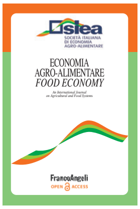
Economia agro-alimentare / Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 1, Art. 7, pp. 1-18 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag1-2021oa11676



Agri-food trade and climate change

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Abstract

Climate change, the agri-food sector and trade are closely related. This contribution aims at presenting issues related to the economic impacts of climate changes on international trade. The agri-food sector is one of the most hit by changes in climate, and it is also responsible of substantial environmental impacts. In a globalised world, these effects do not alter only the agri-food domestic markets but propagate across countries. While climate change may trigger changes in trade patterns by altering food availability and access as well as comparative advantages across countries, trade itself may constitute an adaptation strategy. Our note provides elements to be considered in the future debate that will likely be focused on the interrelations between, climate change, trade and global value chains of agri-food products.

Article info

Type:
Notes
Submitted:
07/12/2020
Accepted:
24/03/2021
Available online:
31/05/2021

JEL codes:
F18, Q17, Q54

Keywords:
Adaptation
Development
Global value chain
Trade

Managing Editor:
Maurizio Canavari

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Introduction

Climate change, agriculture, food systems and trade are intimately interrelated (McCarl and Hertel, 2018). Climate change may cause uncertainty due to short-run shocks and long-run changes in weather conditions. Climate-induced uncertainty poses a threat to the agricultural sector (Briamonte *et al.*, 2020). In addition, the proliferation of extreme weather events (e.g. floods, heat stress, droughts) are responsible of crop yield losses and failures, crop quality reduction, and impacts on livestock with consequences on the global food system (Mrabet *et al.*, 2020).

To cope with the bad consequences that may emerge, the agricultural sector needs to adapt to climate change to reduce greenhouse gas (GHG) emissions and continue to evolve to meet a growing global food demand (FAO, 2018). Among other changes, the adaptation to climate change may involve shifts in patterns of international trade (Baldos and Hertel, 2015) and imply new trade dynamics that may reinforce the efforts made in the agri-food sector to mitigate the impacts. How does climate change affect trade? It seems well established that it alters the comparative advantage and competitiveness of sectors across countries, thus making relatively less or more profitable to trade with new (or other) trade partners (Costinot *et al.*, 2016; Gouel and Laborde, 2021).

The role of connection between economies makes trade a key factor to adapt to challenges posed by climate change, such as food security and availability (FAO, 2018). However, trade may be both beneficial and detrimental. Grossman and Krueger (1993) suggest that trade produces three effects. First, while international trade creates additional output, it also increases resource depletion and pollution with negative effects on climate change (i.e. scale effect). Second, international trade may influence the sectoral composition of economies with climate change impacts that may be either positive or negative depending on whether an economy has a comparative advantage in emission-saving or emission-intensive sectors (i.e. composition effect). Third, international trade may induce technology spillovers reducing the emission per unit of output produced or consumed and improving environmental quality (i.e. technique effect).

Our contribution provides a cursory review of the state of the art of the literature on the linkages between agri-food trade, global value chains and climate change. We discuss on the economic impact of changes in climate – both short-run and long-run – and linger on the importance of considering climatic trends and climatic distances in trade dynamics. Lastly, we provide elements that should be taken into account in the future debate on the interrelations between climate change and trade of agri-food products.

1. Climate change from an economic perspective

Climate change is a phenomenon affecting any regions of the world and producing, for instance, global warming and changes in precipitations patterns. As argued by the Intergovernmental Panel on Climate Change (IPCC), climate change has strong impacts on incomes and economic activities, although heterogeneous across countries (IPCC, 2014). Among economic activities, agriculture is one of the most negatively affected by climate change but also a main driver of changes in climate. In sections 1.1 and 1.2 we discuss on the relationship between climate change and economic development and on the dual linkage between climate change and the agricultural sector.

1.1. *Climate change and development*

Climate change stands for the long-run changes – increases or decreases – in climate, defined as the average weather conditions such as temperature and precipitation, among others (Dallmann, 2019). Mendelshon *et al.* (1994) define the 'normal' climatic variables as the 30-year average of each climate variable (e.g. temperature, precipitation).

