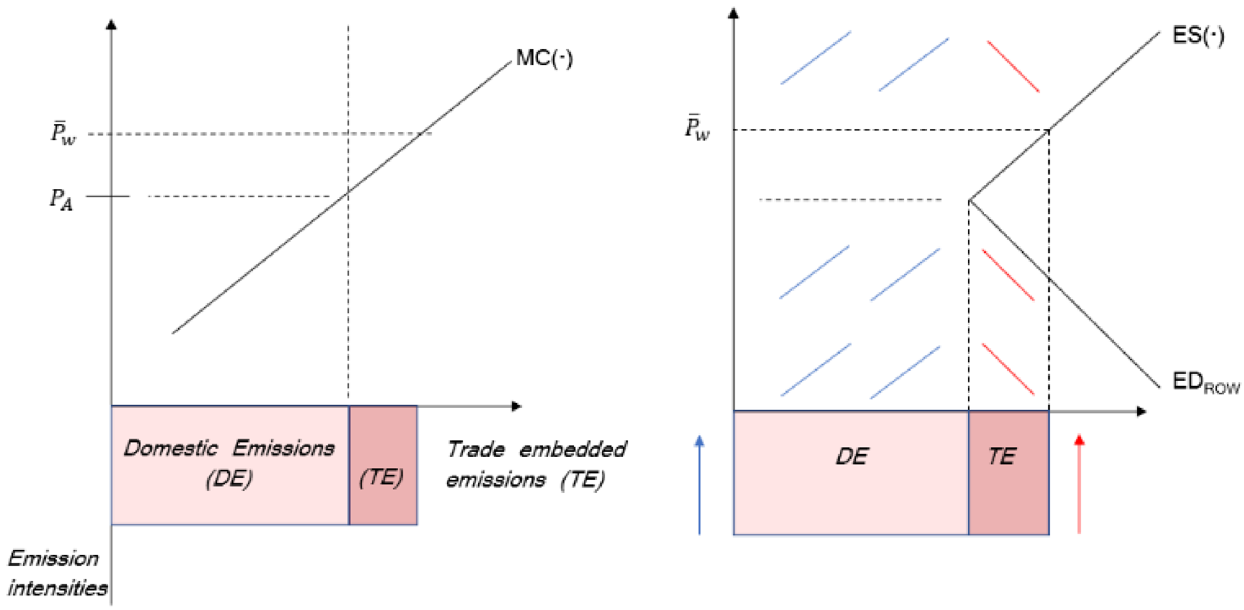
Figure 2 explains the conceptual framework of the climate – trade – policies nexus. The left panel shows the relationships between production, domestic consumption, trade, and emissions. Part of the emissions caused by the production of agricultural products are named "domestic emissions" (DE) as they refer to the emissions connected to the production and consumption in loco of the agricultural products. Differently, the share of emissions connected to the exported goods are named "trade embedded emissions" (TE). The domestic emissions (trade embedded emissions) depend on the quantity produced and consumed domestically (quantity exported) as well as on the emissions connected to the production of the domestically consumed products (exported goods). The emissions intensities for the goods marketed in domestic or international market do not have to be the same. In fact, the goods produced for the domestic market or for the international markets may differ in terms of standards, quality and therefore may differ in terms of emissions intensities.

The right panel of Figure 2 shows the relationships between the domestic and the international mitigation policies. Domestic policies aim at lowering the emissions that are linked to the domestic production and consumption. Differently, international policies (should) target the emissions connected to the traded products. Both the domestic and the international policies are not exempt by side effects, in terms of potential competitiveness loss supplying goods for the domestic market, and in terms of relocation of the productions in countries with less stringent standards or less efficient technologies, thus with higher emissions intensities. These issues are discussed in the next sections.

Figure 2 – Climate – Production – Trade nexus

[4] This is very true for the agricultural sector, and is also the case for other sectors (e.g. tourism).

ù

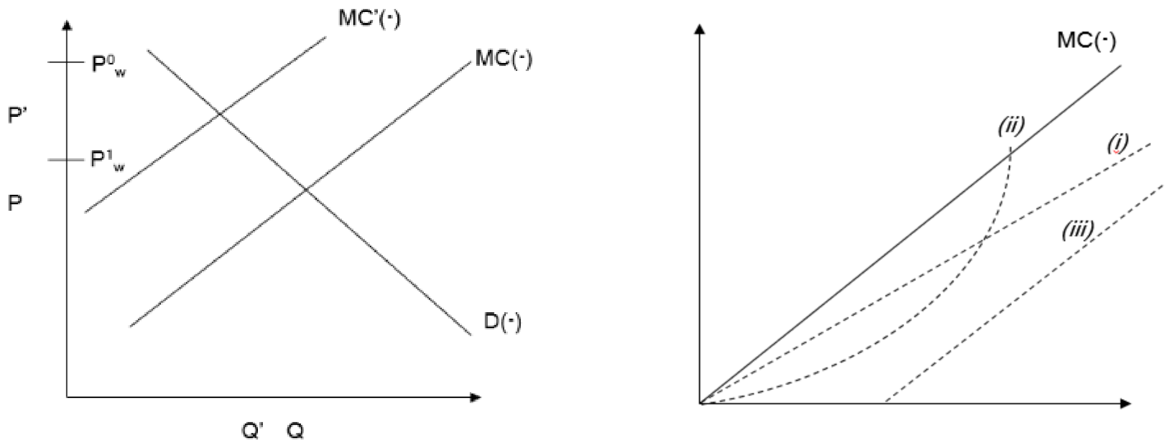


The left panel shows the relationships between production, domestic consumption, trade, and emissions. The right panel shows the relationships between the domestic and international policies. The domestic emissions are represented by DE whereas the trade embedded emissions are referred to as TE.

3.1 Unintended consequences: leakage and competitiveness loss

Trade and environmental domestic and international regulations may cause two major unintended consequences, which may undermine their beneficial effects. The consequences may be either on the domestic market (i.e. on the market of the implementing country) or on the foreign market (i.e. on the market of the trading partner).

Figure 2b – Unintended (economic) consequences of loose international coordination: Competitiveness loss



For exporting countries, the change in regulations increases marginal costs, from MC to MC', causing a decrease in total export (for a relatively high world price) or a switch from net export to net import (for a relatively low world price). For importing countries (not shown in the graph), the change in regulations increases imports.

The basic economic graph (figure 2b) shows that environmental regulations have clear effects on the domestic market, eroding the market share of domestic firms that need to comply with stringent standards and to adapt their production. The competitiveness loss is tightly linked to i) the degree of inputs substitutability (i.e. different supply elasticity); ii) the (flexibility of the) production function; iii) the capability of shifting rightward the production function (i.e. by improving the technology).

Estimating the degree of competitiveness loss is not an easy task, and the studies that provide empirical evidence are remarkable. Albrizio et al. (2014) conclude on a little causal relationship between the stringency of the environmental regulations, aggregate productivity, and competitiveness. Koźluk and Timiliotis (2016) found little evidence (in aggregate terms) on the effects of stringent environmental regulations and competitiveness losses. However, they warn on the peculiarity of agriculture: its vulnerability and dependence on the environment, which tighten the links with resource endowments, let us envisage that the competitiveness loss may be a concrete (not negligible) threat. Despite the effects on global competitiveness may be scarce, it is not necessarily true that the distribution effects is even across countries, especially for the primary sector, which is characterized by rigid market fundamentals (demand and supply).

To the best of our knowledge, the studies on the impacts of environmental regulations in the agricultural sector are very heterogeneous and it is hard to draw general conclusions[5]. However, a simple conceptual framework, supported by common knowledge, would allow us to draw some conclusions. The figure 2c shows that the effects of stringent environmental regulations, when the demand is rigid (up-left panel), are evident on consumers (i.e. "consumers pay"), whereas an elastic demand (up-right panel) put costs on producers, decreasing outputs (i.e. "producers pay"). More complexes are the cases in which the supply, which is subject to shifts, is rigid (down-left panel) or elastic (down-left panel). In both cases the effects are both on consumers and producers (i.e. "consumers and producers pay"). The more rigid the demand, the more the burden on consumers. A simple lesson that can be derived from this intuitive and stylized representation is that, in the agricultural sector, where demand and supply are both rigid, the effects are both on consumers and on producers, but more likely to be evident on consumers. Therefore, although the competitiveness

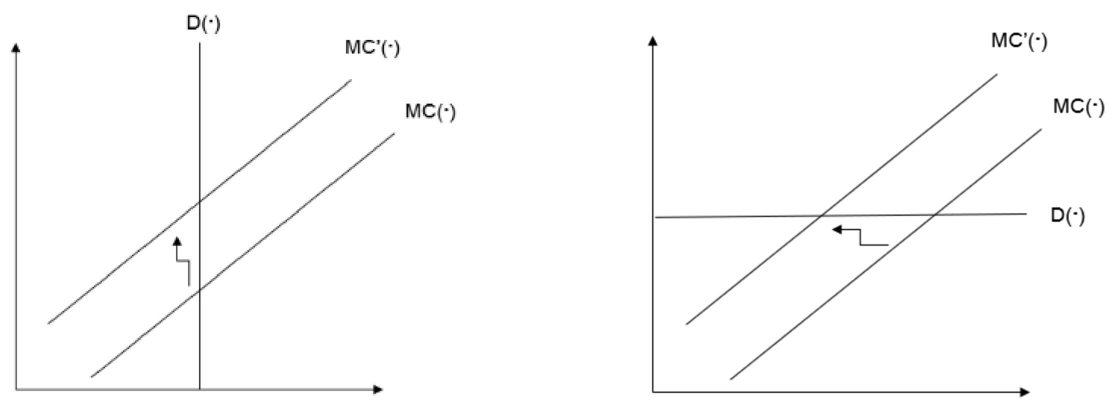
[5] The literature on ex-post evaluation of environmental policies to reduce the impacts of agriculture on the environemtna is readily gworing (e.g. Diaz-Rainey et al., 2018, Läpple et al., 2022, Assunção et al. 2023).

