Trade in Agricultural and Food Products*

Carl Gaigné† [1,2]   Christophe Gouel‡ [3,4]

[1]INRAE, UMR 1302 SMART, 4 Allée Adolphe Bopierre, CS 61103, 35011 Rennes cedex, France
[2]CREATE, Laval University, 2425 Rue de l'Agriculture, Quebec City, QC, Canada
[3]Université Paris-Saclay, INRAE, AgroParisTech, PSAE, 78850, Thiverval-Grignon, France
[4]CEPII, 20 avenue de Ségur, 75007, Paris, France

January 25, 2022

Abstract

This chapter reviews how the literature on trade in agricultural and food products has developed over the last twenty years. Its evolution has been heavily influenced by several developments in the international trade literature. First, related to trade theories that connect closely with observables: new Ricardian models and firm-level analysis. Second, related to a shift toward applied work involving estimated gravity models and counterfactual simulations. Within a unifying framework, we provide a bird-eye overview of recent developments in trade literature that improves the predictive capability of empirical and theoretical studies for agricultural and food sectors. We highlight how land heterogeneity, technology, vertical relationships in the food chain, quality of food products, and taste affect agri-food trade and its welfare consequences. We also discuss the emergence of new policy issues such as climate change, quality standards, food security, market volatility, and nutrition transition, where although trade may not be at the center of the issues it mediates most of the effects. Last, this chapter identifies possible future developments to make agricultural trade a very active research field, with specific focus on the consumer preferences, hidden costs, production technologies, and market structures.

Keywords: agriculture, food industry, heterogeneity, comparative advantage, quality, trade, volatility, input-output relationships.

JEL classification: D50, F10, Q17, L66.

*This paper has been prepared for the Handbook of Agricultural Economics, Volume 6, edited by Chris Barrett and David Just. The authors are grateful to the editors, Chris Barrett and David Just, to the reviewers, and to Cecilia Bellora, Antoine Bouët, Angela Cheptea, Daniele Curzi, José De Sousa, Anne-Célia Disdier, Sabine Duvaleix, Charlotte Emlinger, Alexandre Gohin, Houssein Guimbard, Bruno Larue, Karine Latouche, Chantal Le Mouël, Cecile Leroy, Clément Nedoncelle, Alessandro Olper, Ian Sheldon, Lota Tamini, Stéphane Turolla, and Wendkouni Jean-Baptiste Zongo for helpful comments. This work is supported by a public grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'avenir" program (reference: ANR-10-EQPX-17 – Centre d'accès sécurisé aux données – CASD).

†carl.gaigne@inrae.fr
‡christophe.gouel@inrae.fr

Contents

1 Introduction

Since the previous handbook chapter on agricultural trade was published twenty years ago (Karp and Perloff, 2002), there have been many changes. First, new issues have emerged as the trade policy landscape has evolved (e.g., the rise of non-tariff measures and bilateral trade agreements, China's entry as 143$^{\text{rd}}$ member of the World Trade Organization, and substantial gains in market share by emerging economies such as Brazil and Argentina). Second, new types of datasets have become available (e.g., high-resolution data on soil and climate, and trade data at firm level). Third, new tools have been designed. To account for these changes, this chapter starts from where the previous one left off: in around 2002 when three fundamental contributions set the foundations for the modern trade literature. Eaton and Kortum (2002) provided new bases for comparative advantage models and how to map them to the data; Melitz (2003) developed theoretical foundations for analyzing the behavior of heterogeneous firms and identifying potential winners and losers from trade integration; and Anderson and Wincoop (2003) provided the theoretical grounds for the frequently used gravity model of bilateral trade and show how to connect the model to the data, taking account of the interactions across markets and the income constraints. These three papers do not focus on agricultural and food products but they have had a major effect on the work on this sector, and serve as a structure for this chapter since one of our objectives is to provide a map of the trade literature from the perspective of agricultural and food issues which often require specific modeling choices.

The literature already includes several outstanding surveys of this new theoretical and empirical landscape—for example, Costinot and Rodríguez-Clare (2014) on the quantitative implications of modern trade models and Head and Mayer (2014) on their econometric estimation—which we do not repeat here. The present chapter complements these works by adding a focus on the agricultural and food sectors and their specificities, and showing, for example, how modern trade models capture the fundamental mechanisms explaining trade in agricultural and food products. We also consider the crucial assumptions that are needed to make trade theories more appealing and relevant to agricultural economists. For example, analysis of the internationalization process in the food industry cannot ignore its ties to the farm and retail sectors as well as the role of quality of food products. Also, the role of land in agricultural production, a specific factor with very heterogeneous endowments even within countries, implies a strong role for the forces of comparative advantage.

To try to limit the size of this survey, we decided to focus the discussion on a limited number of topics. For example, we skim the traditional trade and domestic policy issues that are at the center of Karp and Perloff's (2002) handbook chapter on agricultural trade. Even though tariffs, subsidies, and quantitative restrictions imposed by governments are still key determinants of trade in agricultural and food products, most of the theoretical insights in Karp and Perloff's chapter remain valid, and readers can refer also to the chapters in Bagwell and Staiger (2016) for a modern treatment of the issue. A consequence of this first choice is that we also do not cover the political economy literature (surveyed in Anderson et al., 2013) explaining these policies. Rather, we survey the modern literature on the welfare and trade effects of the rise of public standards, which cannot be treated as pure trade barriers since they address market failures such as externalities and asymmetric information. Another dimension of agricultural trade omitted from this survey is the literature on price transmission (Cramon-Taubadel and Goodwin, 2021) because it uses quite different tools from those mobilized in the trade literature presented here. In summary, this chapter focuses on the key economic mechanisms that are relevant in modern trade models applied to the agricultural and food sectors and neglects, because of space constraints, their numerous applications to policy questions.

The survey starts with discussion of a series of stylized facts on trade in agricultural and food products which paves the way to the discussion in the following sections which use models to explain empirical regularities. Although modern trade models differ in their supply specifications which are addressed separately in sections 4 and 5, they have some common elements related to the demand side, the structure of equilibrium prices, and the gravity equation. Therefore, in section 3 we review the common bricks used to build the demand side of trade models and discuss the specificities of the agricultural and food sectors in terms of modeling (both functional forms and elasticities).

In section 4, we describe the work on comparative advantage and agricultural products. The development of the

Eaton and Kortum's model renewed interest in comparative advantage, and in this section we review a series of papers which study how both domestic and international trade costs affect specialization within agriculture, inputs use, and the associated gains from trade. The gains from trade in agriculture are linked also to the ability of trade to smooth idiosyncratic shocks which we also discuss in this section. Application of the principle of comparative advantage is better suited to products with little differentiation; therefore, this section is mostly concerned with trade in agricultural products with minimal processing.

In contrast, section 5 focuses on differentiated food products where imperfect competition is prevalent and whose study requires firm-level analysis. This is a largely absent topic in previous surveys, and has been made possible by the theoretical developments in Melitz (2003) and improved access to firm-level data. Section 5 describes how the Melitz's framework explains the features of international trade in food products, and highlights how the specificities of the food sector, especially the role of access to raw agricultural products for food exporters and the quality sorting of exporters, can be accommodated in this framework. Accounting for these features reveals new channels through which firm performance and real income adjust to trade. In this section, we review the literature that explicitly studies food firms (i.e., using data on trade in food products and/or developing theoretical frameworks to improve the predictive ability of trade theory for food industry).

Trade costs are essential in comparative advantage and firm-level studies but in sections 4 and 5 they are mostly assumed to be exogenous and their nature is left unspecified. Despite declining tariffs, compared to other types of products, agriculture and food products face large trade costs. These products tend to be bulky and perishable, and they have to meet the different quality standards set by countries and multinational companies. Section 6 focuses on the distribution costs (i.e., related to wholesalers and retailers) involved in reaching foreign end-consumers, the costs and gains related to non-tariff measures, and the variability of trade costs. It details the trade costs' nature, origin, and consequences.

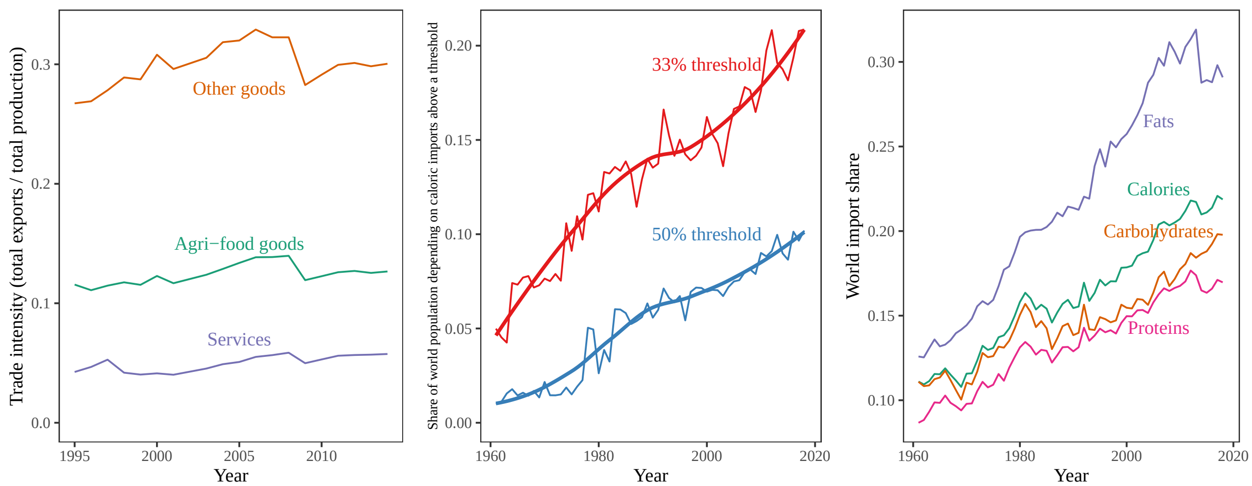
The chapter concludes in section 7. We provide some remarks on the current state of the literature and discuss possible directions for future development and research. The technical derivations of theoretical results reported in this chapter can be found in the online Appendix on the authors' website.

2 Stylized facts

Defining trade in agricultural and food (agri-food) products as trade in chapters 01 to 24 of the harmonized system, between 1995 and 2020 its value represented between 7% and 10% of global trade in goods (source: BACI, Gaulier and Zignago, 2010). While this share has fluctuated over the period, at 5.1% the annual growth of agri-food trade has been close to the 5.6% level for the other goods. If we distinguish agricultural products from food products using chapter 14 as the cutoff, trade in food products has increased at rates similar to trade in agricultural products and represents 45% of the total.

Stylized fact #1: A small share of agri-food products is traded

It is obvious that the small share of agri-food goods in trade is related to the small share of these sectors in overall production of goods. However, it is also true that agri-food goods are traded much less intensively compared to other goods (Xu, 2014). Using the multi-regional input-output database EORA (Lenzen et al., 2012) which represents the trade relationships between 190 countries, we can calculate the trade intensity (ratio of the total value of trade to the total value of production) of agri-food goods, other goods, and services. Figure 1a shows that agri-food goods are traded much less intensively than other goods. In 2014, trade intensity of agri-food goods was 13% compared to 30% for other goods. Agri-food goods are closer to the low trade intensity of services (6% in 2014) than to the trade intensity of most goods. Thus, if agri-food products were traded as intensively as other goods, in 2014 they would account not for 10% but rather 23% of all trade in goods.