Figure 1 summarises country-specific changes in average temperature and precipitation over a period of 55 years[1]. For each country, we compared the mean annual levels of temperature and precipitation[2] in the first three decades of the sample (1961-1987) and in the last three decades of the sample (1988-2016). Descriptive statistics indicates the long-run differences across the two periods. Data show that, on average, the world has become, in a period of about fifty years, about 1 °C warmer, as it has been well- documented in the literature (e.g. Dell *et al.*, 2012). Figures also suggest a potential relationship between the changes in temperature and the level of countries' development[3]. In fact, developed economies – often high-latitude countries – tend to report an increase in temperature greater than 1 °C between the periods 1961-1987 and 1988-2016: a few examples are European countries and Canada. While the differences among countries with the highest increases and the lowest

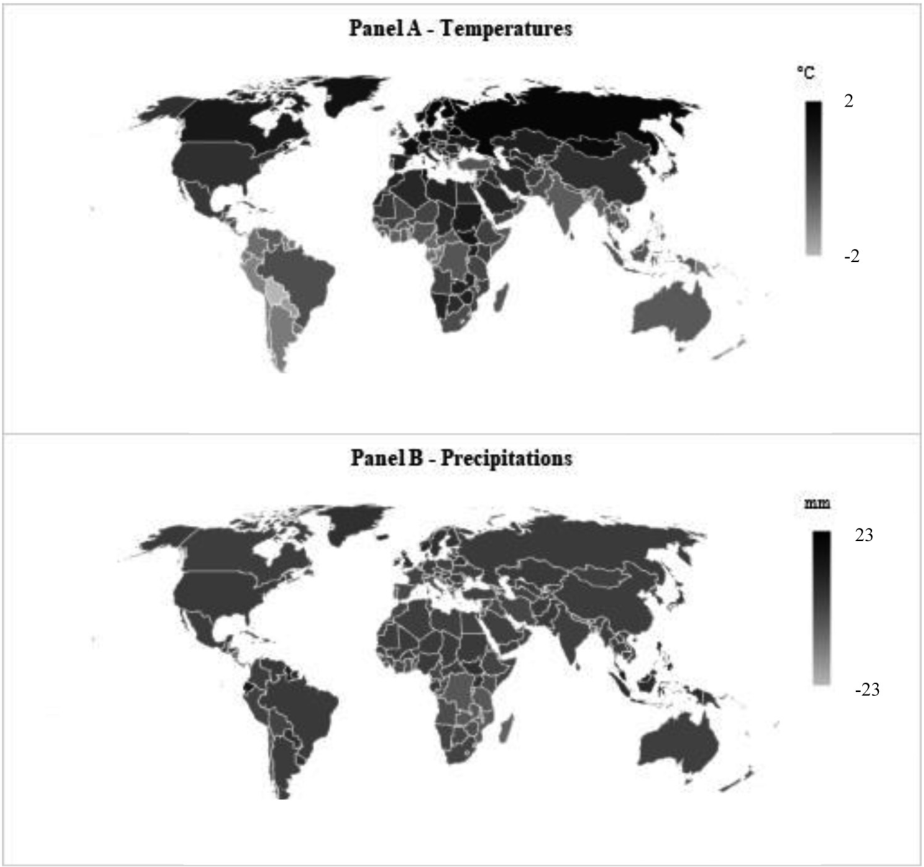
1. Data cover the period between 1961 and 2016 and are from the Climate Change Knowledge Portal, which provides historical average temperatures (in °C) and precipitations (in mm) for each month at the country level.

2. The mean annual levels of temperature and precipitation are obtained as averages of monthly values for each country.

3. Countries have been classified in developed and less developed economies according to the recent classification proposed by the United Nations (2020).

decreases in average temperature is about 1.4 °C, the average precipitation is more volatile with a variation within countries (5.5 mm) that is significantly higher than the average increase that is observed between the two periods (0.3 mm). The data also show a substantial variability in average precipitation between 1961-1987 and 1988-2016 across countries, more marked in less developed countries. If the effects of human activities are locally stronger, the relationship just mentioned is likely to be there: validating this connection is important to better understand how climate change may alter the global agri-food sector.