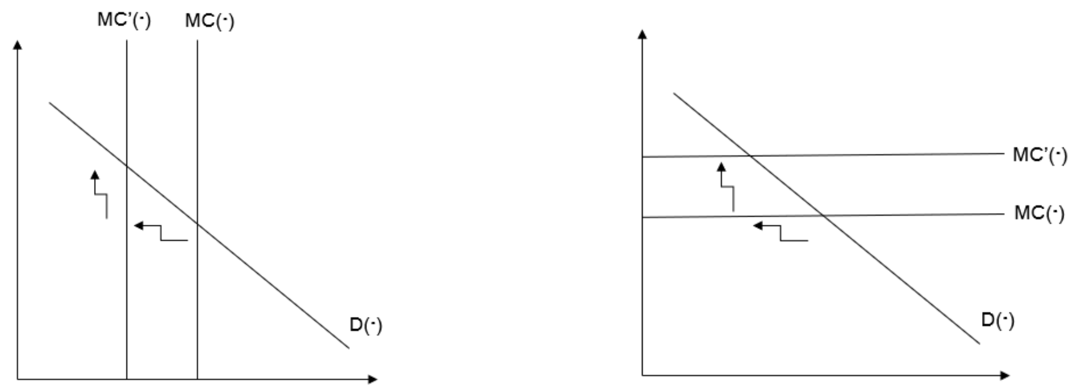
loss may be (relatively) negligible on producers, the effects are larger on consumers, in terms of welfare losses.

As widely known, the primary sector is characterized by both a rigid demand and a rigid supply (both cases are shown in the left part of the figure 2c). It is therefore likely that, ceteris paribus, in the primary sector the domestic effects of stringent regulations are a combination of those depicted in the left panels (i.e. welfare losses for consumers, and producers). Differently, at global level (i.e. for an infinitely elastic demand, as in the up-right panel) the effects in terms of competitiveness loss tend to be negligible, in that the increase in marginal costs (MC) of the implementing country may be offset by a larger production in a third country.

As for leakage, the basic economic graph (figure 2d) shows that environmental regulations have potential displacement effects in terms of emissions: the production of domestic firms, which need to comply with stringent standards, may be substituted by larger imports from foreign markets. As matter of fact, Copeland et al. (2022) show that the most developed economies tend to outsource pollution. The graph shows that the reduction of domestic emissions, named here as “carbon emissions cut”, may be offset by an increase in emissions in the exporting (trading) partner, named here as “leakage”. The magnitude of the leakage depends on three factors: i) the magnitude of the shift in supply (i.e. the stringency of the environmental regulations); ii) the supply elasticity (i.e. the degree of sustainability of production inputs and the capability of adopting technological innovations); iii) the relative differences in environmental efficiency between the implementing market and the trading partner.

Figure 2 – Competitiveness loss and market fundamentals

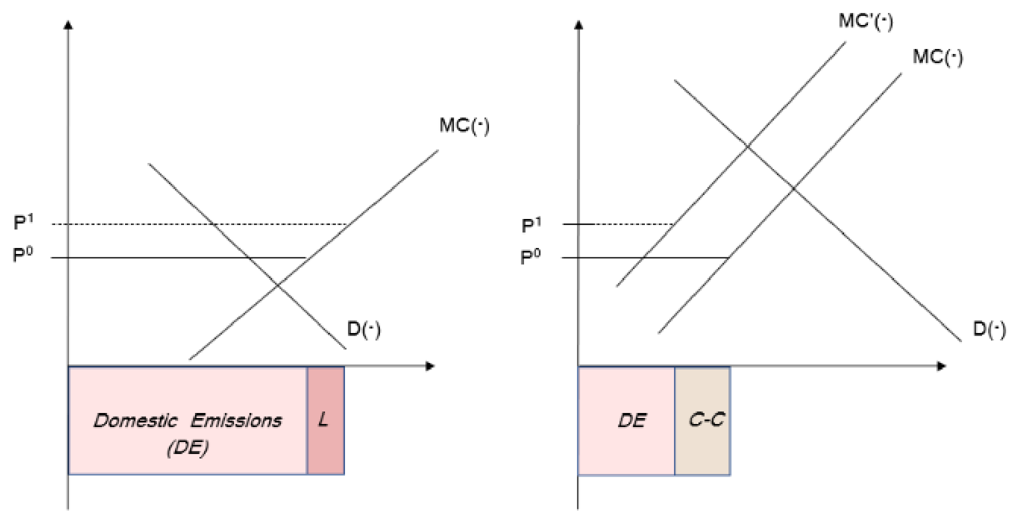




The up-left and down-left panels show, respectively, rigid (inelastic) demand (D) and rigid supply (MC). The up-right and down-right panels show, respectively, flexible (elastic) demand and supply. The vertical arrows show the effects on domestic price, the horizontal arrow show the effect on domestic production.

Again, the simple conceptual framework, supported by common knowledge, allow us to draw some conclusions. In the agricultural sector the emissions (for CO2 and CH4) are concentrated in few industries and few products: bovine meat, milk, and rice. The emission intensities are higher in developing (non-OECD) countries (Mamum et al., 2021). These simple facts allow us to speculate that the leakage is likely to be problematic for regulations imposed in the (dirtier) industries (namely livestock) with larger trade flows from developing countries.

Figure 2d – Unintended (environmental) consequences of loose international coordination: Leakage



For importing countries (right panel), the change in regulations increases marginal costs, from MC to MC', decreasing total imports, and domestic emissions (DE). The exporting country (left panel) increase exports and emissions (DE). The carbon emissions cut (C-C) is traded-off with the leakage (L) in the exporting country. For exporting countries (not shown in the graph), the change in regulations decreases exports.

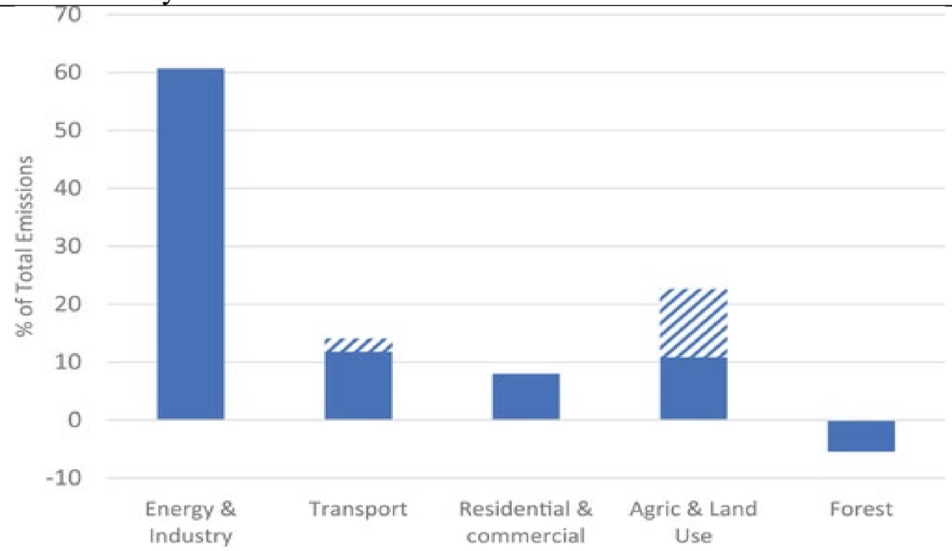
The rationale is simple. Leakage is problematic only for polluting industries, therefore having higher emission intensities is a necessary (not sufficient) condition for observing (of worrying about) leakage. Second, leakage is problematic when the lower domestic production is compensated by larger imports, a condition that occurs when the demand is relatively rigid. This is true for products such as milk, bovine meat, and rice[6]. Third, leakage is problematic when the countries where the production is relocated are less environmental efficient (i.e. have higher emissions intensities).

6 According to the USDA, milk, bovine meat and rice tend to have elasticities in the range 0.2 and 0.8. Data available at: https://data.ers.usda.gov/reports.aspx?ID=17825

4. Empirics of the climate-trade nexus

The agricultural sector is one of the main contributors in terms of global emissions (Crippa et al., 2021). Figure 3 shows that the net contribution of the agri-food sector is about twenty percent (Mamun et al. 2021), second to the energy sector, which accounts for about sixty percent. Within the agricultural sector, livestock and cereals are the main contributors: more precisely, ruminant meat and milk account for about seventy percent, and rice for fifteen percent, summing up to about eighty-five percent of the total emissions in agriculture. In short, in the agricultural sector the emissions are highly concentrated in few productions. The emissions are also concentrated in few countries with developing countries emitting more than the developed countries (the ratio is about 80 to 20).

Figure 3 – Emissions by sectors



Graph from Mamun et al. (2021)

The empirical literature on the impacts of trade on the environment has focused on the manufacturing sector (e.g., Barrows and Ollivier, 2018) particularly in the US (e.g., Grether et al., 2009; Levinson, 2015; Shapiro and Walker, 2018). Brunel (2019) provides the first decomposition of the EU production and imports to determine whether the US results are externally valid. The empirical analyses tend to rely on a standard method proposed by Levinson (2009) to decompose emissions impacts due to scale, composition, and technique[7]. As well described in Grossman and Krueger (1993), and in Copeland and Taylor (1995), changes in trade policies may affect the environment by expanding the scale of economic activities, by altering their composition and by inducing changes in

[7] As Copeland et al. (2021) state, scale refer to the increase in pollution emissions due to the increasing in country's level of production, composition is due to the changing of the share of national output (or value added) from cleaner versus dirtier industries, whereas the technique refers to the change in pollution emitted per unit of output or value added within an industry".

the production techniques. Using this approach, and considering CO2 and NOx emissions, Copeland et al. (2021) provide a cross-countries analysis and find that technique accounts for a larger share of changes in emissions than it does the composition. In a sensitivity analysis, they observe similar patterns for the other pollutants, exception made for ammonia (NH3) and nitrous oxide (N2O), which are emissions coming primarily from the agricultural sector, and for which the composition effects are more systematic and important[8].