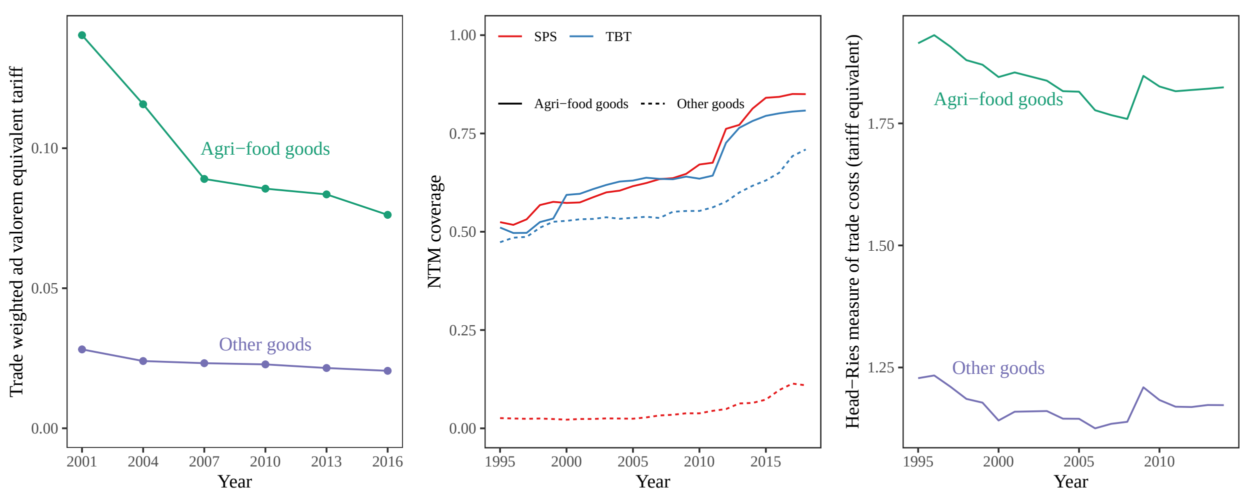


(a) Trade intensity (b) Caloric-intake dependency on trade (c) Trade intensity in macronutrients

Figure 1: Trade measures. Sources: (a) calculated using EORA; (b) and (c) calculated using FAOSTAT food balances.

Stylized fact #2: Trade costs are high for agri-food products

One reason for the low trade intensity of agri-food products is the relatively high trade costs they face. These costs include the high border protections from which they benefit relatively to other goods in the form of higher tariffs and high coverage of tariff rate quotas (Guimbard et al., 2012). Figure 2a illustrates this by depicting the trade-weighted average applied tariffs on agri-food and other goods, calculated from MAcMap-HS6 (Guimbard et al., 2012) and BACI. It shows that in 2001 tariffs were five times higher for agri-food products than for other goods. These tariffs have declined over the last two decades (due mostly to unilateral liberalization as shown in Bureau et al., 2019) but in 2016 were still almost four times higher than for other goods.



(a) Applied tariff protection (b) Non-tariff measures coverage (c) Gravity-based trade costs

Figure 2: Trade costs measures. Sources: (a) calculated using MAcMap-HS6 and BACI, (b) calculated using UNCTAD NTMs TRAINS and BACI, (c) calculated using EORA.

This period has also seen increasing prevalence of non-tariff measures (NTMs) which are especially dominant in agriculture (figure 2b). NTMs do not systematically increase trade costs (as is discussed in section 6.2) but their large presence is indicative of the regulatory burden associated with trade in agri-food products. Figure 2b depicts the coverage of subheading by NTMs weighted by their trade importance (i.e., a value of 0.75 implies that 75% of trade flows are covered by at least one NTM in the family considered).[1] It distinguishes coverage by technical barriers to trade (TBT) and sanitary and phytosanitary (SPS) measures. Given the nature of agri-food goods, they are concerned more strongly by SPS measures than are other goods, while TBTs apply almost equally to both types of goods although with slightly higher coverage of agri-food products. In 2018, more than 80% of trade in agri-foods goods was subject to some NTMs.

In addition to the previous statistics which provide information on specific trade costs, we calculate an overall trade cost measure based on a gravity model following Head and Ries (2001). This measure, which is consistent also with the model structure presented in this chapter (see Novy, 2013a), is defined by $\tilde{\tau}_{ij}^k = [(X_{ii}^k X_{jj}^k)/(X_{ij}^k X_{ji}^k)]^{1/(2\varkappa^k)} - 1$, where X_{ij}^k is trade in sector k between countries i and j, and $\varkappa^k$ is the trade elasticity (the elasticity of bilateral trade to change in variable trade costs). We assume a common trade elasticity of 5 following the meta-analysis in Head and Mayer (2014)[2] and weight the various bilateral measures by bilateral trade. This leads to figure 2c which shows that total trade costs are much higher for agri-food goods compared to other goods, and have been declining too slowly over the period to close the gap significantly. In addition to the above-mentioned tariff and non-tariff measures, possible explanations for these higher trade costs for agri-food products are the perishability of these products and their bulkiness which is likely to increase shipping cost relative to price.[3]

Stylized fact #3: Trade has been rising in importance for food intakes in terms of macronutrients

The previous statistics might suggest that agri-food trade is not so important for feeding people, and that most countries rely on their domestic production to feed their populations. However, these are world level and in value statistics, and therefore do not reveal countries' dependence on trade to feed their population. The FAOSTAT food balances provide a clearer picture of this issue and allow us to calculate the share of imports in terms of quantities consumed (for food, feed, and industrial use). Based on this statistic, figure 1b represents the share of the world population that depends on imports for more than 33% and 50% of their caloric intake, and shows that in the 1960s very few countries depended significantly on trade. However, today 20% of the world population depends on trade for at least 33% of its caloric intake. Figure 1c displays the trade intensity of macronutrients and confirms the increased global dependence on trade for macronutrients intake. Currently, more than 20% of the calories consumed are imported, and trade intensity rises to 30% for fats which traditionally are less protected at borders compared to carbohydrates-based staples such as rice and wheat.

Stylized fact #4: Observable and evolving comparative advantage

In addition to the high trade costs, the low trade share of agri-food products could be explained by limited productivity differences across countries hindering the forces of comparative advantage. Measuring comparative advantage is usually difficult because for most sectors productivity can be observed only if there is actual production, after selecting sectors as profitable activities. A specificity of the agricultural sector is that it is possible to obtain measures of the potential

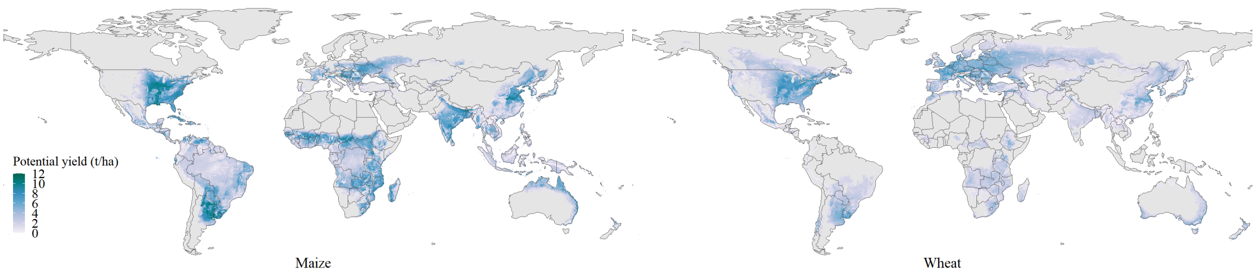
[1] Figure 2b is based on information on 90 countries plus the European Union. For the European Union, in the absence of information before 2009, 2009 measures are assumed to apply before.

[2] Although the trade elasticity is a central parameter in quantifying the welfare effects of trade, there is no consensus on the value of this parameter. Recent estimates of trade elasticities for agri-food products are close to but lower than the central estimates of 5 for all goods (Xu, 2014, finds 4.2 and 4.8 for agricultural products depending on the estimation method; Tombe, 2015, finds 4 for agricultural products; and Fontagné et al., 2020, find 3 and 4 for agricultural and food products respectively). A lower trade elasticity for agri-food goods would further increase their trade costs relative to other goods.

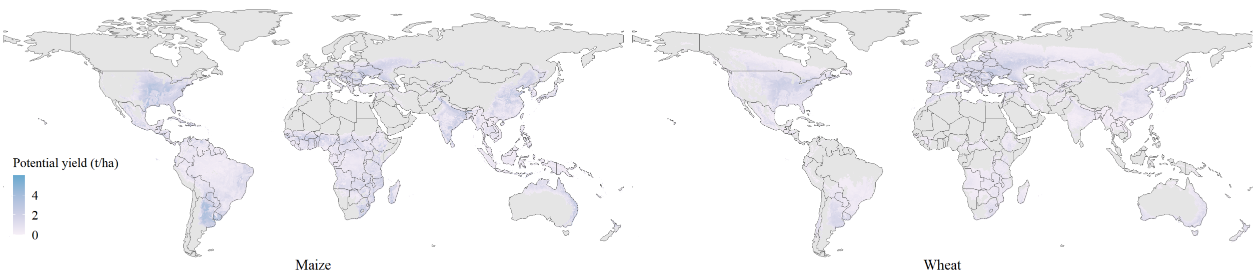
[3] Agri-food products have a weight-to-value ratio in average twice as large as the one of other goods (source: BACI) and Hummels (2007, Table 2) shows that transportation costs increase with this ratio.

productivity of land even for crops not grown there. This is made possible by the work of agronomists who use crop models to simulate how much each piece of land could produce given its soil characteristics and climate. The resulting measure, yield, represents a partial factor productivity measure but can be considered a key primitive of comparative advantage within the sector, and has been used as such in many papers discussed in section 4.

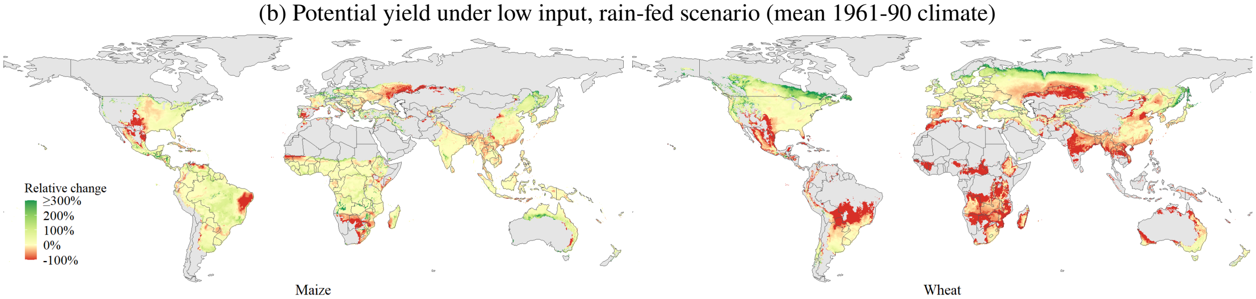
This measure and the extent of comparative advantage among crops are depicted in figure 3a for two staples: maize and wheat. Even for two cereals, potential productivity differences across countries are large and Costinot and Donaldson (2012) show that these differences provide a good basis to understand crop specializations across countries. Note also that there are strong productivity differences within countries, a stylized fact that is at the basis of many important contributions studying the welfare gains from within-country trade in agricultural products (e.g., Costinot and Donaldson, 2016; Donaldson, 2018).



(a) Potential yield under high input, rain-fed scenario (mean 1961-90 climate)



(b) Potential yield under low input, rain-fed scenario (mean 1961-90 climate)



(c) Relative changes in potential yield due to climate change under the RCP8.5 scenario with CO_2 fertilization and the assumptions of high inputs use and rain-fed cultivation. Comparison between 2071–2100 climate and mean 1961–90 climate.

Figure 3: Agro-ecological potential yields and their possible evolution. Source: calculated using data from the GAEZ project (IIASA/FAO, 2021).

The same crop models also provide information on the role of intermediate inputs in agricultural production, which allows us to touch on another source of comparative advantage. Comparing figures 3a and 3b shows that potential productivity and thus comparative advantage are also a function of the use of modern inputs (fertilizers, modern seeds, pesticides). Since these inputs are also traded (Farrokhi and Pellegrina, 2021), their trade costs mean that countries have unequal access to them which in addition to their specific land endowments contributes to shaping their comparative advantage.

Finally, comparative advantage is not fixed in time. It evolves with the availability of technology and it will evolve strongly with climate change. Figure 3c illustrates this possible evolution and shows that comparative advantage patterns within and between countries will be affected between crops.

3 A common model

Although trade models differ in terms of their supply-side assumptions, they share similar demand structure, trade frictions, and welfare decompositions. Preferences are mostly represented by a constant elasticity of substitution (CES) utility function (Dixit and Stiglitz, 1977), or variations of it, because of its high tractability. For trade costs, the iceberg technology is the second main ingredient of trade models: only a fraction of a good shipped between two places reaches the destination, the missing share having melted on the way. This ingenious modeling trick devised by Samuelson (1954) allows integration of positive trade costs without the need to deal explicitly with a transport sector. Hence, Dixit, Stiglitz and Samuelson form the trinity which economists use to combine different market structures and production technologies within their trade models.

Our goal in this section is to present and discuss some common features of modern trade models in a flexible framework which is based on a multi-sector multi-country general equilibrium model of trade that nests the main drivers of agricultural and food trade in a relatively parsimonious form.