Figure 1 - Differences in average temperatures and precipitations between 1961-1987 and 1988-2016



	All	Developed	Less developed
Temperatures (°C)			
Mean	0.7	1.0	0.6
Std. dev.	0.3	0.3	0.2
Max-min variation	1.4	1.1	1.3
Precipitations (mm)			
Mean	0.3	1.3	0.1
Std. dev.	5.5	2.8	6.0
Max-min variation	42.1	12.8	42.1

Source: elaboration on data from Climate Change Knowledge Portal.

Note: differences at the country level are obtained by comparing the mean annual levels of temperature and precipitation in 1961-1987 and in 1988-2016. Countries has been classified in developed and less developed economies following the United Nations classification (2020).

The long tradition of climatic theories of development dates back to 1915 when Ellsworth Huntington wrote about "*Civilization and Climate*". Acemoglu *et al*. (2002) support the 'geography hypothesis' and argue that geographic, climatic, or ecological dissimilarities across countries explain most of the differences in economic development. Sachs (2003) demonstrates that economic dimensions (e.g. per capita income, economic growth) are strongly correlated with geographical and ecological variables such as climate zones. Also, the impacts of extreme weather events may differ depending on countries' income distribution (Miljkovic and Miljkovic, 2014). While climate may affect development, development itself may lead to different responses to changes in climate. Adaptation potential and adaptation capability to climate change are highly dependent on the level of development and may exacerbate inequalities in the economic growth between countries (Reilly and Hohmann, 1993). Limited variations in the economic growth of more developed countries – more likely to adapt – can cause large changes in less developed countries – less likely to adapt – (Fagereng *et al*., 2016).

1.2. *Climate change and agriculture*

Changes in climate, both short-run shocks (i.e. weather variations) and long-run changes, have the potential to impact economic activities. Climate changes alter productivity thus production costs as well as resource availability and market prices, with consequences on welfare, poverty, and food security (McCarl and Hertel, 2018). Changes in climate and agriculture are tied up together. While the agricultural sector is one of the most hit by changes in climate (e.g. Deschenes and Greenstone, 2007, Mendelsohn and Massetti, 2017), it is responsible of great environmental impacts (Tricase *et al.*, 2018). Agricultural activities (e.g. intensive livestock, fertilisation, land use and management) are important contributors of greenhouse gas (GHG) emissions with related consequences in terms of climate changes (Santeramo *et al.*, 2020a).

On the demand side, a growing population and changes in diet is causing an increase in demand for food and for livestock feed (Fukase and Martin, 2016). Consequently, emissions from agriculture are expected to increase (Mrabet *et al.*, 2020). The challenge for the agricultural sector is to achieve an equilibrium between adaptation to climate changes and sustainable intensification of agriculture (FAO, 2018).

On the supply side, climate changes may have substantial impacts on world production growth (Martin, 2018). Climate is an input for the agricultural production, thus changes in climate may affect prices and supply of agricultural outputs (Dellmann, 2019). Changes in climate have both direct and indirect impacts on crop yields (Mrabet *et al.*, 2020). Increases in temperature tend to be detrimental for crop yields, with low-latitude countries being the most negatively affected (e.g. McCarl *et al.*, 2008). Indeed, low-latitude countries may have less potential to adapt; for instance, they are generally characterised by warmer climate and may have difficulties in producing crops that perform better in climates still warmer (Reilly and Hohmann, 1993). The indirect effects of changes in climate on crop yields are mainly related to increases in the cost of inputs and of factor productivity (McCarl and Hertel, 2018), but effects due to land use changes should be not neglected (Santeramo and Searle, 2019; Santeramo *et al.*, 2020b). Climate changes also affect the livestock sector: impacts are evident, for instance, on milk production (Key and Sneeringer, 2014), disease and parasites (Mu *et al.*, 2013), feed intake and feed supplies (e.g. Mader 2014).

Overall, the impacts of climate changes on the demand-supply balances in the agricultural sector are related both to direct losses (e.g. crop failures) and several indirect effects triggered by market reactions to events occurring in other producing regions of the world (Chatzopoulos *et al.*, 2020).

2. On the effects on Trade and Global Value Chains

Impacts of climate change on the agricultural sector led producers to alter their activities to reduce adverse impacts or exploit opportunities, thus adapting to evolving climatic conditions. Agricultural activities may be altered also in an effort to mitigate emissions, the main cause of climate change (McCarl and Hertel, 2018). Impacts of climate change and adaptation and mitigation strategies may be reflected also in trade patterns.