An interesting pattern of emission is observed along the Global Value Chain (GVC), which generates about 13.7 billion metric tons of carbon dioxide equivalents (CO2eq) (Poore and Nemecek, 2018). The farm stage dominates this picture, with four fifth of the emissions: with respect to the total emissions from the farm stage, 31% of agri-food emissions comes from livestock and fish farms, 21% are from crops produced for human consumption, 6% from crops produced for animal feed, and 24% from land use (of which one-third for human food and two-third for livestock). The post-farm stage accounts for 18% of the agri-food emissions: 4% of them comes from food processing, 6% from transport, 5% from packaging, 3% from retail. Another source of emissions, which is intrinsically connected with the complexity of the GVC, is the waste of agri-food products, which account for about 3.3 billion metric tons CO2eq, and occur both at the production stage as well as after the final consumption (Ritchie, 2023). The movement of goods exacerbates the complexity of the GVC and correlates with the likelihood of increasing waste.

Besides the complexity, the length of the GVC, its global and fragmented nature is coupled with a large, cross-boundaries movement of goods, and (not surprisingly) the global freight transport further contributes to emissions (Shapiro, 2016). According to the projections of the Organization for Economic Co-operation and Development (OECD) and of the International Transport Forum (ITF), the emissions from global freight transport are expected to increase fourfold within 2050 (OECD, 2016), a trend that calls for a deeper understanding of the linkages, though trade, of the GVC.

We approach this challenge with a purely descriptive, yet informative, analysis. We focus on the ten top GHG emitters, listed in alphabetic order: Brazil, Canada, China, European Union[9], India, Indonesia, Japan, Russia, and United States of America. We found empirical evidence for the agri-food sector[10] that mimic the tendencies observed for other sectors, but remarkable differences are stressed.

8 For more info the readers may refer to Wood et al. (2018).

9 The numbers presented in different studies may differ. For instance, according to Ge et al. (2021), the European Union emits almost four hundred metric tons of CO2eq, accounting for about 1% of global GHG emissions.

10 With some remarkable differences, the facts echo those presented in Copeland et al. (2021).

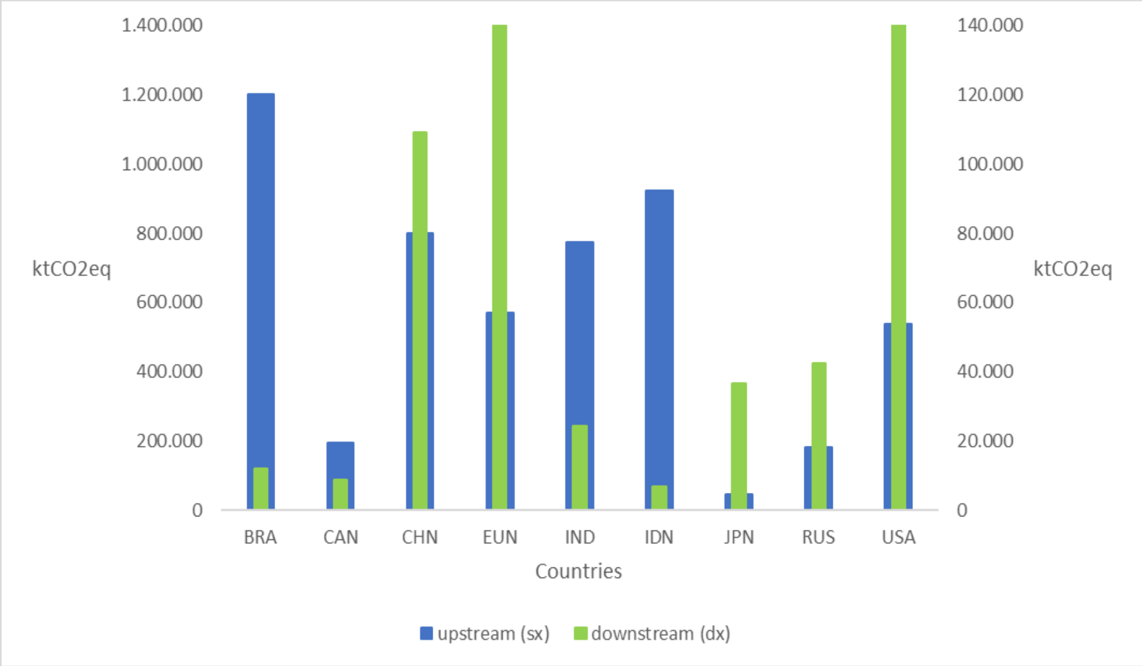
The first set of evidence relates to the emissions produced by the upstream (raw products, i.e. agricultural goods) and the downstream (processed goods, i.e. food) industries, as well as to the emissions intensities associated with the production of goods consume domestically or exported.

4.1 GVC, Trade and Emissions

To get a better understanding of the current issues associated with trade and environment, we deepen on the emissions along the global value chain (GVC). The following stylized facts are important to understand how trade is contributing the most vis-à-vis where the added value is generated along the GVC. These facts help making reflections that are relevant to shape trade policies, and agreements on environmental goals.

- The industries that are more exposed to trade are often dirtier. The outputs from dirtier industries are more often traded than the outputs from cleaner industries. This is evident for Brazil, Canada, and Russia: the outputs derived by the upstream industries are dirtier and more exposed to trade.
- The trade of agri-food products accounts from about one sixth to a fifth of total pollution emissions. More analytically, about 14 percent of emissions are embodied in exports of upstream industries and 22 percent of emissions are embodied in exports of downstream industries.
- The emission intensities tend to be quite heterogeneous across countries and industries. The emission intensities are unbalanced across value chain. Countries tend to specialize in terms of environmental efficiency either in upstream industries (e.g., Brazil, Canada, Indonesia) or in downstream industries (e.g., China, Japan, Russia, US).
- The upstream industries tend to be dirtier (i.e. more pollution intensive). The total farm-gate and land use change emissions tend to be larger than the emissions due to food processing and packaging emissions. Moreover, the difference in total emissions from upstream and downstream industries is large for economies (e.g., Brazil, Indonesia) with a 'dirty' food sector (Friedrich et. al., 2020).
- The least productive industries and countries tend to be dirtier. The economies tend to have higher participation in the global value chains through the downstream, rather than through the upstream industries. The upstream industries are less productive along the value chain and show higher pollution per unit of exports.

Figure 4 – Total emissions in upstream and downstream industries, by countries



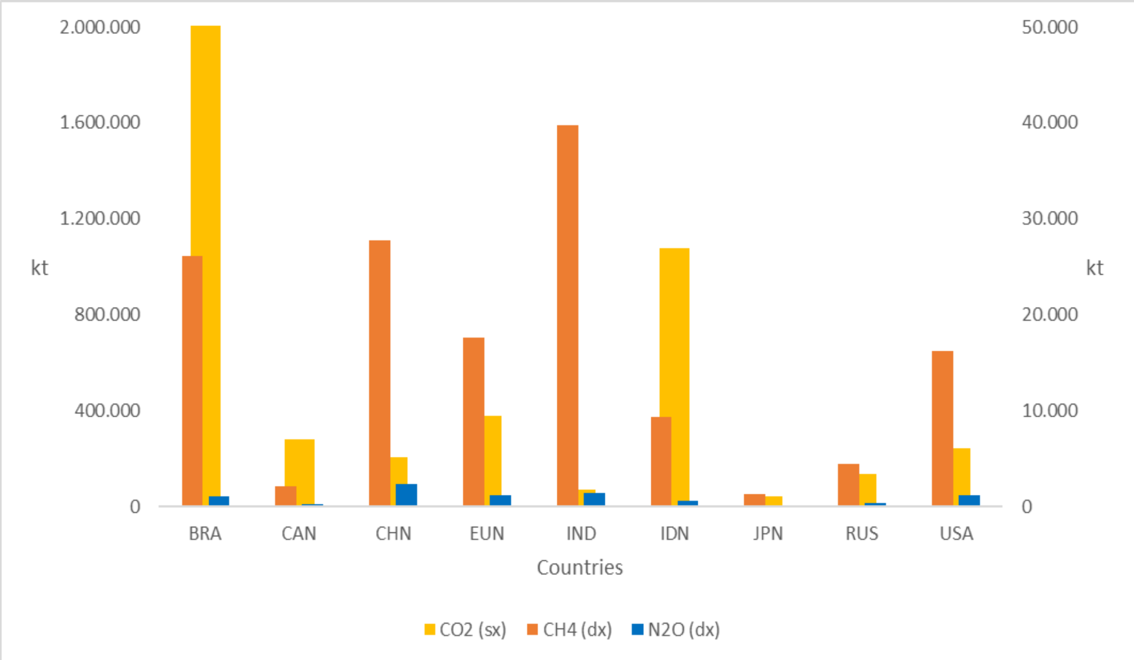
Source: Authors' elaborations on FAOSTAT data

A graphical analysis (figure 4) informs on the higher emissions observed for the upstream industries (left axis) with respect to the downstream industries (right axis), and on (absolute and relative) large differences across and within countries. For instance, in Brazil and Indonesia the upstream industries accounts for total emissions much more than the downstream industries, whereas the opposite is true for USA and EU. Moreover, Canada, Japan and Russia are among the least polluters for the upstream industries, whereas Brazil, Canada and Indonesia stand up for their lower values in the downstream industries.