3.1 Import demand

Throughout the chapter, we index importing countries by j and exporting countries by i (where each country can buy its own output) while we index food sectors (food product class) by $k = 1, \ldots, K$ (fruits, vegetables, dairy products, meat, etc.) and non-food sectors $k = K+1, \ldots, \mathcal{K}$. Trade literature considers the assumption of separable preferences and technology. Each product class has a distinct aggregator of varieties of sectors and can be either a final or an intermediate good. Hence, we can consider that households and producers use two-stage budgeting. The first stage of the process generates a system for the allocation of total expenditures across sectors k (or product groups) while the second stage of the process produces a system for the allocation of expenditure for a type of product across its different varieties. For example, consumers are assumed to derive utility from a two-tier utility function U_j in which the top tier expresses how consumers aggregate consumption in each product group k while the lower tier describes the consumption of varieties v of product k, with

$$U_j = U(C_j^1, \ldots, C_j^K, C_j^{K+1}, \ldots, C_j^{\mathcal{K}}), \tag{1}$$

where C_j^k is the consumption sub-index of the composite good from sector k in country j. Such nested structure allows to consider that within a sector certain varieties are better substitutes than others. The top tier of the utility function is modeled in different ways in the trade literature. The upper-level is often assumed to be either Cobb-Douglas or a CES function, but another possibility is to assume food to be separable from non-food goods in consumer preferences (e.g., Costinot et al., 2016). This is equivalent to separability of the upper-level utility function in the partition $C_j^{\mathcal{F}}, C_j^{\mathcal{O}}$, where $C_j^{\mathcal{F}} = (C_j^1, ..., C_j^K)$ represents the aggregate food consumption and $C_j^{\mathcal{O}} = (C_j^{K+1}, ..., C_j^{\mathcal{K}})$ is the aggregate outside good consumption. Hence, the top tier can also express how consumers aggregate broad classes of products (e.g., food and non-food) and different product groups within each class ($U_j = U(C_j^{\mathcal{F}}, C_j^{\mathcal{O}})$).

Concerning the lower tier, the CES specification is the most often used. The aggregate consumption of the composite product k can be expressed as

$$C_j^k = \left\{ \sum_i \int_{\Omega_{ij}^k} \left[\xi_{ij}^k(v) q_{ij}^k(v) \right]^{1-1/\varepsilon^k} \mathrm{d}\, v \right\}^{\varepsilon^k/(\varepsilon^k-1)}, \tag{2}$$

where Ω_{ij}^k is the set of varieties v of product k available in country j and produced in country i, q_{ij}^k is the demand expressed in country j for a variety of product k imported from country i, and $\varepsilon^k > 1$ is the elasticity of substitution between varieties and is assumed to be constant. $\xi_{ij}^k(v) > 0$ encompasses all attributes of variety v from i other than price which consumers in j value. The standard Dixit-Stiglitz preferences are a special case of (2) with $\xi_{ij}^k(v) = 1$. This implies that the consumer's expenditure in country j for a variety v of sector k produced in country i can be expressed as follows

$$x_{ij}^k(v) = p_{ij}^k(v) q_{ij}^k(v) = \left[\xi_{ij}^k(v)\right]^{\varepsilon^k - 1} E_j^k \left(P_j^k\right)^{\varepsilon^k - 1} \left[p_{ij}^k(v)\right]^{1-\varepsilon^k}, \tag{3}$$

where E_j^k is the amount of income allocated to the differentiated product sector k and p_{ij}^k is the price of a variety of product k, and P_j^k is the price index in country j, which is defined as

$$P_j^k = \left[\sum_i \left(P_{ij}^k\right)^{1-\varepsilon^k}\right]^{1/(1-\varepsilon^k)} \quad \text{with} \quad P_{ij}^k \equiv \left\{\int_{\Omega_{ij}^k} \left[p_{ij}^k(v)/\xi_{ij}^k(v)\right]^{1-\varepsilon^k} \mathrm{d}\, v\right\}^{1/(1-\varepsilon^k)}, \tag{4}$$

where P_{ij}^k is the aggregate price of product k from country i in country j. This simple model captures the main ingredients of the import demand for a variety: its price ($p_{ij}^k(v)$), variety-appeal ($\xi_{ij}^k(v)$), income, and the quality-adjusted prices of all varieties through the price index P_j^k.[4] The price index can be interpreted as an index of the toughness of competition across producers in sector k to serve country j. Each demand curve shifts downward when the quality-adjusted prices of varieties available decrease.

Some comments are in order. First, when trade models are enriched by introducing intermediate goods, it is assumed that, in each sector k, they are produced in the exact same way as composite goods for final consumption so that the sector-level price index P_j^k measures the aggregate price of varieties of sector k in country j for both final consumption and production (exceptions are some works focusing on global value chains, e.g., Antràs and Chor, 2018). In this case, expenditure E_j^k includes the purchases of both final and intermediate consumption goods.

Second, standard trade models impose that all consumers worldwide share the same preferences in the lower tier (demand symmetry), i.e. $\xi_{ij}^k(v) = \xi^k$, which is a restrictive assumption. For example, Jäkel (2019) finds that perception of quality on the domestic market of food products is a poor indicator of export sales in destinations, suggesting that the foreign consumers differ in their taste for quality. More generally, the empirical evidence shows strong variations in export sales across firms and across countries of the same product which cannot be explained by production costs alone. To allow demand to vary (i) across varieties of a product within a country and (ii) across countries for the same variety, some articles consider that $\xi_{ij}^k(v)$ differs across destinations and varieties. Empirical works document the importance of both quality and taste through this parameter for explaining variations in export performance across firms and countries (Aw-Roberts et al., 2020). Formally, it can be assumed that

$$\xi_{ij}^k(v) = \bar{\zeta}_{ij}^k \left[\theta_{ij}^k(v)\right]^{\zeta_j^k}, \tag{5}$$

where $\bar{\zeta}_{ij}^k$ represents consumer taste for product k produced in country i (the popularity of varieties produced in a country varies across destination markets), $\theta_{ij}^k(v)$ represents the true quality supplied by the producer of variety v, and an increase in $\zeta_j^k > 0$ signals greater appreciation for vertically differentiated products. In the standard approach without vertical differentiation, we have $\theta_{ij}^k(v) = 1$. The role of vertical differentiation has received much attention in trade theory (Gaigné and Larue, 2016; Hallak, 2006; Hallak and Sivadasan, 2013; Kugler and Verhoogen, 2012). Hallak (2006) considers that ζ_j^k can capture differences across countries in the demand for quality stemming from their

[4] The CES utility functions imply a taste for variety, and demand for each variety is positive regardless of its price. If individuals consume multiple units of their preferred variety, Anderson et al. (1992) show that it is possible to yield a demand equation that is observationally equivalent to the CES demand. The consumer's taste for each variety is treated as a "random" component which is distributed across varieties in the same way as in the logit demand system.

differences in average income, because countries with higher average income consume a larger fraction of high-quality products. The demand system generated by this type of utility function can capture the positive effect of income on quality demand at the aggregate level by assuming that ζ_j^k increases with income per capita. The international heterogeneity in consumer taste also deserves attention. For most food products, taste varies across countries. For example, import demand for high-quality French cheese may be high in Italy and low in Germany, because food habits in France are closer to those of Italy than Germany. This role of quality and taste in food trade is discussed in section 5.3.

Third, the vast majority of the trade literature assumes that the perceived and true quality of products do not deviate. However, not all attributes are perfectly observed by all consumers (Dulleck et al., 2011). If consumers can learn about the quality level prior to the purchase (search good) or after repeated purchases (experience good), uncertainty about product quality may prevail. In some cases, consumers cannot perfectly judge the quality even after consumption (credence goods). There is demand for attributes in food products which cannot be verified by consumers either ex-ante and ex-post, such as: (i) attributes that have health/safety consequences (e.g., pesticide residues) and (ii) attributes that are related to production processes such as the environmental costs of production, the living and working conditions of farmers, use of child labor, use of genetically modified organisms, animal welfare standards, and use of traditional production process in specific places. In these cases, information asymmetry exists between buyer and seller with respect to the quality of food products. The introduction of minimum quality standards and the use of geographical indications can be justified as they can partially solve a real-world information problem. The effects of standards set by private companies on trade are discussed in section 6.1 while the standards implemented by national governments are discussed in section 6.2.[5]

Four, consumer tastes $\bar{\zeta}_{ij}^k$ are assumed to be exogenously given. Yet, globalization may affect the formation of taste (Olivier et al., 2008). Food preferences may be shaped by habit formation (e.g., sugar-rich and fat-rich food addiction) and the social transmission of preferences. If intergenerational transmission of preferences is likely to play an important role, globalization may have a growing role in food cultures because of increasing international diffusion of information and social interactions across individuals living in different countries (Oberländer et al., 2017). Further research should focus on the role of information and communication technologies in the formation of food preferences.

3.2 Consumer prices and gravity equation

Regardless of the market structure and production technology, trade models share the following general form of prices paid by the consumers in equilibrium:

$$p_{ij}^k(\nu) = m_{ij}^k(\nu) \times \text{mc}_{ij}^k(\nu) \times \tau_{ij}^k, \tag{6}$$

where $m_{ij}^k(\nu) \geq 1$ is the markup over the marginal cost applied by the producer (with $m_{ij}^k(\nu) = 1$ under perfect competition), $\text{mc}_{ij}^k(\nu)$ is the marginal cost of production (of variety ν exported to country j), and $\tau_{ij}^k \geq 1$ captures the variable trade costs such as transportation costs, distribution costs (wholesale and retail), and trade policies. Trade costs borne by exporters, so excluding trade policies, are modeled as iceberg costs and are proportional to the volume shipped because the amount melted, given by $(\tau_{ij}^k - 1)q_{ij}^k$, is proportional to its volume (the distribution of products therefore uses resources). Trade costs satisfy the triangle inequality (it is not cheaper to ship a product via a third country rather than to sell directly to a destination).

The technology of production plays a key role in modern trade models. Marginal costs are assumed in most trade models to be given by $\text{mc}_{ij}^k(\nu) = c_i^k/\phi_{ij}^k(\nu)$ where c_i^k denotes input cost and $\phi_{ij}^k(\nu)$ is a (factor-neutral) productivity shifter. The unit cost c_i^k can be broken down into different inputs costs (labor, land, intermediate inputs). Even though factor prices are equalized across industries in competitive factor markets, the unit cost of using a composite factor of

[5] We do not provide in this chapter a review of the effects of standards set by non-governmental organizations such as fair trade standards which aim at improving the living and working conditions of farmers in developing countries (see Dragusanu et al., 2014, and Meemken et al., 2021, for a discussion on the effects of fair trade standards on farmers).

production c_i^k can differ across industries k in each country due to differences in factor intensity. However, trade models consider that the unit cost of using a composite factor of production c_i^k does not vary across suppliers of product k located in the same country and with output size. This point is discussed in section 5. The productivity shifter $\phi_{ij}^k(\nu)$ can be split into two components. It is increasing in the producer-specific efficiency parameter $z_i^k(\nu)$ and decreasing in product quality $\theta_{ij}^k(\nu)$ (since higher-quality output is more difficult to produce and requires more inputs). Formally, it is assumed that $\phi_{ij}^k(\nu) = z_i^k(\nu)[\theta_{ij}^k(\nu)]^{-\alpha^k}$ where $\alpha^k \geq 0$ is the quality-elasticity of marginal costs so that

$$\mathrm{mc}_{ij}^k(\nu) = \frac{c_i^k[\theta_{ij}^k(\nu)]^{\alpha^k}}{z_i^k(\nu)}. \tag{7}$$

In the standard approach without vertical differentiation $\theta_{ij}^k(\nu) = 1$, implying that the marginal cost of production is not specific to the destination market and is given by $c_i^k/z_i^k(\nu)$.

Markups arise from monopoly power. Under imperfection competition, the markup of firms that produce and distribute variety ν is $m_{ij}^k(\nu) = \mathcal{E}_{ij}^k(\nu)/[\mathcal{E}_{ij}^k(\nu) - 1]$ where $\mathcal{E}_{ij}^k(\nu)$ is the price elasticity of demand faced by the firm $(\partial \ln q_{ij}^k(\nu)/\partial \ln p_{ij}^k(\nu))$. Most trade models with imperfect competition assume a continuum of producers, implying monopolistic competition. Combined with CES demand systems, monopolistic competition implies that the price elasticity of demand is equal to the elasticity of substitution ($\mathcal{E}_{ij}^k(\nu) = \varepsilon^k$) and markup is invariant over destinations and over producers as $m_{ij}^k(\nu) = \varepsilon^k/(\varepsilon^k - 1) \equiv m^k$. As a result, under a continuum of producers and CES demand, the delivered price without vertical differentiation equals the factory(farm)-gate price $p_i^k(\nu)$ times trade costs τ_{ij}^k, where $p_i^k(\nu) = c_i^k/z_i^k(\nu)$ under perfect competition and $p_i^k(\nu) = m^k c_i^k/z_i^k(\nu)$ under monopolistic competition. Variable markup and its implications are discussed in section 5.5.