The literature on the impacts of changes in climate tends to consider agricultural domestic markets, leaving underinvestigated the effects on world production, markets, and trade patterns (Reilly and Hohmann, 1993). However, the production of agriculture and food products is more and more globally interconnected: the global value chains[4] (GVCs), which involve both developing and developed countries, are replacing the domestic value chains (Hernández et al., 2014). This emerging trend implies that countries are not isolated but linked through socio-economic and geopolitical interdependences (Santeramo and Lamonaca, 2019), and the impacts of climate changes on agricultural domestic markets may propagate at the international level, especially through trade. However, participation in the GVCs is heterogenous, with countries serving as resource-based economies and others providing their specialisation to manufacturing (Taglioni and Winkler, 2016). The differences in participation to the GVCs are mainly due to a persistent heterogeneity in trade costs (Hoeckman, 2014), which matter the most when trade patterns change.

Trade may help achieving the ambitious mitigation strategies set by the Paris Agreement[5]; it impacts climate either through the emissions of the transport industry, or by favouring (or disfavouring) emissions-saving productions (Hertel, 2018). Climate is a major exogenous input in agri-food production, and a potential source of absolute or comparative advantage. Moreover, climatic differences may explain, and even motivate, bilateral trade among *climatic distant* countries, which therefore differ in terms of comparative advantages (Santeramo *et al.*, 2021). Changes in climate may directly impact trade by modifying comparative advantages[6] (Costinot *et al.*, 2016; Gouel and Laborde, 2021), or indirectly impact it by legitimating trade as an adaptation strategy to climate change (Burke and Emerick, 2016). Put differently, climate changes alter global trade dynamics, and exchange terms in bilateral trade.

The relationship between climate and trade has traditionally been quantified using two approaches (Table 1). One approach, based on panel methodologies and reduced form equations, examines the effects of weather variations on sectoral and/or national output, productivity, international trade

4. Trade in agricultural products often involves global value chains, with commodities produced in any countries and processed in other countries (Hoeckman, 2014).

5. The Paris Agreement target global warming to be below 1.5 °C.

6. Changes in climate may alter comparative advantage, i.e. the relative ability of a country to produce a certain product (and export the excess of production) as compared to its trade partners.

Table 1 - Relationships between trade and climate: evidence from literature

Reference	**Case study**	**Model**	**Climatic phenomenon**	**Impacts**
Impacts of weather variation on trade				
Gassebner *et al.* (*Rev. Int. Econ.*, 2010)	170 countries	Gravity model	Climatic disaster	An additional climatic disaster reduces imports by 0.2% and exports by 0.1%
Oh and Reuveny (*Global Env. Change*, 2010)	116 countries	Gravity model	Climatic disaster	An additional climatic disaster in importer or exporter countries reduces imports by 2.68% and 0.59%, respectively
Jones and Olken (*Am. Econ. Rev.*, 2010)	World exports to the United States	Empirical model	Weather variations	An additional degree Celsius reduces the export growth rate by 2.0-2.4% from all countries and by 3.8-5.7% from poor countries
Li *et al.* (*Econ. Letters*, 2015)	China	Empirical model	Weather variations	Exports decline by 8.8% per degree Celsius rise and increase by 1.6-2.0% with 100 mm higher precipitation
Dallmann (*Env. Res, Econ.*, 2019)	134 countries	Empirical model	Weather variations	Bilateral trade reduces by 3.1% with an additional degree Celsius in exporter and by 2.1% with an increase in difference of temperatures between exporter and importer
Dall'Erba *et al.* (*Am. J. Agric. Econ.*, 2021)	Countries of the United States	Gravity model Ricardian model	Severe drought	Trade is expected to act as a 14.5 billion USD adaptation measure
Impacts of climate change on trade				
Reilly and Hohmann (*Am. Econ. Rev.*, 1993)	United States, Canada, European Community, Australia, Argentina, Thailand, China, Brazil, the former Soviet Union, Sweden, Finland, Norway, Austria, Switzerland, Japan, Rest of World	Equilibrium model	Climate change	Net global welfare changes are between 115-190 billion USD with carbon dioxide fertilisation effect and between 7-25