Another remarkable difference is in term of global emissions (expressed in CO2 equivalent) and specific pollutants (CO2, CH4, and N2O), in upstream and downstream industries, and across countries.

The different types of pollution are somehow correlated (Figure 5): the levels of CO2 emissions tend to be correlated with the level of emissions of CH4 and N2O emissions. A remarkable feature of the agri-food sector is that the level of emissions of CO2 is high both in upstream and downstream industries.

Figure 5 – Total emissions for major pollutants, by countries



Source: Authors' elaborations on FAOSTAT data

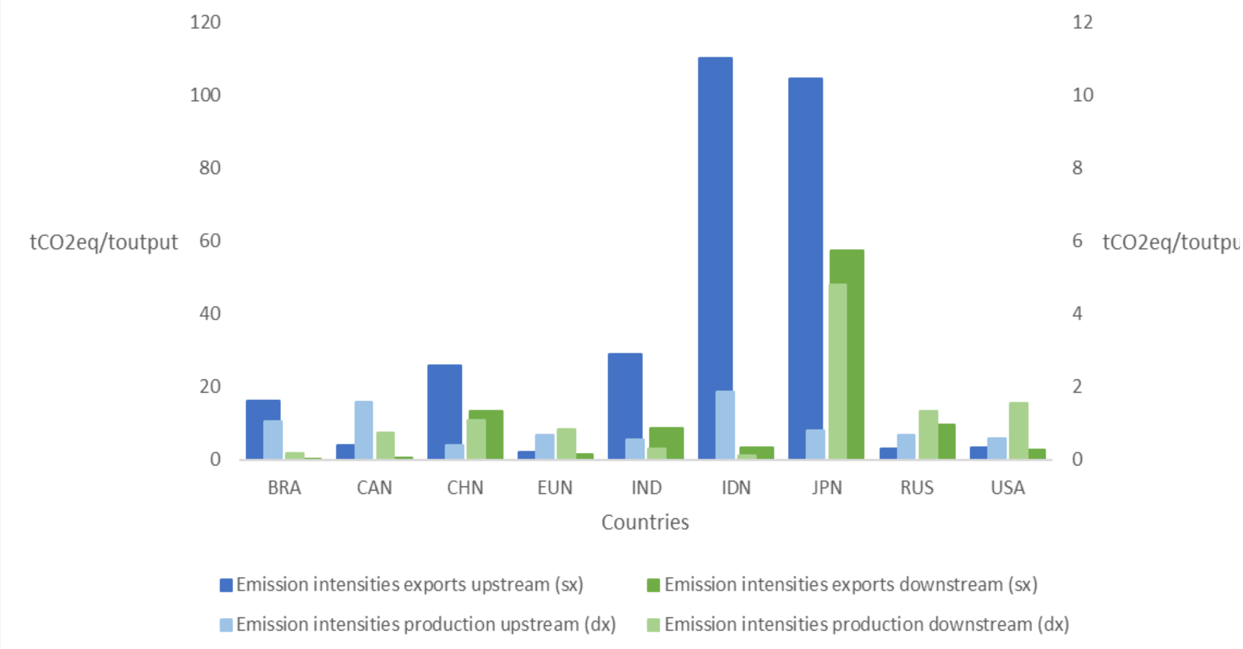
Table 1. Agri-food emission intensities for selected countries.

	Emission intensities		Emission intensities		Participation in GVC	
	(A)	(B)	(A)	(B)	(A)	(B)
BRA	1.05	0.16	16.01	0.14	0.169	0.188
CAN	1.58	0.73	4.05	0.42	0.024	0.286
CHN	0.38	1.07	25.82	13.37	0.003	0.021
EUN	0.68	0.82	2.05	1.46	0.004	0.037
IND	0.54	0.31	28.91	8.56	0.185	0.178
IDN	1.87	0.12	110.07	3.26	0.114	1.430
JPN	0.81	4.80	104.54	57.33	0.002	0.143
RUS	0.67	1.33	2.85	9.53	0.051	0.207
USA	0.59	1.54	3.38	2.55	0.005	0.065

Source: elaboration on data from FAOSTAT and WITS.

A graphical analysis (Figure 6) informs on the much larger emissions intensities in the upstream industries with respect to the downstream industries (*cfr*. blue vs green) and in export-related activities with respect to production-related activities (*cfr*. left vs right axis).

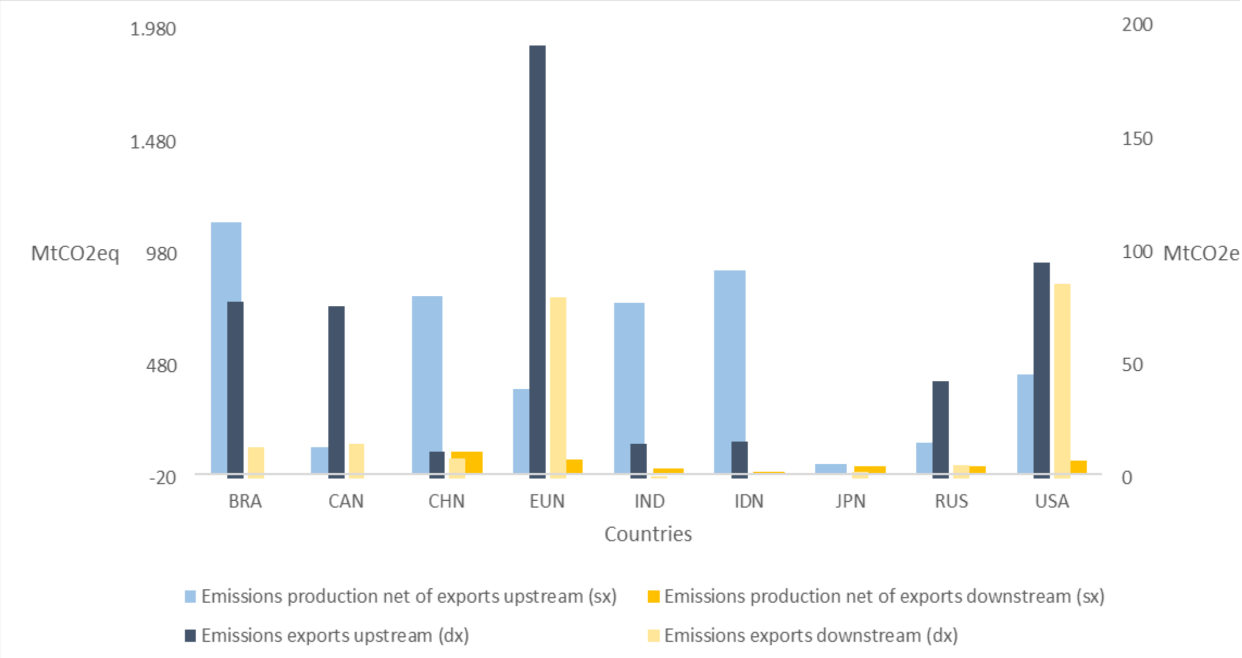
Figure 6 – Production- and export-related emissions intensities in upstream and downstream industries



Source: Authors' elaborations on FAOSTAT data

As for the total emissions, larger emissions are observed in the upstream industries with respect to the downstream industries (cfr. blue vs yellow), and the volume of export-related activities is smaller than the number of emissions generated by production-related activities (cfr. left vs right axis).

Figure 7 – Production- and export-related total emissions in upstream and downstream industries



Source: Authors' elaborations on FAOSTAT data

The industries (Figure 7), and the countries, also show remarkable differences in terms of emissions (and emission intensities) trends.

- The emissions growth is more evident for developing countries. Over a decade, the emissions from developing and middle-income countries (e.g. India, Indonesia, Brazil, China) have grown markedly. Differently, the emissions from the EU have been steady for the downstream industries and declining for the upstream industries.
- Developed countries tend to outsource pollution. The statistics suggest that developed economies have increased the participation in global value chains more through the downstream industries, which tend to be cleaner, and they have reduced pollution emissions from those industries.
- When the emissions are decomposed according to the contribution of scale, composition, and technique, the last two components (technique and composition) account for a larger share of changes in emissions. Over a decade, country's level of production (scale) has decreased and changed its composition: production in downstream industries has increased to the detriment of upstream industries. Accordingly, the share of national output has moved from dirtier versus cleaner industries. Countries has also changed the pollution emitted per unit of output (technique): emission intensities have increased for upstream but not for downstream industries.