We are now equipped to determine the value of aggregate bilateral trade at the product group level k, given by $X_{ij}^k = \int_{\Omega_{ij}^k} x_{ij}^k(\nu)\,\mathrm{d}\,\nu = E_j^k(P_j^k/P_{ij}^k)^{\varepsilon^k-1}$. By imposing that budget constraints are met and the prices of factors and varieties are such that all markets clear (full general equilibrium), this bilateral trade equation corresponds to a structural gravity equation. Indeed, assuming a continuum of producers and plugging equations (5)–(7) into equations (3) and (4) imply

$$X_{ij}^k = E_j^k(P_j^k)^{\varepsilon^k-1}(m^k c_i^k \tau_{ij}^k)^{1-\varepsilon^k}(Z_{ij}^k)^{\varepsilon^k-1} \quad \text{with} \quad Z_{ij}^k \equiv \bar{\zeta}_{ij}^k \left\{ \int_{\Omega_{ij}^k} [z_i^k(\nu)]^{\varepsilon^k-1}[\theta_{ij}^k(\nu)]^{\Lambda_j^k}\,\mathrm{d}\,\nu \right\}^{1/(\varepsilon^k-1)}, \tag{8}$$

with $\Lambda_j^k \equiv (\varepsilon^k - 1)(\zeta_j^k - \alpha^k)$ and where Z_{ij}^k captures the role of heterogeneity in productivity and quality in international trade which depends on the assumptions about consumers taste, market structure, and technology.[6] It is straightforward to check that $\sum_i X_{ij}^k = E_j^k$. An additional accounting identity must hold: the total value of production equals the sum of exports to all destinations $Y_i^k = \sum_j X_{ij}^k$. This condition and (8) imply $Y_i^k/Y^k = (m^k c_i^k \Pi_i^k)^{1-\varepsilon^k}$ with $Y^k = \sum_i Y_i^k = \sum_j E_j^k$, i.e. world sales equal world expenditure, and $(\Pi_i^k)^{1-\varepsilon^k} = \sum_j (\tau_{ij}^k/P_j^k)^{1-\varepsilon^k}(E_j^k/Y^k)(Z_{ij}^k)^{\varepsilon^k-1}$ described by Anderson and Wincoop (2003) as "outward multilateral resistance" (OMR hereafter). This index is a weighted average of all bilateral trade costs for the producers in each country which accounts also for selection effects through Z_{ij}^k. Using this index, the price index (4) can be rewritten as $(P_j^k)^{1-\varepsilon^k} = \sum_i (\tau_{ij}^k/\Pi_i^k)^{1-\varepsilon^k}(Y_i^k/Y^k)(Z_{ij}^k)^{\varepsilon^k-1}$ and defined as "inward multilateral resistance" (IMR hereafter). This index represents a weighted average of all the bilateral trade costs that fall on the consumers in each country and the quality-adjusted productivities of the suppliers. This index measures the degree of competition in destination markets. Hence, we obtain a generalized version of the structural gravity equation developed in Anderson and Wincoop (2003) which combines the intensive and extensive

[6] Productivity and appeal (quality or taste) are isomorphic under the assumption of CES preferences. When productivity and appeal are exogenous parameters, they enter equilibrium firm revenue in the same way.

margins of trade:

$$X_{ij}^{k} = \frac{Y_i^k E_j^k}{Y^k} \left(\frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right)^{1-\varepsilon^k} \left(Z_{ij}^k \right)^{\varepsilon^k - 1}. \tag{9}$$

The first ratio in the right-hand side (RHS hereafter) of this equation corresponds to the frictionless trade flows, the second ratio captures the role of relative trade costs, and the last term indicates the role of heterogeneity across producers through a selection mechanism to reach foreign markets. In a frictionless and homogeneous world, each destination would face the same price (p_i^k) so that each country j spends a proportion of its total expenditure on imports from every other country i that is equal to the country i's share in world sales (Y_i^k/Y^k). The second ratio on the RHS reveals how relative trade costs modify this relationship. Through the IMR and OMR indices in the second ratio, the bilateral flows account for the set opportunities of the importers and exporters (each exporter has multiple possible destinations and each importer has multiple possible origins). The term $(Z_{ij}^k)^{\varepsilon^k - 1}$ reflects changes at the extensive margin, i.e., changes in the set of varieties imported in country j from country i. In a world endowed with homogeneous producers, we fall back on the gravity equation à la Anderson-van Wincoop (Z_{ij}^k is dropped). Fally (2015) showed that the IMR and OMR indices can be recovered from the importer and exporter fixed effects in the trade equation estimated by Poisson pseudo maximum likelihood (see Feenstra, 2016, for more details on the methods used to estimate trade equations).

3.3 Trade and welfare

The welfare impacts of freer trade or protectionism measures have received much attention because modern gravity-based trade models are amenable to sufficient-statistic formulas for the welfare consequences of foreign shocks or changes in trade policy (Arkolakis et al., 2012; Costinot and Rodríguez-Clare, 2014) that are functions of (i) observable shares (the share of expenditures on domestic products, the share of intermediates in production, the share of expenditures on a product, the share of total revenue generated from a sector, etc.), and (ii) key elasticities in particular the elasticity of bilateral imports with respect to variable trade costs (trade elasticity).[7] This new approach complements traditional welfare decompositions (a deadweight loss, a terms-of-trade effect, a markup effect, etc.) that are still useful in several settings (see, e.g., section 4.2.3) with an approach that can be applied to analyze non-marginal shocks and so compare gains from trade across trade model generations.

The gains associated with international trade are not difficult to compute with homothetic preferences. Assuming that the first tier of the utility function is a Cobb-Douglas and the lower level is a CES, the indirect utility of a representative consumer in country j is given by $V_j = R_j (P_j^O)^{-\beta_j^O} \prod_{k=1}^K (P_j^k)^{-\beta_j^k}$ where $\sum_k^K \beta_j^k + \beta_j^O = 1$, P_j^O is the price index of the aggregate outside good, and R_j is the total income in country j derived from factor income (labor and land) and profits of firms located in j (if any). Standard calculations show that $P_j^k = (\lambda_{jj}^k)^{1/(\varepsilon^k - 1)} P_{jj}^k$ where $\lambda_{jj}^k \equiv X_{jj}^k / E_j^k$ is the share of expenditure on domestic varieties of product k. Hence, regardless of assumptions about market structure and production technology, the log change in real income associated with an arbitrary shock can be expressed as[8]

$$\ln \hat{V}_j = -\sum_{k=1}^{K} \frac{\beta_j^k}{\varepsilon^k - 1} \ln \hat{\lambda}_{jj}^k - \sum_{k=1}^{K} \beta_j^k \ln \hat{P}_{jj}^k + \ln \left[\hat{R}_j \left(\hat{P}_j^O \right)^{-\beta_j^O} \right]. \tag{10}$$

This change can be decomposed into three components. The first component of the RHS of (10) is common to trade models based on a CES demand system and represents the change in the own trade share in product k. It measures only the consumption-related welfare gains associated with trade openness and does not take account of the effects on domestic markets. The magnitude of this effect depends on the price elasticity of import demand ($\varepsilon^k - 1$) and the

[7] Although there are some differences, this approach is related to the literature in public economics on the welfare consequences of changes in policy which can be expressed as functions of high-level elasticities rather than deep primitives. This "sufficient statistics approach" combines the advantages of both reduced-form approaches and structural models (see Chetty, 2009).

[8] Any variable with a hat indicates a proportional change, i.e., $\hat{x} = x'/x$, a notation popularized by Dekle et al. (2007) and denoted "exact hat algebra".

share of expenditures allocated to product k (β_j^k). The second and third terms capture the effects on the price index of domestic varieties and on income, respectively. The magnitude of these effects depends on assumptions on the supply-side of the economy (i.e., market structure and technology) and involves selection effects and variety effects. Using equations (4)–(6), the marginal change in the aggregate price of domestic varieties is

$$\ln \hat{P}_{jj}^k = \ln \hat{c}_j^k - \ln \hat{Z}_{jj}^k, \tag{11}$$

where $\hat{c}_j^k$ captures the changes in input prices (which depend on assumptions about technology production) while $\hat{Z}_{jj}^k \neq 1$ implies a selection mechanism and/or a change in the number and the quality of domestic varieties. For example, a higher average quality of domestic varieties and average productivity of domestic producers due to tougher import competition lower the aggregate price of domestic varieties, and in turn, improve welfare. In contrast, more foreign competition can force the exit of the least productive producers implying a lower set of domestic varieties and a higher aggregate price of domestic varieties. The net welfare effect is therefore ambiguous and depends on supply-side assumptions. We will see in the next two sections that $\hat{P}_{jj}^k$ and $\hat{P}_j^O$ are also a function of the change in the own trade share in product k and in the aggregate outside good, respectively, as well as other observable shares such as the share of intermediates in production.

We discuss the impact of trade openness (i.e., a lower share of home spending on domestic products) on real income, holding other RHS variables constant (abstracting from the effects on domestic markets) as they are discussed in the next sections. The consumer gains from more trade openness shrink as the elasticity of substitution increases, indicating that the imported varieties are close substitute for domestic varieties. By combining UNIDO data on domestic production and BACI data on bilateral trade flows from BACI, we can compute β_j^k and λ_{jj}^k.[9] The price elasticity of bilateral imports is inferred from the available trade data which give information on quantity (generally in kilograms) and price (unit value). Its estimation requires only assumptions about the demand system, an appropriate identification strategy to deal with the simultaneous determination of import prices and quantities, and an export supply function which is often assumed to be a flexible upward-sloping curve. However, no assumption on market structure and production technology is needed. Using this approach developed by Feenstra (1994) and Broda and Weinstein (2006), Imbs and Mejean (2017) and Ossa (2015) estimate the sensitivity of trade to price adjustments. The price elasticity estimates obtained by Ossa (2015) range from 2 to 18 for the agriculture and food industries with a mean of 4.3.

The gains from trade in country j are measured as the absolute value of the percentage change in real income that would be associated with moving to autarky in country j. Starting in 2014, the Russian ban on agri-food imports from several Western countries provides a rare opportunity to compute the effects of an elimination of trade from partner countries. Before the ban, Russia imported around 40% of its agri-food consumption and the ban covers 35% of these imports. From Russian data, Cheptea and Gaigné (2020) quantified the impact of the Russian food embargo on the real incomes of Russian consumers. Abstracting from selection and variety effects, they report that the ban induced a 0.21% drop in Russian consumers' real income. This represents €18 of average Russian consumer's 2013 revenue. The welfare consequences associated with a counterfactual scenario in which countries move to food self-sufficiency can also be computed. For example, if France moved to food autarky where agriculture and food imports are zero ($\lambda_{jj}^{k\,\prime} = 1$ with $k = A, F$, A for agricultural sector and F for food processing industry), real income would decline by 0.98% without taking account of the adjustments in domestic markets.[10] Under these circumstances, the return to food self-sufficiency in France would be equivalent to a decrease in per household annual income of €415. We discuss in sections 4 and 5 how the supply-side assumptions affect the magnitude of costs from moving to food autarky.

[9] See Imbs and Mejean (2017) for a description of the methodology.

[10] According to the French national account in 2018, the share of imports in the consumption of agricultural and food products was approximately 19% and 25%, and the share of total expenditure of households allocated to agricultural and food products was approximately 2.9% and 14.9%. We take the elasticities of agriculture and food demand to be 5 as in section 2. Note that the cost of moving to food autarky is sensitive to the level of aggregation, as pointed out by Ossa (2015).