Table 1 - Continued

Reference	**Case study**	**Model**	**Climatic phenomenon**	**Impacts**
Rosenzweig and Parry (*Nature*, 1994)	Global analysis	Equilibrium model	Climate change	With trade liberalisation, production reduced by 11-20% without direct CO_2 effects on yields and by 0-5% with adaptation
Randhir and Hertel (*Agr. Res. Econ. Rev.*, 2000)	Canada, United States, Mexico, European Union, China, ASEAN, Australia, and Rest of World	Equilibrium model	Climate change	Trade liberalisation increases the global welfare gain from climate change (6,855 million USD) if the tariffication of trade policies is accompanied by substantial reductions in farm support
Costinot *et al.* (*J. Pol. Econ.*, 2016)	Global analysis	Equilibrium model	Climate change	Global GDP reduces by 0.26% whit adjustment in trade and production patterns
Gouel and Laborde (*Env. Econ. Mang.*, 2021)	Global analysis	Equilibrium model	Climate change	Production and trade adjustment reduce global welfare losses by 55% and 43%, respectively

(e.g. Dell *et al.*, 2012; Dellmann, 2019), as described in section 2.1. The second approach, presented in section 2.2, relies both on macro and micro evidence to simulate the effects of climate change in scenarios with and without trade adjustments (e.g. Costinot *et al.*, 2016; Gouel and Laborde, 2021).

2.1. *Impacts of weather variation on trade*

A recent strand of literature examines the impacts of weather variations on international trade. As argued in Jones and Olken (2010), international trade may provide more accurate information on sectors of countries' economic activities affected by climatic changes. A niche of this literature analyses the effects of natural disasters on trade (e.g. Gassebner *et al.*, 2010; Oh and Reuveny, 2010) suggesting that a higher incidence of natural disasters is detrimental for bilateral trade: Gassebner *et al.* (2010) suggest that an additional climatic disaster reduces imports by 0.2% and exports by 0.1%, whereas Oh and Reuveny (2010) conclude that imports decrease by 2.68% and 0.59% if a climatic disaster occurs, respectively, in the importer or exporter countries (Table 1).

By examining the impacts of climate shocks on international trade in China, Li *et al.* (2015) find an impact of increases in temperatures and rainfall levels (i.e., exports decline by 8.8% per degree Celsius rise and increase by 1.6-2.0% with 100 mm higher precipitation) and compute high welfare losses induced by weather variations. Jones and Olken (2010) quantify the impacts of temperature shocks on exports in a panel regression framework and reach two main findings: impacts of weather shocks are sector-specific and differ according to countries' economic development (Table 1). Consistent with a long-standing climate-economy literature (e.g. Dell *et al.*, 2012), findings of Jones and Olken (2010) highlight a substantial impact on agricultural exports. In addition, while temperature shocks seem to have no effect on high-income countries, impacts of higher temperatures are detrimental for low-income countries, whose exports reduce by an amount ranging between 3.8% and 5.7% for each degree Celsius increase. Heterogeneity in the impacts of weather variations across sectors and level of economic development is also found in Dallmann (2019). However, his conclusions contrast with findings of Jones and Olken (2010). The sector-specific analysis of Dallmann (2019), in fact, reports a significant positive impact of higher temperatures on the agricultural trade and no effect of precipitations. He also finds no differentiated impacts of temperature shocks on exports of low-income countries. A value added of the analysis by Dallmann (2019) is the evaluation of cross-border effects of climate changes.

By examining the relationship between the weather of trade partners, he finds that bilateral trade reduces for each additional degree Celsius increase in differences between the exporter and importer temperatures (-2.1%), but differences in levels of precipitation between trade partners do not have effects on bilateral trade (Table 1). A recent article by Dall'Erba *et al.* (2021) reveals that bilateral trade is impacted by severe drought: droughts occurring in the exporter lower its export capacity, but the impact is not as relevant as the trade creation effect resulting from droughts occurring in the importer. They suggest that trade is expected to act as a 14.5 billion USD adaptation measure.

Overall, the literature suggests there are marked impacts of temperature shocks and limited effects of variations in rainfall levels[7]. Mixed evidence characterising the relationship between temperatures and trade may be explained by the fact that the effects are observed in the short-run and no information are provided on their persistence through time. Long-term analyses may be more informative on the effects of climate changes on international trade and how trade adapt to changes in climate.