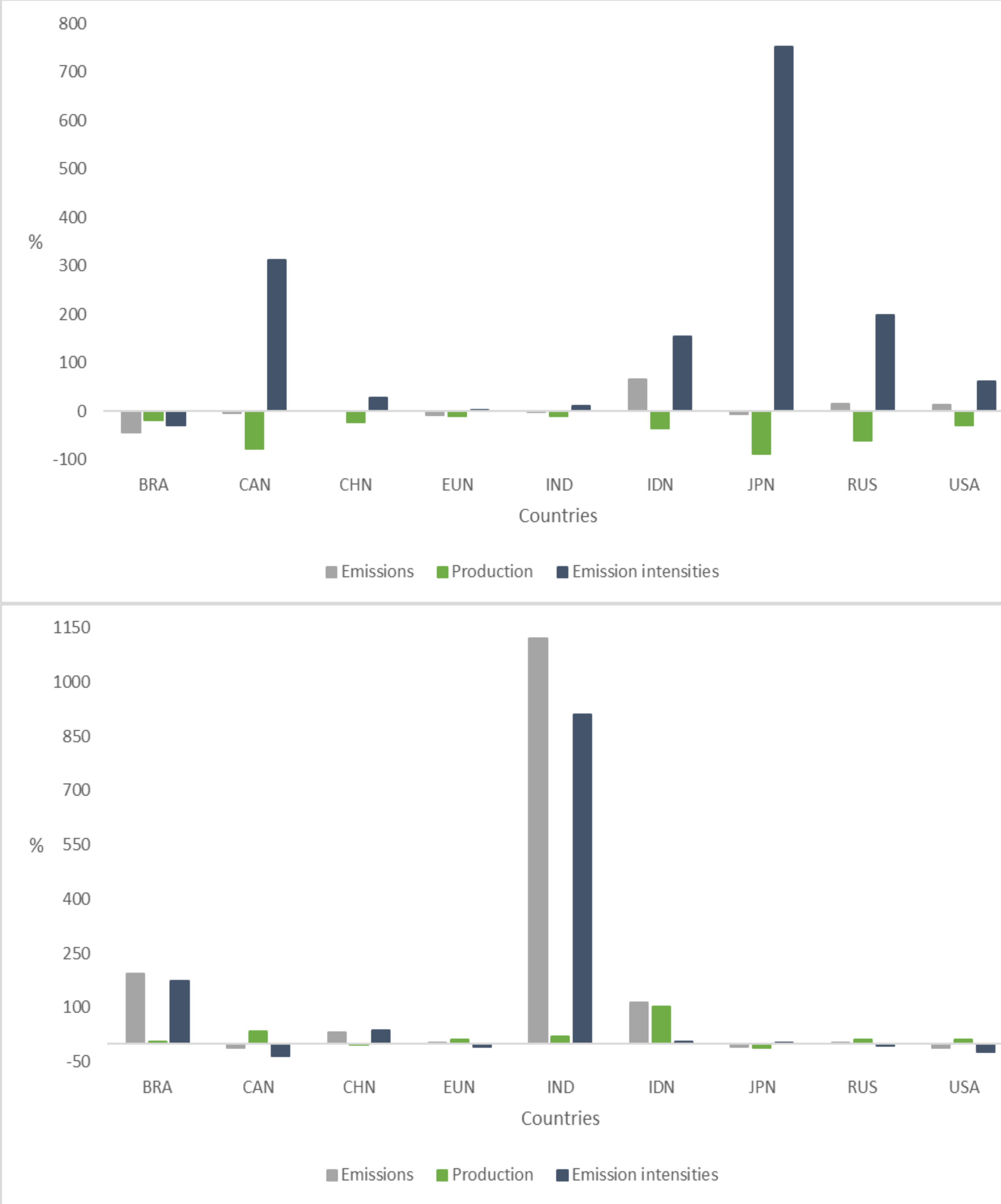
The set of evidence that we have listed above describe a situation in which trade contributes to emissions due to an (environmentally) inefficient specialization of countries (and industries)[11]. The trade relationships, motivated by country-specific welfare maximization goals contrast with the search for (trade) solutions compatible with a global reduction of emissions. In other words, a *laissez faire* approach is not recommended: the economies are not able to converge toward a cleaner, sustainable, and rich world, exactly because the country-specific[12] search of profits still conflict with the world-specific need of a reduction of global emissions[13]. The need for policy interventions is clear. What is not too clear is if (and how) regulations may prove effective in leading the necessary coordination effort.

[11] However, trade can also be part of the solution. For instance, trade can be a potential adaptation mechanism, capable of exploiting regional differences in climate change, helping to reduce hunger and food insecurity (Janssens et al., 2020; Bozzola et al., 2023)

[12] A further complication derives by the presence of multinational firms, which may have goals that contrast with those supported by the different countries in which they operate their business.

[13] An alternative explanation is that the allocation of resources is based on incomplete information insofar price signals do not reflect environmental costs.

Figure 8 – Changes in emissions, production, and emission intensities



Source: Authors' elaborations on FAOSTAT data

5. Empirics of the climate-trade-policies nexus

Again, the empirical evidence discussed above points to trade as a key factor. A legitimate, but rather simplistic, solution would be to shape trade to be more aligned with the environmental goals, without reducing trade. To derive some conclusions, we deepen on further evidence.

First, we need to stress that, while in terms of volume of production the upstream industry is larger than the downstream industry, the economic profits generated by the downstream industry are large. This characteristic of the value chain explains the attitude of developed economies to adopt different policies in upstream and downstream industries. The upstream industries tend to benefit of domestic support whereas the downstream industries are more exposed to import tariffs. The structure of the trade regime has been a puzzle for decades but has been finally explained through the political economy. The political economy helps explaining why the support has a seemingly opposite (and counterintuitive) structure in developing and developed economies. In developed economies, the domestic support is provided to the upstream industry, which is less rich than its industrial counterpart, whereas the downstream industry is (implicitly) subsidized through import tariffs. In the developing economies, it is the downstream industry that benefits of support, whereas the upstream industry has negative support (i.e. positive taxation)[14].

The domestic support is large in Europe, United States, and Canada[15], as form of subsidy to the primary sector. Differently, the processed goods are indirectly subsidies through import tariffs, which tend to be larger in the downstream industry (as compared to the upstream industry): according to data provided by Anderson et al. (2006) the ratio is, for instance, about two for the European Union, three for the United States, and ten for Canada.

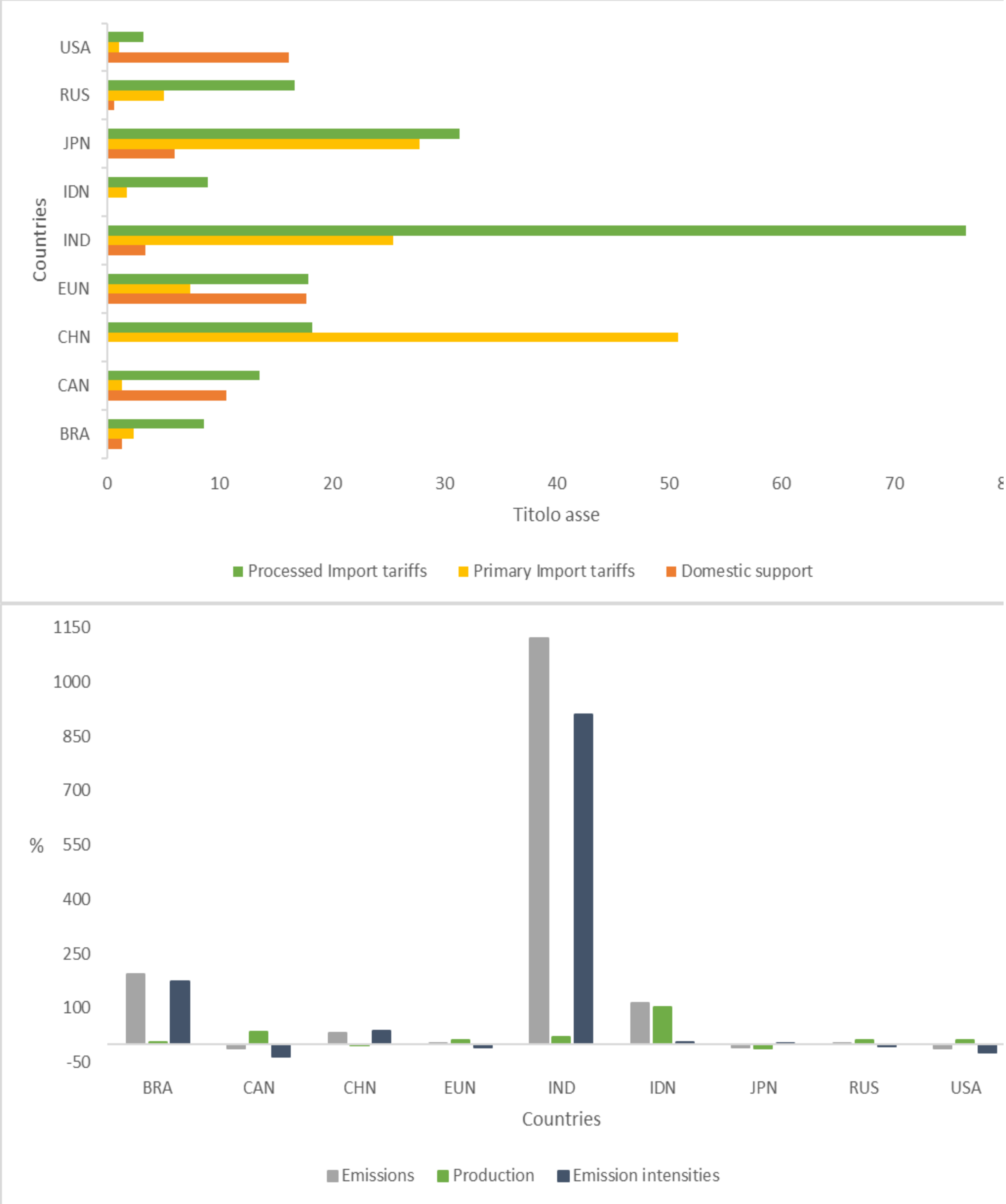
The structure of trade regime, which reflect the vested interests in the upstream and downstream industry, helps explaining where it is likely to have the strongest opposition to agricultural reforms with environmental goals. It also emphasizes the necessity to plan a mixture of policy reforms on subsidies, tariffs, and other policies.

Another aspect that deserves attention is the unbalanced structure of pricing and non-pricing mechanisms. The pricing mechanisms (i.e., import tariffs) tend to outweigh the non-pricing mechanisms (i.e. non-tariff barriers). According to the estimates provided by Kee et al. (2009) the

[14] It is also true that agriculture-based countries are taxing agriculture relatively less than the non-agriculture-based economies. According to the World Bank (2007), for agriculture-based countries the net agricultural taxation is declining.
[15] Although an important proportion of domestic support may not affect trade flows, as it is the case for Canada.

ratio of protection is about two for the top agri-food economies, exception made for Indonesia, China and Canada, which have a ratio between four and five.