3.4 Discussion: non-homothetic preferences and hidden costs

The demand systems based on CES preferences imply that income elasticities of trade flows do not vary across products and are equal to 1 (homothetic preferences). This convenient simplification allows a focus on the supply side to explain the causes and consequences of trade. This convenience is at odds with the empirical evidence, and especially Engel's law which states that the food share is inversely related to income or total expenditures (income elasticities of food expenditures are less than 1), but also the large variations across products and countries in the income elasticities of food demand (Fémenia, 2019) and of food import demand (Feenstra and Hong, 2022; Gohin and Fémenia, 2009). In practice, assuming homotheticity of preferences is problematic for three types of research questions: in the case when (i) income distribution and income per capita are important determinants of trade in agricultural and food products between countries, (ii) the gains from agricultural trade liberalization are unequal across consumers within countries, and (iii) counterfactual shocks are expected to have large income effects. We discuss the first two points below. The third point is relevant only for a few large shocks such as climate change (see section 4.2.3) but not for most agricultural policy changes, and the discussion of the first point is relevant in this case.

First, differences in income elasticities across products and per-capita income can shape international trade. The role of non-unitary income elasticities in explaining trade flows was introduced in Linder (1961) and has recently received much interest. Linder predicts that trade volumes are larger across countries with similar per-capita income levels. Rich countries develop comparative advantage in high-income elastic products and non-homotheticity reduces trade volumes among countries with different per-capita expenditure levels. The modern trade literature uses various representations of non-homothetic preferences to study the role of income per capita heterogeneity across trading countries.

The simplest way to get non-homotheticity is to consider nested preference structures with Stone-Geary utility functions in the upper stage (yielding a linear expenditure system) and CES in the lower stage (as in Bergstrand, 1989). However, this approach is not a good fit with the data since it implies that marginal expenditures are constant and income elasticities are very sensitive to income. A solution to this problem is to consider directly-additive utility functions generating variable income elasticities. For example, Fieler (2011) uses "constant relative income elasticity" preferences (formally (1) is given by $U_j = \sum_k (C_j^k)^{1-1/\sigma_j^k}$ where σ_j^k govern the price elasticity and income elasticity of demand).[11] She shows that average per-capita income has an increasing effect on trade while population size has no influence on trade. This result conflicts with the standard gravity equation where elasticities of trade with respect to income per capita and to population are identical. However, own-price elasticities and income elasticities of demand are linked under a directly-additive utility.[12]

The literature on the role of the agricultural sector in structural change uses preferences allowing for good-specific parameters which control income elasticities of demand. Boppart (2014) considers a "Price Independent Generalized Linearity" (PIGL) preference class. In our context, PIGL preferences can be represented by an indirect utility function (in the upper stage) of the following form $V_j = (R_j/P_j^{O})^{\varsigma}/\varsigma - (\beta/\sigma)(P_j^{\mathcal{F}}/P_j^{O})^{\sigma}$ where $0 \leq \varsigma \leq \sigma < 1$ and $P_j^{\mathcal{F}}$ is the price index of the aggregate food good.[13] It follows that $\varsigma = 0$ implies homothetic preferences and $\sigma = \varsigma = 0$ corresponds to the indirect (log-transformed) Cobb-Douglas utility function. Applying Roy's identity, the demand for food is $C_j^{\mathcal{F}} = \beta(R_j)^{1-\varsigma}(P_j^{\mathcal{F}})^{-(1-\sigma)}(P_j^{O})^{\varsigma-\sigma}$ so that the income elasticity of demand for food (given by $1-\varsigma$) is constant but less than unity. An alternative approach is to use the implicitly additive preferences developed by Hanoch (1975) which also allow for good-specific parameters which govern variable elasticities of demand with respect to income. Matsuyama (2019) introduced this type of preference with constant elasticity of substitution (named as non-homothetic CES preferences) in a general equilibrium multi-sector trade model. In our context, the utility function

[11] We are back to standard homothetic CES preferences if $\sigma_j^k = \sigma_j$.

[12] Under such preferences, income elasticity of demand for a good in a country is equal to own-price elasticity σ_j^k times the inverse of the consumption-weighted average of σ_j^k.

[13] The general form is $[R/A(\mathbf{p})]^{\varsigma}/\varsigma - B(\mathbf{p})$ where $\mathbf{p}$ is the vector of the price of goods and the functions $A(\mathbf{p})$ and $B(\mathbf{p})$ are homogeneous of degree 1 and 0, respectively.

in the upper stage (1) can be defined implicitly through the following constraint

$$\left[\beta_j^{\mathcal{F}}\left(U_j\right)^{\varsigma^{\mathcal{F}}-\sigma_j}\left(C_j^{\mathcal{F}}\right)^{\sigma_j-1}\right]^{1/\sigma_j}+\left[\beta_j^{O}\left(U_j\right)^{\varsigma^{O}-\sigma_j}\left(C_j^{O}\right)^{\sigma_j-1}\right]^{1/\sigma_j}=1, \tag{12}$$

where $\varsigma^{\mathcal{F}}$ and ς^{O} control the income elasticity of the demand for food and for outside goods, respectively (sector-specific income elasticities while keeping the constant elasticity of substitution σ_j between aggregate food consumption and the aggregate outside good). Notice that (12) becomes the standard homothetic CES if $\varsigma^{\mathcal{F}} = \varsigma^{O} = 1$. Using cross-country data on agricultural and non-agricultural sectors, Liao and Wang (2018) find that non-homothetic CES preferences fit empirical patterns better than Stone-Geary-CES preferences.

Second, trade has a distributional impact through an expenditure channel. As expenditure shares in food products vary with income, the impact of a trade-induced change in the prices of food products varies according to consumers' income. Because low-income consumers have larger food expenditure shares than richer consumers, more imports implying lower quality-adjusted prices of food may have a stronger positive effect on low-income consumers. Fajgelbaum and Khandelwal (2016) and Nigai (2016) study the gains from trade across households by allowing for income heterogeneity within countries. The approach developed in Fajgelbaum and Khandelwal (2016) embeds Deaton and Muellbauer's (1980) almost ideal demand system (AIDS) preference structure in the upper stage (1) (food, manufacturing and services) into a standard model of international trade. Using aggregate trade data from many countries, they find that falling costs of importing in the food sector exhibits a pro-poor bias. In addition, a pro-poor bias arises from the fact that poor households spend relatively more in sectors that are more traded (food and manufacturing sectors), while high-income individuals consume relatively more in the least traded sectors (services). However, the choice of the demand system can have a significant impact on the quantification of distributional effects of trade. Using the data from Fajgelbaum and Khandelwal (2016), Borusyak and Jaravel (2021) find that (i) the import shares on food expenditure for poorest (resp., richest) households imputed by AIDS imply too high (resp., low) values and (ii) the pro-poor expenditure channel of trade becomes small with a demand system derived from (12). From US detailed expenditure data, they also document that import shares in expenditures do not vary across households according to their income when the levels of product aggregation are low and indirect import spending through imported inputs is taken into account.

Once it is recognized that non-homotheticity of food import demand can play a significant role in determining trade patterns and the heterogeneous welfare gains and losses from trade, the choice of non-homothetic preferences to improve trade models remains an open question. Another open question is how to use non-homothetic utility functions to capture that as consumers become richer, they spend less on food goods but also switch from low-quality food to high-quality food given the problem that one cannot interpret the high income-elastic goods as high-quality goods and the low income-elastic goods as low-quality.[14]

Furthermore, the research on the impact of trade on consumers focuses mainly on price, quality, and the number of varieties. More trade is expected to provide welfare gains to consumers from access to new import varieties and lower quality-adjusted prices. Yet, empirical studies document that rising trade exposure is also associated with hidden costs for consumers, whose assessment is crucial for a correct evaluation of the net welfare gains from trade. A growing strand of literature has started to quantify the trade adjustment costs associated with the changes in dietary patterns and associated health outcomes. For example, Giuntella et al. (2020) study the case of Mexico's increased imports of food from the US since the late 1980s and following NAFTA. They apply a shift-share approach to explain the change in the share of obesity at state level as a function of the exposure to US food imports, using the initial food share expenditures as shares in a shift-share approach. They provide evidence of a causal link of US exports on obesity in Mexico which explains 20% of the increase between 1988 and 2012. The main mechanism they identify is the price lowering effect of higher imports. Using German reunification as a clean natural experiment, Dragone and Ziebarth (2017) identify another mechanism contributing to increased body weight: availability of novel food enabled by trade. Following

[14]There are different types of food products: some are inferior goods (negative income elasticity) others are luxury goods (income elasticity greater than 1).

reunification, East Germans increased their consumption of formerly unavailable western food beyond consumption by West Germans. This difference in consumption of novel food persisted for several years and explains significant weight gain among East Germans. Last, food preferences can be also shaped by the development of communication technologies, which has increased international transmissions of information and contacts across individuals living in different countries. This social dimension of globalization has a positive effect on the national supply of animal proteins and sugar, as well as on mean body mass index, according to Oberländer et al. (2017). The quantification of trade-induced costs related to food consumption represents a critical area for future research.

4 Comparative advantage

Welfare gains from trade are a common object of study for textbook trade models but for a long time were not studied in the context of models able to capture the main characteristics of international trade data. Eaton and Kortum (2002) changed this and contributed to the development of a rich literature analyzing the gains from trade in various settings (see Costinot and Rodríguez-Clare, 2014, for a model-oriented presentation of this literature). This section takes stock of the application of this literature to the agricultural sector, with a focus on historical evidence from large trade costs reductions and counterfactual analysis of the gains from trade in relation to the agricultural sector. In addition, it includes analyses of the gains from trade under uncertainty, a common situation in agricultural markets which are very volatile. However, the analysis of market volatility is much less amenable to using the tools developed for standard trade models.[15]

4.1 Theory: main modeling elements

Here, we provide modeling elements that are common to most of the papers presented in this section. Corresponding to the demand-side elements already introduced we include the supply-side of a model focused on comparative advantage, where the source of the gains from trade comes from Ricardian differences in productivity (à la Eaton and Kortum, 2002), Heckscher-Ohlin-Samuelson differences in factor endowments (labor and land), and different uses of intermediate inputs.

Each product k exists along a continuum of varieties $\nu \in [0,1]$. Production of a variety is obtained by combining land, labor, and intermediate inputs using a CES function. The unit cost function then has the form $c_i^k / z_i^k(\nu)$ with

$$c_i^k = \left[\left(\gamma_i^{k,\text{land}}\right)^{\kappa_i^k} \left(w_i^{\text{land}}\right)^{1-\kappa_i^k} + \left(\gamma_i^{k,\text{labor}}\right)^{\kappa_i^k} \left(w_i^{\text{labor}}\right)^{1-\kappa_i^k} + \left(\gamma_i^{k,\text{input}}\right)^{\kappa_i^k} \left(w_i^{k,\text{input}}\right)^{1-\kappa_i^k} \right]^{1/(1-\kappa_i^k)}, \tag{13}$$

where the $\gamma_i^{k,\text{x}} \geq 0$ are productivity shifters, w_i^{labor} is the return to labor, assumed to be perfectly mobile between sectors, w_i^{land} is the return to land, $w_i^{k,\text{input}}$ is the price of intermediate inputs, and $\kappa_i^k \in (0,\infty)$ is the elasticity of substitution between factors and material inputs. $z_i^k(\nu)$ characterizes the efficiency in producing the variety ν of crop k in country i and follows a Fréchet distribution with a shape parameter $\varkappa^k > 0$, with $\varkappa^k > \varepsilon^k - 1$, and a scale parameter $\bar{\Gamma}^k \mathcal{Z}_i^k \geq 0$, where $\bar{\Gamma}^k \equiv [\Gamma(1 + (1-\varepsilon^k)/\varkappa^k)]^{1/(1-\varepsilon^k)}$ is a scaling parameter and $\Gamma(\cdot)$ is the Gamma function.[16] $\mathcal{Z}_i^k$ determines how productive country i is in producing all varieties of crop k, while $\varkappa^k$ is common across countries and determines the variance of productivities.

It is common to account also for the fact that land is heterogeneous within a country in its productivity for growing crop k, thus limiting the extent to which land can be reallocated across crops. It is not strictly necessary to introduce it here, so we rely on a simpler assumption of perfect factor mobility within country. See the discussion in Costinot et al. (2016), Farrokhi and Pellegrina (2021), Hertel (2002), and Sotelo (2020) for various approaches to this question.

[15] The distinction between gains from trade under certainty and uncertainty in a comparative advantage context is borrowed from Donaldson (2019).

[16] The cumulative distribution function of a Fréchet distribution with shape parameter $\varkappa > 0$ and scale parameter $s > 0$ is given by $\Pr(X \leq x) = \exp(-(x/s)^{-\varkappa})$ if $x > 0$.