2.2. *Impacts of climate change on trade*

The linkage between international trade and climate change adaptation in the agricultural sector has been investigated mainly with partial equilibrium or general equilibrium models. Assuming that impacts of climate change on agricultural domestic markets cannot be considered in isolation from the rest of the world, Reilly and Hohmann (1993) and Rosenzweig and Parry (1994) suggest that climate-induced changes in the agricultural production may be shaped by international trade (Table 1). Reilly and Hohmann (1993) conclude that interregional adjustments in production and consumption buffer the severity of climate change impacts both at global and domestic level. They found that net global welfare changes are between 115-190 billion USD with carbon dioxide fertilisation effect and between 7-25 billion USD with adaptation. Rosenzweig and Parry (1994) suggest that doubling of the atmospheric carbon dioxide concentration would lead to only a small decrease in global agricultural production, when adjustments in trade flows are not constrained: indeed, with trade liberalisation, production reduced by 11-20% without direct CO_2 effects on yields and by 0-5% with adaptation. Randhir and Hertel (2000) assess the potential interaction between climate change and agricultural trade policies and find that, with agricultural

7. Such evidence is confirmed by the erratic correlation between exports and short-run precipitations (see Figure A.1, panel B in the Appendix).

subsidies, increased price transmission reduces global welfare in the wake of climate change. They conclude that trade liberalisation would increase the global welfare gain from climate change (6,855 million USD) if the tariffication of trade policies is accompanied by substantial reductions in farm support (Table 1). More recent studies by Costinot *et al.* (2016) and Gouel and Laborde (2021) assume that if impacts of climate changes on productivity differ between regions, then adjustments through trade patterns may dampen the adverse effects of climate changes. Costinot *et al.* (2016) quantify gains from adaptation to climate change through changes in production and trade patterns. They find larger welfare losses from climate change (–0.26% in global GDP) when trade and production patterns can adjust. Similarly, Gouel and Laborde (2021) examine the role of trade in attenuating effects of climate change through new climate-induced pattern of comparative advantages. Differently from Costinot *et al.* (2016), they conclude that climate-induced welfare losses are greater when adjustments in trade flows are constrained versus when they are not: production and trade adjustment reduce global welfare losses by 55% and 43%, respectively (Table 1).

Evidence from literature are mixed and potentially reflect divergences across countries. All in all, the dual contribution of trade in mitigating the effects of climate change and fostering adaptation to climate change – limited (Costinot *et al.*, 2016) *versus* crucial (Gouel and Laborde, 2021) – is not surprising. In fact, as climate change alters the comparative advantage and competitiveness of agriculture across countries, some countries could lose while others could gain (FAO, 2018). Less developed countries start with a disadvantage (Reilly and Hohmann, 1993) and measures of adaptation to climate change seem to play a limited role in reducing inequalities between developed and developing countries (Rosenzweig and Parry, 1994). Very far from being conclusive, the research on the effects of climate change on trade and on the GVCs should be promoted and intensified.

3. Conclusions

Climate changes is a central issue for agriculture. Some effects, already observed, are likely to intensify in the future, contributing to declines in agricultural production, fluctuations in world market prices, growing levels of food insecurity (Reilly and Hohmann, 1993; Briamonte *et al.*, 2020). These effects are also likely to be detrimental in some countries and positive in others with potential impacts on their economic development. Agriculture in low latitude countries – often developing economies –, already suffering from poverty and food insecurity, could be negatively affected. High latitude countries – often developed economies –, characterised by temperate climates, could observe positive effects on agriculture with warmer weather (FAO, 2018). Uneven impacts of climate changes across countries and consequent changes in food availability and access as well as in comparative advantages are likely to affect international trade patterns (Baldos and Hertel, 2015; Martin, 2018; Santeramo *et al.*, 2021). By allowing the reallocation of food from surplus to deficit regions, agricultural trade has the potential to lowering inequalities between regions with different levels of economic development, helping countries adapt to climate change. It is of utmost importance to find adaptation and mitigation solutions to climate change in agriculture and food systems to face and combat food insecurity (Mrabet *et al.*, 2020). These solutions may involve actions to reduce net emissions from agriculture and food production, for instance by modifying management practices (e.g., manure management, use of fossil fuel and nitrogen fertiliser), by increasing carbon sequestration (e.g., avoiding deforestation or land conversion), by producing substitutes for emission-intensive products (e.g., bioenergy, wood).