Figure 9 –Tariffs and subsidies vis-à-vis emissions, production, and emission intensities



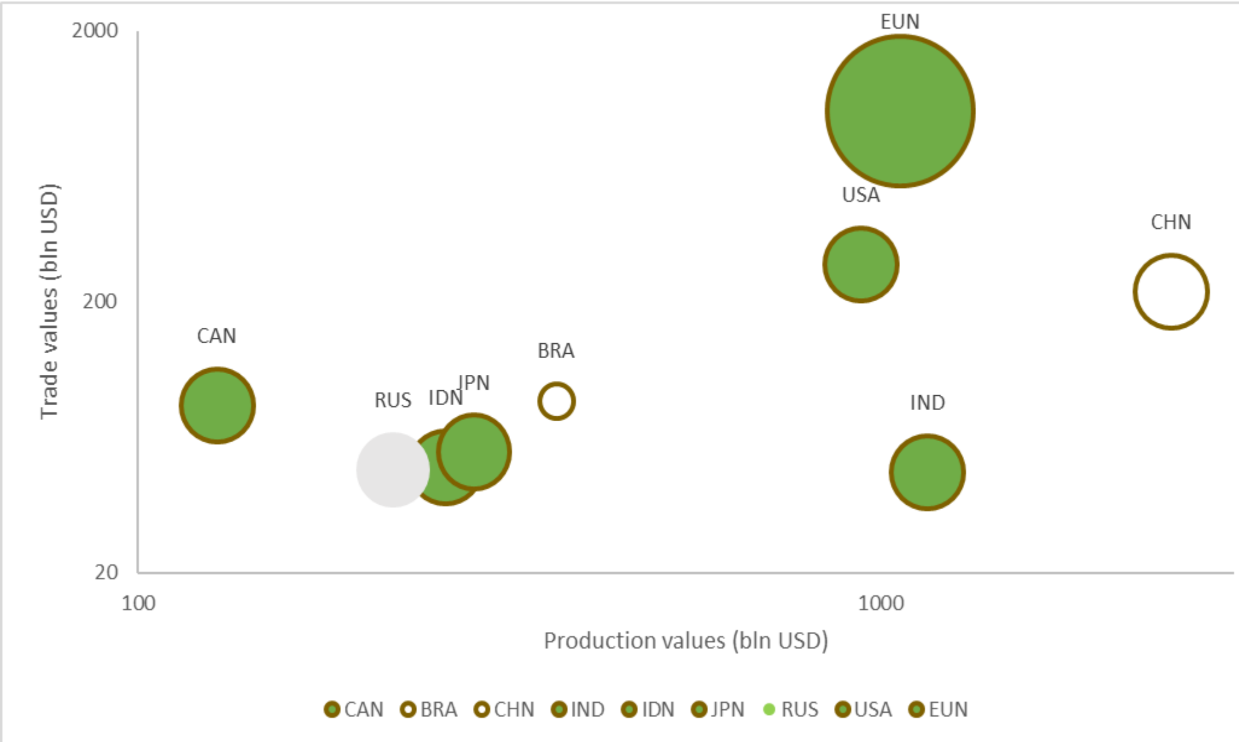
Source: elaboration on data from FAOSTAT and WITS

The top agri-food economies are clustered in small clubs sharing trade agreements on agricultural and environmental issues.

The top agri-food economies have numerous Regional Trade Agreements (RTAs) in place (about fifteen on average, with remarkable differences for the European Union that has more than forty RTAs)[16]. The presence of Preferential trade Agreements (PTAs) is also relevant: for instance, the United States have five schemes which involve about one hundred and eighty countries; the European Union has two schemes in place, which involve about ninety countries. These forms of cooperation are particularly important in that the agreements tend to include non-trade policy objectives (NTPOs) to target relevant non-trade issues, such as the environmental protection. As a concrete example, since 2011, all EU trade agreements include a Trade and Sustainable Development (TSD) chapter to ensure that economic growth, development, and environmental protection go hand in hand. These chapters contain binding provisions and establish principles and commitments related to fundamental labor rights and environmental protection, climate change. The recent EU TSD chapter (e.g., UK, Japan, Singapore and Vietnam) contains an article on Trade and Climate Change, which specifies that each party shall effectively implement the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, including its commitments about its Nationally Determined Contributions (Velut et al., 2022). Formulating trade policies to achieve multiple targets, including environmental, nutritional, and social objectives requires careful analysis. Trade policies can support the achievement of multiple objectives, including environmental and sustainability ones, but they might not be always the best and most efficient instruments. Complementary policies targeting specific environmental aspects should always accompany trade policies to achieve these objectives (Zimmermann and Rapsomanikis 2021).

16 Many trade agreements include environmental provisions. To deepen on these aspects the readers may refer to Brandi et al. (2020), Blumer et al. (2020), Hoekman et al. (2022, 2023), among others. Another strand of research focus on non-tariff measures adopted for environmental purpose. The readers may refer to Santeramo et al. (2023).

Figure 10 – Trade vs production values



Source: elaboration on data from FAOSTAT

6. Conclusions and policy reflections

Our analysis has been motivated by the raising attention on trade-related environmental issues. The agricultural sector is one of the top emitting industries, and is also, by far, one of the sectors with the largest number of regulatory interventions on trade, spanning from tariffs to NTMs (e.g. technical measures, quota, , subsidies, etc.). Countries tend to regulate the primary sector for national security, targeting food security, self-sufficiency, or strategic in-dependency (or 'de-risking'). The general tendency to include environmental provisions in trade agreements, coupled with the emergence of unilateral policies (e.g. CBAM, environmentally-related TBTs) to foster the transition toward a low emission global economy, are concrete commitments. However, the very slippery nature of the environmental outcomes, difficult to measure, monitor and (consequently) to regulate, pose serious problems on how countries should coordinate and regulate trade to achieve climate change and environment goals without imposing protectionist measures that slow trade and reduce welfare.

We review several aspects to allow reaching conclusions and feed the policy debate. First, we examined the economics of the climate-trade nexus and the climate-trade -policies nexus, pointing at main unintended consequences: leakage and competitiveness loss. We conclude that the competitiveness loss is likely to have (more) pronounced effects on consumers than on producers. Leakage is likely to be problematic for dirtier industries (e.g. livestock) and countries with larger trade flows from developing countries.

Second, we reflect on key statistics on trade and associated policies and derive some policy considerations. First, emissions are very unevenly distributed across countries, with the most developed economies being relatively cleaner than the developing counterpart. Second, the heterogeneity is marked along the GVC: most emissions are due to the upstream (and trade exposed) portion of the GVC, which is however responsible of the lowest share of the added value generated through trade. The emissions from international trade of agri-food products are mostly due to the indirect emissions embodied in products. Developed countries tend to outsource pollution by importing dirtier inputs and imposing trade policies that are generally biased against the environment.

There is a clear need to foster international cooperation to overcome the contrasting political economy forces that have led to environmentally biased trade and support policies in agriculture. Reforms to target (shared) environmental objectives require a coordination effort that would be feasible only with the involvement of entrepreneurs, traders, consumers, regulators and the epistemic community. The policy agenda should contain several elements. First regional trade agreements should adopt a new paradigm to move from the inclusion of provision, to their effective enforcement. The current literature shows that the non-trade policy objectives (e.g. protection of the environment) are not well achieved by trade policies. Part of the problem is the difficulty (and heterogeneity) in measuring environmental outcomes, insofar metrics, procedures and certifications are heterogenous if not completely lacking in least advanced economies. Another bottleneck to improve the environmental standards is the complexity of enforcement mechanisms, that is particularly problematic for transboundary phenomena. The future policy debate has to make a clear step forward to ensure policies translate into practice.

Furthermore, trade regulations and environmental goals should be harmonized through effective regulatory cooperation, to achieve global standards. What we need is not additional measures (as we already stand on top of many policy interventions for the protection of the environment), but rather the prioritization of regulatory cooperation and harmonization.

Lastly, we the wide heterogeneity of trade, emissions and policies along the global value chain flags disparity of interests and political economy factors. The uneven distribution of added values along the chain, within the countries, and across firms has to be taken into account. The policy agenda seems to have not sufficiently addressed these issues, whereas a deep dive on the political economy of trade policies is key to make future agreements more feasible and effective.

References

1. Albrizio, S., Botta, E., Koźluk, T., & Zipperer, V. (2014). Do environmental policies matter for productivity growth?: insights from new cross-country measures of environmental policies.
2. Anderson, K., Martin, W., & Valenzuela, E. (2006). The relative importance of global agricultural subsidies and market access. World Trade Review, 5(3), 357-376.
3. Anderson, K., & Nelgen, S. (2013). Updated national and global estimates of distortions to agricultural incentives, 1955 to 2011. Database uploaded in June at www. worldbank. org/agdistortions.
4. Anderson, K., Rausser, G., & Swinnen, J. (2013). Political economy of public policies: insights from distortions to agricultural and food markets. Journal of Economic Literature, 51(2), 423-477. Assunção, J., McMillan, R., Murphy, J., & Souza-Rodrigues, E. (2023). Optimal environmental targeting in the amazon rainforest. The Review of Economic Studies, 90(4), 1608-1641.

1. Barrows, G., & Ollivier, H. (2018). Cleaner firms or cleaner products? How product mix shapes emission intensity from manufacturing. Journal of Environmental Economics and Management, 88, 134-158.
2. Blümer, D., Morin, J. F., Brandi, C., & Berger, A. (2020). Environmental provisions in trade agreements: defending regulatory space or pursuing offensive interests?. Environmental Politics, 29(5), 866-889.
3. Bozzola, M., Lamonaca, E., & Santeramo, F. G. (2023). Impacts of climate change on global agri-food trade. Ecological Indicators, 154.
4. Brandi, C., Schwab, J., Berger, A., & Morin, J. F. (2020). Do environmental provisions in trade agreements make exports from developing countries greener?. World Development, 129, 104899.
5. Brunel, C. (2019). Green innovation and green Imports: Links between environmental policies, innovation, and production. Journal of environmental management, 248, 109290.
6. Burke, M., & Emerick, K. (2016). Adaptation to climate change: Evidence from US agriculture. American Economic Journal: Economic Policy, 8(3), 106-140.
7. Conte, B., Desmet, K., Nagy, D. K., & Rossi-Hansberg, E. (2021). Local sectoral specialization in a warming world. Journal of Economic Geography, 21(4), 493-530.
8. Copeland, B. R., & Taylor, M. S. (1995). Trade and the environment: a partial synthesis. American Journal of Agricultural Economics, 77(3), 765-771.