In this section, we assume perfect competition, so a trader will source its imports from the cheapest exporter, leading prices of a variety to obey

$$p_j^k(\nu) = \min_i \left\{ p_{ij}^k(\nu) \right\}, \tag{14}$$

where, in the absence of markups and quality differences, the price of a variety is given by the product of the unit cost and the trade cost, $p_{ij}^k(\nu) = c_i^k \tau_{ij}^k / z_i^k(\nu)$. The key methodological innovation in the modeling approach in Eaton and Kortum (2002) is to use the properties of the extreme value distributions to render tractable equation (14). Since z_i^k is Fréchet distributed, this implies that $c_i^k \tau_{ij}^k / z_i^k(\nu)$ is Weibull distributed with shape $\varkappa^k$ and scale $c_i^k \tau_{ij}^k / \bar{\Gamma}^k \mathcal{Z}_i^k$. The properties of the Weibull distribution imply that the probability that country i provides the lowest price of variety ν of product k is

$$\lambda_{ij}^k = \frac{\left(c_i^k \tau_{ij}^k / \mathcal{Z}_i^k\right)^{-\varkappa^k}}{\sum_n \left(c_n^k \tau_{nj}^k / \mathcal{Z}_n^k\right)^{-\varkappa^k}}. \tag{15}$$

where we assumed that $\xi_{ij}^k(\nu) = \xi^k$. Since all varieties of a product share the same production function and the same probability distribution for z_i^k, λ_{ij}^k also corresponds to the budget share of imports in j coming from i. It is simple to relate equation (15) to the gravity equations (8) and (9): the properties of extreme-value distributions allow us to derive the price index of imports, $(P_j^k)^{-\varkappa^k} \equiv \sum_n (c_n^k \tau_{nj}^k / \mathcal{Z}_n^k)^{-\varkappa^k}$, and the Z_{ij}^k follows: $Z_{ij}^k = \mathcal{Z}_i^k (\lambda_{ij}^k)^{1/(\varepsilon^k - 1) - 1/\varkappa^k}$. So this model presents a standard gravity equation with $\varkappa^k$ playing the role of the trade elasticity. The equivalence between the trade elasticity and the shape of the heterogeneity of firms' productivity is leveraged in many studies due to the ease to estimate the former using only information on aggregate trade flows.[17]

The modeling trick proposed by Eaton and Kortum (2002) of using an extreme-value distribution to obtain tractable solutions for a maximization with a finite number of alternatives is now ubiquitous in the literature and is used for other contexts than the representation of trade. In the papers referred to in this chapter, it is used also to represent crop choice (Costinot et al., 2016), technology choice (Aggarwal et al., 2018), and household location choice (Conte et al., 2021).

One of the problems involved in empirically validating comparative advantage models such as this is lack of observability of the potential productivity of sectors that do not produce in equilibrium. However, as shown by stylized fact #4 the agricultural sector is specific in this respect: thanks to the agronomists crop models, we have estimates of potential productivity even for land that is not cultivated. Using the GAEZ project estimates, Costinot and Donaldson (2012) propose a simple test of Ricardian theory based on confirming whether the log crop output predicted at country level by a simple linear programming model (a simplified version of the above model with land as the only input and an infinite trade elasticity) based only on observed prices and potential yield, is similar to the log observed crop output. The estimated slope coefficient is 0.21. Given the simplicity of the framework which ignores many other determinants of crop production that we will study in what follows, this is a remarkable confirmation that Ricardo's theory of comparative advantage is relevant to explain today's global crop allocation.

4.2 Gains from trade under certainty

Most of the results presented in this section have been obtained using the so-called "New Quantitative Trade Models", built using the elements described above (for more on these models see Costinot and Rodríguez-Clare, 2014). Except for the Eaton-Kortum specification replacing often the Armington assumption, these models have very similar structure as the earlier computable general equilibrium (CGE) models applied to this sector (Hertel, 2002). The differences between these strands of literature are less related to the elementary building blocks and the solution methods, which are common, and more to the model applications and model development philosophy. A New Quantitative Trade Model is generally built for one purpose and used in one paper, which promotes parsimony, while CGE models are generally built

[17] However, Simonovska and Waugh (2014) show that neglecting disaggregate information is likely to bias the trade elasticity estimates.

for repeated uses in policy settings, where more emphasis will be on modeling many details of policies and specific markets.

4.2.1 Specialization

The gains from trade tend to be studied in settings that include several countries and trade between countries but this poses important empirical challenges due to limited information on the changes to international trade costs and the fact that these costs can change for political reasons. Working with domestic trade costs removes some of these problems. In addition, analyzing a situation where domestic trade costs decrease from very high levels provide the rare opportunity to observe a textbook-like evolution from autarky to integrated market (see also Donaldson, 2019, on this). There is a strand of work which studies the outcome of domestic trade cost reductions. It tends to focus on agriculture because the periods of strong reductions in domestic trade costs are often periods when economies were still mostly agrarian.

A groundbreaking paper in this literature is Donaldson's (2018) "Railroads of the Raj". He studies the benefits derived from the development of railroads in colonial India using a simpler model than the one presented above: the various regions in the model are assumed to be India's regions, land is the only productive factor, there are no intermediate inputs, and agricultural products are the only goods. Under these assumptions, after simplifying equation (10), welfare in period t takes a simple form:

$$\ln V_{jt} = \Xi + \sum_{k=1}^{K} \beta_j^k \ln \mathcal{Z}_{it}^k - \sum_{k=1}^{K} \frac{\beta_j^k}{\varkappa_k} \ln \lambda_{jjt}^k, \tag{16}$$

where Ξ is a constant. This equation shows that the trade share, λ_{jjt}^k, is a sufficient statistic for welfare in the sense that the effect of access to the railroad network should be captured by this variable. This equation allows to a linking between the annual data and the Ricardian model. Welfare in the data corresponds to real income (i.e., the value of agricultural production divided by the price index), the trade share of a district to itself is obtained from the Ricardian model prediction estimated using its gravity structure, and the productivity can be approximated by rainfall. Donaldson (2018) shows that a district real income, corrected for rainfall, is increased by access to a railroad. However, this positive effect is halved if the predicted trade share is included as a control. This result demonstrates that the gains from domestic trade in agricultural products are in large part consistent with the mechanisms of the Ricardian model: lower trade costs enabled India's districts to exploit their Ricardian comparative advantage.

A simple Ricardian model also provides important insights into the role of trade costs in determining the value of land as Donaldson and Hornbeck (2016) demonstrate using a model of agricultural trade among US counties. This work is also informative about welfare effects because in their setting with fixed utility, welfare impacts are capitalized into land values. Compared to the above model, they assume one aggregate agricultural sector, a Cobb-Douglas technology, perfect labor mobility between counties, and perfect capital mobility (but no intermediate inputs). Using this model, they find a sufficient statistic expression of the log of the land rental rate: it is a function of the land productivity and a measure of market access which is negatively related to the price index P_j^k. The price index summarizes market access because it combines the prices of the trading partners and the associated distance to trade with them. It accounts also for the network effect of trade: the lowering of trade costs between partners will be reflected in the price index. Using this theoretical insight, Donaldson and Hornbeck (2016) regress the log value of agricultural land on a measure of market access which accounts for the fall in transport costs allowed by the expansion of the railroad network in the late 18^{th} century. They find that increased market access increases the value of land to the extent that removing all railroads in 1890 would have decreased the total value of US agricultural land by 60%.

Another approach to analyze the gains from economic integration and to compare them to the benefits from productivity gains is the backcasting exercise proposed by Costinot and Donaldson (2016). They use a linear programming model of US agriculture (a simple Ricardian model between US counties with land as the only factor of production and an infinite trade elasticity) to recover historical prices (and thus trade costs) and productivity shifters from 1880 to 1997. This exercise rests on the key insight that with a few assumptions the production possibility frontier is observable in agriculture at one point in time thanks to the crop potential yields simulated by agronomists (see stylized fact #4). Provided that the pattern of comparative advantage does not change between the pixels within a county, it is possible to use the model optimality conditions combined with observations of the value of agricultural output, the quantity produced, and the corresponding acreages to recover the prices and productivity shifters. Using this model and recovered information, Costinot and Donaldson (2016) simulate two counterfactual scenarios: the first removes the observed reductions in domestic transport costs between counties and the second removes the observed increases in crop productivity. They find that the reductions in transport costs led to a 1.5% annual growth rate in real output between 1880 and 1920 and a 1% growth rate between 1954 and 1997. The effect of the productivity increases is similar to that of transport costs reductions. These results show that in agriculture the historical gains from specialization allowed by better trade integration are very important and commensurate with the gains from improved productivity.[18]

Historical evidence on episodes of trade costs reductions show that trade costs are crucial determinants of the gains from trade in agriculture, crop specialization, and the value of land.[19] Given these results, it is natural to wonder how much gain could be expected in countries where trade costs are still sizable. For example, Porteous (2019) documents that trade costs between Sub-Saharan African markets are five times higher than international benchmarks (similar figures are found in Atkin and Donaldson, 2015). To address this question requires trade models representing the current market situation in order to conduct counterfactual simulations. Several papers develop such models (more are discussed below in relation to inputs use) and confirm the importance of the overall gains from agricultural trade from lowering the trade costs but show also that such a shock could have distributional effects: winners and losers across regions and across groups (farmers and non-farmers). Porteous (2019, 2020) and Sotelo (2020) highlight two key mechanisms determining the distributional effects: first, the baseline specialization pattern, whether the region is a net seller or a net buyer of crops, and second, the price effect of the shock on these crops, i.e., the terms of trade effect. Porteous (2019, 2020) shows that in Sub-Saharan Africa, where most markets are net-importers, the dominant effect of lower trade costs is a reduction in the output price, so farmers tend to lose from lower trade costs but overall the gains from lower food prices and higher consumption of the outside good dominate the welfare effects and only a small number of regions experience welfare losses. In the case of Peru, Sotelo (2020) shows that the welfare losses from a policy to pave all roads affect more than 20% of farmers concentrated in already well connected net-exporting regions where lower trade costs would lead to increased competition.[20]

The papers discussed so far in this section are all concerned with gains from domestic trade in settings with large domestic trade costs. Few papers analyze gains from international trade focusing on agricultural products. Reimer and Li (2010) adapt Eaton and Kortum's (2002) approach to the crop sector and find modest gains from trade (0.6% of GDP for the median country). These small gains could be explained by trade costs which tend to be higher for agricultural than for manufacturing products, explaining also the relatively low trade intensity of agricultural products (see stylized facts #1 and 2 and Xu, 2014). Another explanation for these low gains is the combination of the low share of agricultural and food products in consumers' budgets combined with the modeling framework (in Table 4.1, Costinot and Rodríguez-Clare, 2014, show that in a one sector model the gains from trade are modest).

Considering multiple crops instead of one aggregate agricultural sector is a first step to avoid aggregation bias and leads to higher gains (Farrokhi and Pellegrina, 2021). This acknowledges that the agricultural sector is heterogeneous which opens important opportunities for specialization. A second step could be acknowledging the specificities of this sector. Although Fally and Sayre (2018) do not provide numbers on the gains from trade associated with trade in agricultural products, their work provides insights into why they could be much higher than predicted by a simple neo-Ricardian model which does not account for sector characteristics. Agricultural goods and commodities are special: their production requires a fixed factor, land in the case of agriculture, with very heterogeneous spatial endowments whose quality also differs. Their demand is also quite inelastic because of their role in human nutrition. Hence, for

[18] See also Herrendorf et al. (2012) on the role of the reduction in transportation costs in sector specialization within the US.

[19] In addition to studies based on estimated trade models already mentioned, historical episodes of lower trade costs in rural contexts have been studied using program evaluation techniques (e.g., Asher and Novosad, 2020; Shamdasani, 2021).

[20] See also Pellegrina (forthcoming) for the distributive effects of demand and supply shocks on agriculture in Brazil.

many agricultural products, production is concentrated in a few countries but consumption is global (e.g., cocoa, coffee, soybeans). According to Fally and Sayre (2018), this combination of limited demand and supply reactions implies much larger gains from trade attributable to commodities than in a standard setup.

4.2.2 Inputs use

Another source of gains from trade in agriculture is the interaction with the non-agricultural sector through the use of inputs and their productivity-enhancing effects. Costinot and Rodríguez-Clare (2014) show that in modern trade models, based on comparative advantage or imperfect competition, accounting for (compared to neglecting) input-output relationships magnifies the gains from trade. Modern agriculture relies hugely on inputs (modern seeds, machinery, fertilizer, pesticides, fuel, livestock feed, etc.), and many of them are involved in significant domestic and international trade.