For these reasons, in recent years, the relationships between agriculture, trade, GVCs, and climate change have been at the forefront in trade and development policy agendas of different agreements. In fact, one of the aims of the 2030 Agenda for Sustainable Development, of the 17 Sustainable Development Goals (SDGs), and of the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) is to support developing countries, to promote a sustainable development and the provision of agri-food produce, by intensifying climate change adaptation and mitigation efforts. The return of the United States in the Paris Agreement would strengthen the global cooperation towards the achievement of these goals.

Future research should be devoted to a better understanding of the effects of climate change on the global agri-food sector. In fact, as weather and climate conditions change, firms, communities, and countries need to develop new adaptation strategies to the climate regimes. Understanding the relationships between trade and climate change is one of the efforts towards the promotion of sustainable development.

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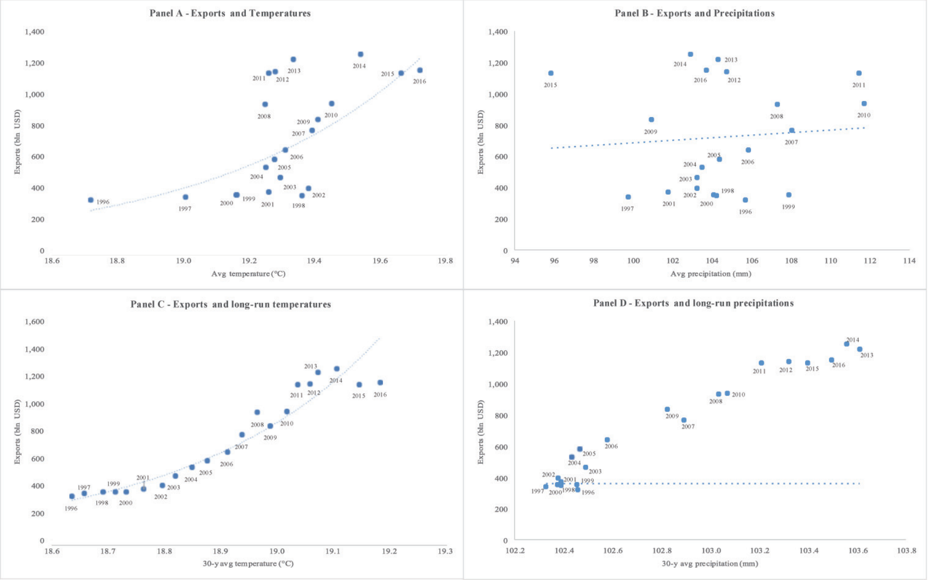
Appendix

Figure A.1 summarises the annual value of exports in food and beverage sectors for the period 1996-2016, plotted against climate. In particular, year-by-year (short-run) changes in average temperatures and precipitations are shown in panels A and B, respectively. Similarly, 30-years (long-run) changes in average temperatures and precipitations are shown in panels C and D, respectively.

Figure A.1 - Scatter plot of trade and climate data



Source: authors' elaboration on data from Climate Change Knowledge Portal and World Integrated Trade Solution database.

Notes: export data aggregated at one-digit level of the classification by Broad Economic Categories (BEC) and consider 'Food and beverages' (BEC, 1996: 01).

Temperatures and precipitations are annual averages in panels A and B and 30-years annual averages in panels C and D.

At the global level, the value of exports and average temperatures (both short- and long-run) are characterised by a growing trend overtime; the rainfall levels are more erratic in the short-run (figure A.1, panel B), but present a steadily growing trend in the long-run (figure A.1, panel D). Trade in the food and beverage sectors and climate are positively correlated. By connecting countries, trade may transfer geographically limited climate effects on a global scale (Jones and Olken, 2010). A warmer climate overtime has increased exponentially the value of exports; the greater the rainfall levels, the higher the export values. Such relationships, less marked in the short-run, become stronger in the long-run.

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