9. Copeland, B. R., Shapiro, J. S., & Taylor, M. S. (2021). Globalization and the environment. In Gopinath, G., Helpman, E., Rogoff, K., (Eds.). Handbook of International Economics: International Trade. North Holland.
10. Costinot, A., Donaldson, D., Vogel, J., & Werning, I. (2015). Comparative advantage and optimal trade policy. The Quarterly Journal of Economics, 130(2), 659-702.
11. Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. J. N. F. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2(3), 198-209.
12. Dallmann, I. (2019). Weather variations and international trade. Environmental and resource economics, 72(1), 155-206.
13. Desmet, K., & Rossi-Hansberg, E. (2024). Climate Change Economics over Time and Space. University of Chicago, Becker Friedman Institute for Economics Working Paper, (2024-25).
14. Diaz-Rainey, I., & Tulloch, D. J. (2018). Carbon pricing and system linking: lessons from the New Zealand emissions trading scheme. Energy Economics, 73, 66-79.
15.
16. Friedrich, J., Ge, M., Pickens, A., & Vigna, L. (2020). This interactive chart shows changes in the world's top 10 emitters.
17. Grether, J. M., Mathys, N. A., & de Melo, J. (2009). Scale, technique and composition effects in manufacturing SO 2 emissions. Environmental and Resource Economics, 43, 257-274.
18. Heerman, K. E. (2020). Technology, ecology and agricultural trade. Journal of International Economics, 123, 103280.
19. Hoekman, B., Francois, J. F., Santi, F., & Manchin, M. (2022). Pursuing environmental and social objectives through trade agreements. Robert Schuman Centre for Advanced Studies Research Paper No. RSC_73.
20. Hoekman, B. M., Mavroidis, P. C., & Nelson, D. (2023). Non-economic objectives, globalisation and multilateral trade cooperation.
21. Hoekman, B., Santi, F., & Shingal, A. (2023). Trade effects of non-economic provisions in trade agreements. Economics Letters, 226, 111081.
22. IFPRI (2021) Agincentives database. Available at: http://www.ag-incentives.org
23. Kee, H., Nicita, A., & Olarreaga, M. (2009). Estimating trade restrictiveness indices. The Economic Journal, 119(534), 172-199.

24. Koźluk, T., & Timiliotis, C. (2016). Do environmental policies affect global value chains. A new perspective on the pollution haven hypothesis, 293-338.
25. Krueger, A. O. (1993). Who's Bashing Whom? Trade Conflict in High-Technology Industries.
26. Janssens, C., Havlík, P., Krisztin, T., Baker, J., Frank, S., Hasegawa, T., Leclere, D., Ragnauth, S., Schmid, E., Valin, H., Van Lipzig, H. & Maertens, M. (2020). Global hunger and climate change adaptation through international trade. Nature Climate Change, 10(9), 829-835.
27. Lamonaca, E., Bozzola, M., & Santeramo, F. G. (2024). Climate distance and bilateral trade. Economics Letters.
28. Läpple, D., Carter, C. A., & Buckley, C. (2022). EU milk quota abolition, dairy expansion, and greenhouse gas emissions. Agricultural Economics, 53(1), 125-142.
29. Levinson, A. (2009). Technology, international trade, and pollution from US manufacturing. American economic review, 99(5), 2177-2192.
30. Levinson, A. (2015). A direct estimate of the technique effect: changes in the pollution intensity of US manufacturing, 1990–2008. Journal of the Association of Environmental and Resource Economists, 2(1), 43-56.
31. Mamun, A., Martin, W., & Tokgoz, S. (2021). Reforming agricultural support for improved environmental outcomes. Applied Economic Perspectives and Policy, 43(4), 1520-1549.
32. Maneschi, A. (1998). Comparative advantage in international trade: A historical perspective. Edward Elgar Publishing.
33. Mendelsohn, R., Nordhaus, W. D., & Shaw, D. (1994). The impact of global warming on agriculture: a Ricardian analysis. The American economic review, 753-771.
34. OECD, I. (2016). The Carbon Footprint of Global Trade. Tackling Emissions from International Freight Transport. In International Transport Forum.
35. Poore, J., & Nemecek, T. (2018). Reducing food’s environmental impacts through producers and consumers. Science, 360(6392), 987-992.
36. Reilly, J., & Hohmann, N. (1993). Climate change and agriculture: the role of international trade. The American Economic Review, 83(2), 306-312.
37. Ritchie, H., Rosado, P., & Roser, M. (2023). Emissions by sector. Our World in Data.
38. Santeramo, F. G., Lamonaca, E., & Emlinger, C. (2023). Technical measures, Environmental protection, and Trade. RSCAS Working Paper.

39. Shapiro, J. S. (2016). Trade costs, CO2, and the environment. American Economic Journal: Economic Policy, 8(4), 220-254.
40. Shapiro, J. S., & Walker, R. (2018). Why is pollution from US manufacturing declining? The roles of environmental regulation, productivity, and trade. American Economic Review, 108(12), 3814-3854.
41. Stern, N. (2008). The economics of climate change. American Economic Review, 98(2), 1-37.
42. Tol, R. S. J. (2009). The economic effects of climate change. Journal of economic perspectives, 23(2), 29-51.
43. Velut, J. B., Baeza-Breinbauer, D., De Bruijne, M., Garnizova, E., Jones, M., Kolben, K., Oules, L., Rouas, V., Tigere Pittet, F., & Zamparutti, T. (2022). Comparative analysis of trade and sustainable development provisions in free trade agreements. London School of Economics.
44. Wood, R., Stadler, K., Simas, M., Bulavskaya, T., Giljum, S., Lutter, S., & Tukker, A. (2018). Growth in environmental footprints and environmental impacts embodied in trade: resource efficiency indicators from EXIOBASE3. Journal of Industrial Ecology, 22(3), 553-564.
45. Zimmermann, A., & Rapsomanikis, G. (2021). Food Systems Summit Brief Prepared by Research Partners of the Scientific Group for the Food Systems Summit June 8, 2021.

Appendix – Tables and graphs

Table. Agri-food emissions and global value chain participation for top emitters.

	Emissions		**Tot emissions production net of exports**		**Tot emissions exports**		Emissions share due to exports		**Emission intensities production**		**Emission intensities exports**		Exports (A)/(B)	Global Value Chain		
	(A)	(B)	**(A)**	**(B)**	**(A)**	**(B)**	(A)	(B)	**(A)**	**(B)**	**(A)**	**(B)**		(A)	(B)	(A)+(B)
BRA	1,201	12	**1,123**	**-2**	**78**	**14**	0.07	NA	**1.05**	**0.16**	**16.01**	**0.14**	1.93	0.169	0.188	0.357
CAN	194	9	**119**	**-6**	**76**	**15**	0.39	NA	**1.58**	**0.73**	**4.05**	**0.42**	0.78	0.024	0.286	0.310
CHN	802	109	**790**	**101**	**12**	**9**	0.01	0.08	**0.38**	**1.07**	**25.82**	**13.37**	0.06	0.003	0.021	0.023
EUN	571	142	**380**	**62**	**191**	**80**	0.33	0.56	**0.68**	**0.82**	**2.05**	**1.46**	0.10	0.004	0.037	0.041
IND	775	24	**760**	**24**	**15**	**1**	0.02	0.04	**0.54**	**0.31**	**28.91**	**8.56**	0.21	0.185	0.178	0.363
IDN	923	7	**907**	**7**	**16**	**0**	0.02	0.04	**1.87**	**0.12**	**110.07**	**3.26**	0.12	0.114	1.430	1.540
JPN	46	37	**45**	**34**	**0**	**3**	0.01	0.08	**0.81**	**4.80**	**104.54**	**57.33**	0.01	0.002	0.143	0.145
RUS	181	42	**138**	**36**	**43**	**6**	0.24	0.14	**0.67**	**1.33**	**2.85**	**9.53**	1.39	0.051	0.207	0.258
USA	539	142	**444**	**57**	**95**	**86**	0.18	0.60	**0.59**	**1.54**	**3.38**	**2.55**	0.50	0.005	0.065	0.070

Source: elaboration on data from FAOSTAT and WITS. Notes: Data represent the year 2018 (last year available for all countries and industries). (A) refers to upstream industries (i.e., farm-gate and land use change emissions, production and trade of raw agri-food products, domestic value-added agri-food products in the global value chain); (B) refers to downstream industries (i.e., food processing and packaging emissions, production and trade of processed agri-food products, foreign value-added agri-food products in the global value chain). Emissions and total emissions of production net of exports and of exports are in million tonnes of CO_2 equivalent. Total emissions refer to the mean value across countries weighted by the share of production net of exports and by the share of exports. Share of emissions due to exports are calculated by dividing total emissions of exports by total emissions. Emission intensities are measured as tonnes of pollution emitted (CO_2 equivalent) per tonnes of output (production or exports). For Global Value Chain, domestic value-added (upstream contribution to global value chains) is computed as the share of input and intermediate goods' exports over final goods' imports in gross exports; foreign value-added (downstream contribution to global value chain) is computed as the share of intermediate and final goods' exports over inputs' imports in gross exports. NA: Brazil exports large quantities of processed coffee, food preparations, and beer; Canada exports large quantities of food and cereal preparations, chocolate products and beverage. Acronyms are Brazil (BRA), Canada (CAN), China (CHN), European Union (EUN), India (IND), Indonesia (IDN), Japan (JPN), Russia (RUS), United States (USA).