In order to illustrate the size of the gains from trade in the presence of traded inputs, we simplify unit costs in the agricultural sector as: $c_j^A = (w_j^{\text{land}})^{\gamma_j^{A,\text{land}}} (w_j^{\text{labor}})^{\gamma_j^{A,\text{labor}}} (P_j^F)^{\gamma_j^{A,F}} (P_j^A)^{\gamma_j^{A,A}} (P_j^O)^{\gamma_j^{A,O}}$. Agricultural production combines land, labor, and intermediate inputs with constant shares. Intermediates comprise the full set of agricultural and processed food products, combined according to the CES aggregator (4), and the aggregate outside good (corresponding to, e.g., fertilizers and pesticides). We assume that $P_j^O = (\lambda_{jj}^O)^{1/(\varepsilon^O-1)} w_j^{\text{labor}}$ and $P_j^F = (\lambda_{jj}^F)^{1/(\varepsilon^F-1)} w_j^{\text{labor}}$, which implies that each product of the aggregate outside good and the food good is aggregated through a specific CES aggregator and is produced under perfect competition by homogeneous firms using only labor (we relax these assumptions for food products in section 5).

Under these assumptions, we can compute the cost of food autarky (see our online Appendix for details). If imports of inputs supplied by agricultural and non-agricultural sectors and used by farmers cease ($\hat{\lambda}_{jj}^k = 1/\lambda_{jj}^k$ with $k = A, F, O$), the welfare change equation (10) associated with a move to food autarky becomes

$$\ln \hat{V}_j = -\frac{\beta_j^A \left(1 + \tilde{\gamma}_j^{A,A}\right)}{\varkappa^A} \ln \hat{\lambda}_{jj}^A - \frac{\beta_j^F + \beta_j^A \tilde{\gamma}_j^{A,F}}{\varepsilon^F - 1} \ln \hat{\lambda}_{jj}^F - \frac{\beta_j^A \tilde{\gamma}_j^{A,O}}{\varepsilon^O - 1} \ln \hat{\lambda}_{jj}^O + \ln g\left(\hat{\omega}_j\right), \tag{17}$$

where $\tilde{\gamma}_j^{A,\text{land}} \equiv \gamma_j^{A,\text{land}}/(1-\gamma_j^{A,A})$, $\tilde{\gamma}_j^{A,F} \equiv \gamma_j^{A,F}/(1-\gamma_j^{A,A})$, $\tilde{\gamma}_j^{A,O} \equiv \gamma_j^{A,O}/(1-\gamma_j^{A,A})$, and $g(\hat{\omega}_j) \equiv [\hat{\omega}_j s_j + (1-s_j)](\hat{\omega}_j)^{-\beta_j^A \tilde{\gamma}_j^{A,\text{land}}}$ captures the welfare consequences associated with the change in relative prices of factors $\hat{\omega}_j \equiv \hat{w}_j^{\text{land}}/\hat{w}_j^{\text{labor}}$, with s_j the share of land income in the total income in country j. As we consider more than one factor of production, the welfare formula now depends also on intermediate inputs cost shares. More trade in intermediates used in agricultural production (lower λ_{jj}^k with $k = A, F, O$) leads to a decline in the price index of agricultural products, which implies additional welfare gains. In addition, given import shares, trade gains are greater the larger the share of intermediates ($\gamma_j^{A,A}$, $\gamma_j^{A,F}$ and, $\gamma_j^{A,O}$). As a consequence, the introduction of tradable inputs magnifies the gains from trade

Using the factor market clearing conditions, one can quantify $\hat{\omega}_j$. If France moved to food autarky (${\lambda_{jj}^k}' = 1$), real income would decline by 1.42%, equivalent to a decrease in per household annual income of €623.[21] Hence, predicted costs from food autarky are 50% higher than those predicted by the trade models without vertical linkages.

Farrokhi and Pellegrina (2021) and McArthur and McCord (2017) provide interesting evidence on the importance of trade in agricultural inputs. Farrokhi and Pellegrina (2021) document that a large share of agricultural inputs is imported (65% of fertilizers, machinery, and pesticides). McArthur and McCord (2017) note that the production of ammonia requires important fixed costs, so fertilizer production sites are limited in number. Synthetic fertilizers must be shipped to each farmer using them, and the distance between the production site and the farms matters when determining the costs of fertilization. The authors use this insight to instrument fertilizer use by distance from the

[21] According to the French national account in 2018, $\gamma_j^{A,A}$ is 0.19, $\gamma_j^{A,F}$ is 0.09, and $\gamma_j^{A,O}$ is 0.29. Our calculations show that the relative price of land should increase by 1.1%, but $g(\hat{\omega}_j) \approx 1$ so that the welfare effects of relative price adjustments are negligible. Note also that $\hat{\mathcal{Z}}_i^A$ are assumed to be equal to one.

fertilizer plant, confirming that this distance increases the farmer's fertilizer costs and decreases its use and the farmer's yields. This decreasing relationship between transport costs and inputs is confirmed, inter alia, in Aggarwal et al. (2018) and Porteous (2020) in the context of Sub-Saharan Africa.[22]

Following the literature referred to in the previous section, most papers studying the role of trade costs in inputs use are based on a developing country context where high transport costs are an impediment to their wider use. For example, Adamopoulos (2020), Aggarwal et al. (2018), Porteous (2020), and Sotelo (2020) build quantitative trade models featuring traded inputs to analyze the counterfactual effects of lower domestic trade costs (mixing the domestic and international trade costs in the case of Porteous, 2020). However, they do not distinguish the effects of these lower costs on specialization and inputs use. To our knowledge, the only paper to decompose the gains from trade between specialization and inputs use, and to study the question in a global context is Farrokhi and Pellegrina (2021). They use a quantitative trade model to study the effects of the 1980–2017 globalization (i.e., lower international trade costs) on input availability and agricultural productivity and distinguish between the effects of lower trade costs on input choice and on crop choice. Their results show that increasing trade costs in agriculture to their 1980 values would decrease welfare by 2.4%, and increasing trade costs just for agricultural inputs would decrease welfare by 1%. Farrokhi and Pellegrina's results show that the gains from trade in agricultural inputs is comparable with the gains from trade associated to standard comparative advantage related to crop specialization.

In addition to the work done from a trade perspective, the question of inputs use has received great attention in the development literature. The experimental development literature identifies other important barriers to modern inputs adoption in addition to trade costs, relating to credit, insurance, and information (Magruder, 2018). However, there are major differences between this stream of work and the trade literature. Works analyzing local policy interventions identify how those interventions affect farmers' adoption of inputs but tend to overlook market feedbacks were the policies to be scaled up. On the other hand, the trade literature tends to rely on a combination of functional form assumptions and structural estimations to focus on the market effects of a counterfactual shock. Bergquist et al. (2019) try to close the gap between these approaches. The results from a local intervention could be used to calibrate the reaction of a general equilibrium model at constant prices which then could be used to analyze a scaled-up intervention. They apply this idea in a single-country model for Uganda, accounting for domestic trade. They show that the policy's implications differ with scale: regressive for a local intervention but more evenly distributed at scale after accounting for price effects. This paper confirms the importance of accounting for general equilibrium effects and domestic trade costs when studying inputs use, even in cases where the intervention is not related to those trade costs.

When discussing inputs use and their benefits in agriculture, there are several limits to the use of conventional functional forms such as presented in section 4.1. One is that instead of a CES, it is more common to simplify the production function to a Cobb-Douglas. Given the share of inputs in production costs (depending on the level of development, from 25% for the 1st quartile of per capita GDP to 60% for the 4th quartile according to Farrokhi and Pellegrina, 2021, Figure 2), this choice results in very high supply elasticities from the possibility to intensify production, which is at odds with most of the estimates in the agricultural economics literature (Keeney and Hertel, 2009).[23] Inappropriate yield elasticities will lead to misleading values for the welfare gains of trade in intermediate inputs.[24] In the CGE literature, this problem is usually dealt with by using nested CES functions. However, two other solutions have been proposed. To deal with the problem that the cost share of inputs is not constant across levels of development, Aggarwal et al. (2018) and Farrokhi and Pellegrina (2021) introduce two different production techniques: either traditional with no inputs or modern with intensive input use. This modeling relies on the Fréchet distribution central to the Eaton and Kortum's model, and allows countries to transition from one technology to another with the evolution of input prices (see also Bergquist et al., 2019, for a similar approach). Porteous (2020) proposes another

[22]Other work on the effects of trade costs on agricultural inputs use include Aggarwal (2018), Brooks and Donovan (2020), Ferguson and Olfert (2016), Minten et al. (2013), and Shamdasani (2021).

[23]Neglecting composition effects from land-use change, the yield elasticity from intermediate inputs is $\kappa_i^k\left(1/s_i^{k,\text{inputs}}-1\right)$, with $s_i^{k,\text{inputs}}$ the cost share of inputs. Thus, with a Cobb-Douglas, the yield elasticity is 3 for $s_i^{k,\text{inputs}}=0.25$ and 2/3 for $s_i^{k,\text{inputs}}=0.6$.

[24]Yield elasticities are at the center also of the debate on the effects of biofuels policies (Keeney and Hertel, 2009).

approach to account for non-marginal changes in fertilizer use in Sub-Saharan African countries: substituting the CES function by a quadratic yield response function (restricted to the upward-sloping region) estimated on experimental data. This choice solves the problem that the CES may approximate well a production function locally but may not be adequate to represent larger technological changes. This discussion highlights that an adequate modeling of intermediate inputs may be crucial when evaluating non-marginal shocks as is typically the case in studies of gains from trade and large infrastructure projects.

4.2.3 Evolving comparative advantage because of climate change

An important application of the role of comparative advantage in agricultural trade is climate change. Agriculture is one of the sectors most heavily impacted by climate change but this impact can differ widely between and within countries. Northern regions with historically cold temperatures and short growing seasons may benefit from warming in the form of higher yields from some crops. Tropical regions that experience extreme temperatures may see reduced yields (see figure 3c for an illustration of regional and crop variations). Due to the heterogeneity of the impact, climate change affects comparative advantage and should induce changes in specializations at different levels: within and between countries, across crops, and between agriculture and non-agriculture. These changes to comparative advantage imply large changes in crop allocation across the world which to be consistent with market equilibrium will demand adjustments to trade flows. So trade flow adjustment may play a role in reducing the direct burden of climate change by allowing regions benefiting relatively from climate change to supply regions negatively affected.

To address climate change questions in agriculture from a global perspective requires combining predictions of the yield impacts of climate change with an economic model predicting the future allocation of supply, demand, and trade. Work on this began in the early 1990s with partial equilibrium (Reilly and Hohmann, 1993) and general equilibrium models (Darwin et al., 1995; Randhir and Hertel, 2000; Rosenzweig and Parry, 1994; Tsigas et al., 1997). While many of these works emphasize the role of international trade to justify use of global economy models, they do not specifically analyze its role. Randhir and Hertel (2000) is an exception. They analyze the role of international trade in adaptations to climate change, and reach the counterintuitive conclusion that the adjustments facilitated by international trade could have detrimental welfare effects. This result illustrates potential outcomes in a second-best world. Climate change leads to increase production in developed countries with contemporaneous high level of distortionary agricultural support; therefore, it aggravates preexisting distortions. Limiting trade adjustments would limit this increase in distortions and improve global welfare. While this is a valid point, agricultural policies empirically tend to evolve with comparative advantages and market conditions (Anderson et al., 2013), and thus, are unlikely to stay the same with climate change. This makes difficult interpreting counterfactual simulation involving constant agricultural policies but very different comparative advantages.

With the exception of Darwin et al. (1995), these early works on international trade and climate change rely on models which assume that land is uniform within countries with respect to exposure to climate change, and neglect the role of within-country heterogeneity of climate change effects for opening new adaptation possibilities. Therefore, they overstate the cost of climate change.