Table 1. Agri-food emissions for top emitters, different pollutions.

	Farm-gate and land use change emissions (upstream)				Food processing and packaging emissions (downstream)			
	$ktCO_2eq$	$ktCO_2$	$ktCH_4$	ktN_2O	$ktCO_2eq$	$ktCO_2$	$ktCH_4$	ktN_2O
BRA	1,201,357.7	2,304,413.0	26,123.0	1,064.9	12,160.6	14,651.5	56.1	0.4
CAN	194,333.0	279,335.1	2,042.0	225.6	8,651.9	16,793.7	50.7	0.3
CHN	801,605.1	206,599.0	27,760.4	2,339.1	109,279.9	186,833.2	163.1	1.9
EUN	571,227.0	379,498.6	17,620.7	1,194.2	142,020.2	268,975.2	417.8	3.0
IND	774,750.4	69,241.6	39,713.3	1,411.0	24,417.4	25,587.0	27.9	0.2
IDN	922,606.9	1,078,864.1	9,284.8	534.2	6,992.6	9,998.3	7.7	0.1
JPN	45,673.1	43,992.3	1,229.3	62.7	36,585.2	73,849.6	103.7	0.8
RUS	180,754.5	132,990.7	4,379.6	306.4	42,351.3	79,055.3	155.5	0.9
USA	538,857.8	242,990.1	16,202.4	1,224.0	142,406.1	296,684.2	277.3	2.6

Source: elaboration on data from FAOSTAT.

Notes: Data represent a comparison between years 2008 and 2018 (last year available for all countries and industries). Acronyms are Brazil (BRA), Canada (CAN), China (CHN), European Union (EUN), India (IND), Indonesia (IDN), Japan (JPN), Russia (RUS), United States (USA).

Table 2. Growth in agri-food emissions and global value chain participation for top emitters.

	Emissions						Global Value Chain						Production									Emission intensities					
	(A)			(B)			(A)			(B)			(A)+(B)			(A)			(B)			(A)			(B)		
	‘08	‘18	**Δ%**	‘08	‘18	**Δ%**	‘08	‘18	Δ%	‘08	‘18	Δ%	‘08	‘18	Δ%	‘08	‘18	**Δ%**	‘08	‘18	**Δ%**	‘08	‘18	**Δ%**	‘08	‘18	**Δ%**
BRA	2,117	1,201	**-43**	4	12	**192**	0.24	0.17	-30	0.24	0.19	-22	1,483	1,225	-17	1,411	1,149	**-19**	72	77	**7**	1.5	1.1	**-30**	0.1	0.2	**174**
CAN	202	194	**-4**	10	9	**-10**	0.04	0.02	-38	0.41	0.29	-30	535	135	-75	526	123	**-77**	9	12	**34**	0.4	1.6	**311**	1.1	0.7	**-33**
CHN	802	802	**0**	83	109	**32**	0.02	0.003	-86	0.04	0.02	-46	2,825	2,232	-21	2,719	2,129	**-22**	105	102	**-3**	0.3	0.4	**28**	0. 8	1.1	**36**
EUN	618	571	**-8**	139	142	**2**	0.01	0.004	-18	0.03	0.04	16	1,081	1,008	-7	926	835	**-10**	155	174	**12**	0. 7	0.7	**3**	0.9	0.8	**-9**
IND	780	775	**-1**	2	24	**1120**	0.39	0.19	-53	0.26	0.19	-30	1,662	1,504	-10	1,597	1,425	**-11**	65	79	**21**	0.5	0.5	**11**	0.03	0.3	**910**
IDN	558	923	**65**	3	7	**115**	0.83	0.11	-86	2.30	1.43	-38	784	554	-29	754	494	**-35**	30	61	**103**	0.7	1.9	**153**	0.1	0.1	**6**
JPN	49	46	**-7**	40	37	**-9**	0.003	0.002	-34	0.09	0.14	53	530	64	-88	521	57	**-89**	9	8	**-11**	0.1	0.8	**752**	4.7	4.8	**1**
RUS	156	181	**16**	41	42	**3**	0.03	0.05	48	0.38	0.21	-45	721	300	-58	692	269	**-61**	29	32	**10**	0.2	0.7	**198**	1.4	1.3	**-7**
USA	482	539	**12**	163	142	**-12**	0.01	0.01	-56	0.06	0.07	16	1,385	998	-28	1,302	906	**-30**	83	93	**12**	0.4	0.6	**61**	2.0	1.5	**-22**

Source: elaboration on data from FAOSTAT and WITS.

Notes: Data represent the year 2018 (last year available for all countries and industries). (A) refers to upstream industries (i.e., farm-gate and land use change emissions, production and trade of raw agri-food products, domestic value-added agri-food products in the global value chain); (B) refers to upstream industries (i.e., food processing and packaging emissions, production and trade of processed agri-food products, foreign value-added agri-food products in the global value chain). Emissions are in million tonnes of CO_2 equivalent. Production is in million tonnes. Emission intensities are measured as tonnes of pollution emitted (CO_2 equivalent) per tonnes of output. For Global Value Chain, domestic value-added (upstream contribution to global value chains) is computed as the share of input and intermediate goods' exports over final goods' imports in gross exports; foreign value-added (downstream contribution to global value chain) is computed as the share of intermediate and final goods' exports over inputs' imports in gross exports. Acronyms are Brazil (BRA), Canada (CAN), China (CHN), European Union (EUN), India (IND), Indonesia (IDN), Japan (JPN), Russia (RUS), United States (USA).

Table 3. Domestic and trade policies for top agri-food economies.

	Anderson et al. (WorldTradeRev, 2006) data refer to 2001					Kee et al. (EcJ, 2009) data refer to 2002-2004			Anderson & Nelgen (2013) data refer to 2010		AgIncentives IFPRI (2021) data refer to 2018
	Primary			Processed		Total			Primary (mainly)		Primary (mainly)
	Domestic support	Export subsidies	**Import tariffs**	Export subsidies	**Import tariffs**	Domestic support	**Import tariffs**	**NTB**	Domestic support	Import tariffs	Nominal rate of protection
BRA	**1.30**	0.00	**2.40**	0.00	**8.60**	0.00	**0.97**	**0.46**	0.00	0.01	0.97
CAN	**10.60**	0.00	**1.30**	0.00	**13.60**	0.00	**0.61**	**0.15**	-0.01	0.13	4.85
CHN	**0.00**	0.00	**50.80**	0.00	**18.30**	0.00	**0.98**	**0.19**	0.00	0.16	11.55
EUN	**17.70**	4.40	**7.40**	8.60	**17.90**	0.01	**0.83**	**0.29**	NA	NA	5.49
IND	**3.40**	0.00	**25.50**	0.00	**76.40**	0.00	**0.99**	**0.43**	0.00	0.14	-14.30
IDN	**0.00**	0.00	**1.80**	0.00	**9.00**	0.00	**0.80**	**0.13**	0.00	0.29	
JPN	**6.00**	0.00	**27.80**	0.00	**31.40**	0.00	**0.56**	**0.32**	0.07	0.94	77.55
RUS	**0.60**	0.00	**5.10**	0.00	**16.70**	0.00	**0.99**	**0.39**	0.01	0.14	9.58
USA	**16.20**	0.00	**1.10**	0.20	**3.20**	0.00	**0.76**	**0.27**	0.00	0.01	3.96

Notes: Acronyms are Brazil (BRA), Canada (CAN), China (CHN), European Union (EUN), India (IND), Indonesia (IDN), Japan (JPN), Russia (RUS), United States (USA).

Table 4. Regional Trade Agreements (RTAs) and Preferential Trade Agreements (PTAs) between top agri-food economies.

RTAs			RTAs co-signatories and PTAs beneficiaries									PTAs	
In force	Announced	Signatories	CAN	JPN	EUN	USA	RUS	IDN	IND	BRA	CHN	Providers	Schemes and countries
14	1	CAN										CAN	2 schemes 122 countries
18	2	JPN	in force AG, EP					beneficiary	beneficiary			JPN	1 scheme 132 countries
46	10	EUN	in force AG, EP	in force AG, EP				beneficiary	beneficiary		beneficiary	EUN	2 schemes 94 countries
14	1	USA	in force AG, EP		announced			beneficiary		beneficiary		USA	5 schemes 180 countries
12	2	RUS						beneficiary	beneficiary	beneficiary	beneficiary	RUS	1 scheme 153 countries
12	2	IDN		in force AG, EP	announced							IDN	
17	4	IND		in force AG, EP	announced			in force AG				IND	1 scheme 48 countries
9	2	BRA	announced					in force AG	in force AG			BRA	
16	3	CHN						in force AG	accession AG			CHN	1 scheme 42 countries

Source: elaboration on data from Regional Trade Agreements Database and Preferential Trade Agreements Database. Notes: Data represent the year 2021. Figures for each country refer to RTAs in force and for which an early announcement has been made (announced) on the left-hand side, and to providers (number of schemes and number of countries to which preferences are granted) of PTAs in force on the right-hand side. In the matrix, the entries below the main diagonal describe the mutual agreements in force or announced (RTAs) and specify if the RTA regulate the agri-food sector (AG) and the environmental protection (EP); the entries above the main diagonal indicate the beneficiaries of PTAs provided by countries in row. Acronyms are Brazil (BRA), Canada (CAN), China (CHN), European Union (EUN), India (IND), Indonesia (IDN), Japan (JPN), Russia (RUS), United States (USA). Major agreements under negotiation (announced) are between the EU and the US (EU-US TTIP), or the EU and the Eastern African Community (EAC) EPA, or the EU and West Africa EPA, or the EU and India.