Since these early works, the within-country heterogeneity of land and its interaction with climate change in a global setting have received a lot of interest in research using either gridded information or different land classes based on agroecological zones frameworks (e.g., see Costinot et al., 2016; Gouel and Laborde, 2021; Leclère et al., 2014; Nelson et al., 2014). Among these contributions, Costinot et al. (2016) was the first paper to show how the rich spatially-explicit information on potential crop yields generated by crop scientists could be used in a standard gravity trade model. This innovation allowed them also to assess the adaptive role of within- and between-country adjustments arising from changes in comparative advantage within and between countries. Their approach builds on Eaton and Kortum's (2002) modeling of trade flows using extreme value distributions. Fields (5-arcminute pixels) are assumed to be composed of heterogeneous parcels of land with crop potential yields drawn from Fréchet distributions. This assumption involves decreasing returns to specialization in one crop which implies incomplete specialization in each field and allows a simple mapping with biophysical data.

These various models have been used to analyze the economic consequences of climate change in agriculture and to assess the role of some adaptation margins such as crop and trade reallocations. One of the challenges related to this question and to the comparison of the findings from the various papers on this topic is choosing the counterfactual situation under which the trade adjustments are limited. It is not possible to fix trade flows at their values under the current climate, given that this situation would be unlikely to be compatible with a market equilibrium. Therefore, it is necessary to propose a scenario where trade adjustments are constrained to be lower than they would be otherwise while still compatible with market equilibrium. Trade adjusts in various ways, so there are various legitimate counterfactual exercises that can be used to capture the role of trade adjustments. For example, Costinot et al. (2016) fix for each crop the share of its domestic production which the country exports to its value under the current climate. They find a negligible role of trade in adaptation to climate change but a very important role of crop reallocation with global welfare losses which would almost triple were this reallocation prevented. Using a model with a broader crop and country coverage and a different calibration, Gouel and Laborde (2021) confirm that this export adjustment margin plays a negligible role but they consider another counterfactual where bilateral import shares are fixed to their values under the current climate (the same counterfactual is used in Randhir and Hertel, 2000, but with the assumption of a fixity of the shares in volume). Under this counterfactual, welfare losses increase significantly, although less than if crop reallocation is prevented, showing that the international reallocation of demand and supply allowed by international trade is an important adaptation margin. Since climate change has heterogeneous effects across countries, an important adjustment pathway of trade is through reallocation between import sources, which is not prevented by fixing the total export shares as in Costinot et al. (2016).

Another way to analyze the role of international trade in relation to climate change is to consider the counterfactual evolution of the terms of trade. Abstracting from distortions and from endogenous factor supply, the effect of climate change on welfare can be decomposed into two terms (Gouel and Laborde, 2021): the direct effects of the productivity shock, and the terms-of-trade effects which sum to zero at the world level. Baldos et al. (2019) and Gouel and Laborde (2021) show that the terms-of-trade effects are important and can reverse the sign of the direct effects related to yield changes. Because total food demand is quite inelastic, an average decrease in crop productivity will increase food prices substantially. So despite lower yields some net-food-exporting regions may benefit from climate change by receiving higher prices. The burden of adjustment to climate change then falls on net-food-importing regions. Through the changes in trade prices, climate change may generate large transfers between countries.

In addition, these terms-of-trade effects are related to the geography of the climate change shock. Baldos et al. (2019) show that were the climate shock uniform across the world, then the strength of the terms-of-trade effects would half. Dingel et al. (2019) also investigate the role of the spatial distribution of the shock in their analysis of the effects of climate change. Currently-poor countries are particularly exposed to the effect of climate change in agriculture: the share of agriculture in their GDP is high, so they are particularly vulnerable to shocks to this sector, and because many of them are located in the tropics, they are more exposed to climate change than countries with temperate climates where higher temperatures could even increase yields. There is an additional aggravating factor: trade costs imply that countries have more trade relationships with countries which are proximate compared to distant countries. Since the effects of climate change tend to be spatially correlated, a country with lower yields under climate change is likely to be located close to countries similarly affected which will reduce the potential adaptive role of international trade compared to a situation where the shock is not spatially correlated.

Other papers consider the effect not on welfare but on food security. Baldos and Hertel (2015) and Janssens et al. (2020) analyze the role of trade in reducing the occurrence of malnutrition. Baldos and Hertel (2015) compare a benchmark situation relying on segmented markets following the Armington assumption with an integrated world market which allows assessment of the maximal contribution of trade were all barriers to trade to be removed. Janssens et al. (2020) impose an upper bound on agricultural imports which cannot exceed their values without climate change. This counterfactual focuses on the role that trade could play in net-food-importing countries were climate change to worsen their production potential. Both papers find that under the more flexible trade assumption, the increased malnutrition caused by climate change is greatly mitigated which highlights the significant role of trade in reducing global hunger under climate change.

A limitation of most of these papers is that they consider only changes in comparative advantage occurring within the agricultural sector, between crops, and so assume that climate change has no effect on the productivity of the other sectors. This necessarily applies to papers using partial equilibrium models of the agricultural sector but applies also to papers relying on general equilibrium models (e.g., Baldos et al., 2019; Costinot et al., 2016; Darwin et al., 1995). This might matter for the overall allocation of resources between agriculture and non-agriculture if the changes in relative productivity are sizable. A few studies are providing promising results on this issue (Conte, 2021; Conte et al., 2021; Desmet and Rossi-Hansberg, 2015; Nath, 2020).

Nath (2020) studies this question using a structural transformation framework and points out that in many countries, climate change will take place amid already strong tensions between food problem and comparative advantage (see also section 4.4). Climate change will affect productivity in both agriculture and non-agriculture sectors, but Nath provides evidence of lower effects on non-agriculture in currently hot countries. This would call for a shift in specialization in tropical countries away from agriculture. However, the opposite situation could occur: because of subsistence food requirements, agricultural specialization could increase despite worsening comparative advantage which would exacerbate welfare losses from climate change.[25]

Some of the papers discussed previously predict very strong welfare losses from climate change for several currently poor countries. These large losses suggest that it is important to account for migration when assessing the welfare effects of climate change.[26] Using quantitative spatial models, Desmet and Rossi-Hansberg (2015) define a location as a continuum defined only by its latitude, while Conte et al. (2021) study the world and Conte (2021) only Sub-Saharan Africa using 1-degree pixels. In their models, adaptation can take the form of sectoral specialization between agriculture and non-agriculture (and within agriculture in Conte, 2021), trade, and migration. In all three papers, the modeling of migration builds on Eaton and Kortum's (2002) modeling of trade flows: there are continuums of agents who have location preferences drawn from a Fréchet distribution. To analyze the role of these adaptation margins, the authors conduct counterfactual simulations varying migration and trade frictions around their benchmark values.[27] In these models, trade costs limit the extent of profitable sectoral adaptation leading people to migrate to more productive places. So, trade and migration are substitutes in adaptation.

4.3 Gains from trade under uncertainty

A specificity of agricultural commodities (common also to other commodities) is that their production and their price are much more volatile than those in other tradable sectors (Jacks et al., 2011). This high volatility implies that trade may also play a role in smoothing idiosyncratic shocks. Neglecting the gains from trade under certainty as discussed previously, identical countries could benefit from trade because of the stability in consumption it provides. Agricultural economists frequently use the observation that world cereal production is less volatile than that of most individual countries in order to emphasize the potential role of international trade in smoothing idiosyncratic shocks (e.g., Gouel, 2014, Table 7.2). However, this statistic says little about how much a market with trade costs can enable or hinder risk sharing. Some works have addressed this crucial issue by comparing periods with different levels of trade costs or analyzing how shocks are transmitted in the market. While the Eaton-Kortum model is based on productivity distributions, those distributions are integrated away in the analytical solution implying that the model does not present any aggregate risk. As a consequence, the works discussed below rely not on this model but on a variety of approaches.

At the world level one problem related to addressing this question is that periods of increased price volatility are often

[25]The prediction that climate change could prevent structural transformation out of agriculture is confirmed in Liu et al. (2021) in the Indian case. They show that higher temperatures lead to a reallocation of demand away from non-agricultural goods and services, inhibiting reallocation out of agriculture, especially in districts where liquidity constraints and migration costs are important.

[26]There is a rich climate-migration literature but it often neglects trade issues.

[27]Conte (2021) does not simulate a counterfactual with different migration or trade frictions but rather uses regressions to explain the heterogeneity of counterfactual results.

periods of increased barriers to trade in reaction to this price volatility (see section 6.3.1 for a discussion of the reaction of trade policies to price volatility). Thus, it is important to find episodes of trade barriers unrelated to commodity market events. To do this, Jacks et al. (2011) draw on three-century-long time series of commodity prices and show that during periods of war or autarkic regimes, i.e. when there are impediments to the smoothing of idiosyncratic shocks by international trade, commodity prices are significantly more volatile than during peace time. At the world level, another approach to measuring the role of trade with respect to mitigating the impact of production shocks is to compare the effects of these shocks to a theoretical benchmark. For many agricultural products, this is made possible by the fact that yield changes between two years can reasonably be assumed to be exogenous shocks. So, Ferguson and Gars (2020) use yield changes to instrument production changes where production appears in the RHS of a gravity equation. They show that exported quantities vary with production shocks, so in the case of a poor harvest a country downward adjusts its agricultural exports. However, at 0.5 the elasticity of trade flows to the produced quantity is significantly lower than 1 (the theoretical benchmark in a gravity model without trade costs), indicating that the global smoothing of shocks through trade is incomplete: a part of the idiosyncratic shocks is absorbed by the domestic economy, possibly through other mechanisms such as storage.

In the case of eighteenth-century China this role of storage is confirmed by Shiue (2002) who shows that the smoothing of production shocks by trade was much more important in the prefectures with good river access, while inland prefectures relied more on inter-annual storage.[28] Because of the interactions with storage, the reduction in uncertainty allowed by trade can also have beneficial effects on agricultural productivity. Brooks and Donovan (2020) note that in rural villages with limited financial access, storage and expenditure on intermediate inputs compete for resources. So a reduction in trade costs (in their case the construction of a bridge allowing access to the outside labor market at the wet season) which reduces the need for storage liberates resources for investment and increases productivity.

Because of the difficulties related to identifying episodes with higher trade costs unrelated to commodity events at the world level, one solution is to exploit the national level as do several papers on the gains from trade under certainty. Building on the data on railroads in colonial India in Donaldson (2018), Burgess and Donaldson (2010) show that the relation between famine severity and rainfall shortage is reduced by the connection of the affected district to the railroad network.

These papers show that although trade may not achieve a perfect smoothing of idiosyncratic shocks, it reduces agricultural price volatility and the food security risk associated to localized harvest failures. However, price volatility is not related directly to welfare (famine is more likely to be). Since the above-mentioned literature on trade and uncertainty is econometric based and does not involve full-fledged trade models where uncertainty matters, it is silent about the interactions between trade openness, volatility, and welfare. However, these interactions can matter. As shown theoretically by Newbery and Stiglitz (1984), the price stabilization brought by trade could be detrimental to welfare. If markets for risk are missing, the variation in the domestic price in contrast to domestic production provides an insurance for risk-averse producers. So, by loosening the connection between prices and yield, trade may remove an implicit insurance mechanism.

Sorting out these various effects credibly, beyond the simple theoretical model of Newbery and Stiglitz, is a difficult endeavor. The difficulties include that risk-averse agents will base their allocations on the distribution (or at least the mean and variance) of returns which are themselves a function of the chosen allocations. In a standard trade model setup, this would involve costly numerical methods to solve for the rational expectations equilibrium of the problem. A workaround was proposed by Allen and Atkin (2016). Based on new theoretical foundations, they develop a general equilibrium Ricardian trade model with an analytical solution and approximate the risk-averse farmer problem as a mean-variance problem. Using this framework, they analyze 40 years of reduced intranational trade costs in India. They confirm that lower trade costs decrease the sensitivity of local prices to local production shocks but that lower trade costs increase farmers' revenue volatility if the farmer maintains a constant crop choice, which reduced the welfare gains

[28] Porteous's (2019) counterfactual simulations also demonstrate the substitution between storage and trade. Lower trade costs decrease price volatility and incentives to store.

from lower trade costs. If the farmer adjusts the crop choice to the new distribution of returns, this can mitigate almost completely the increase in the variance of the farmer's returns and he/she will benefit from even higher welfare gains.

4.4 Discussion

We next discuss three limitations of the works discussed previously: (i) those related to the gravity model, (ii) those related to the interactions between comparative advantage and the level of development, and (iii) those related to the endogeneity of tastes.

Limits of gravity

Apart for works on trade under uncertainty, the gravity model has been the dominant framework for comparative advantage analysis. This framework imposes several restrictions including the implication of constant trade elasticities. Several alternatives are explored in the trade literature (see Novy, 2013, for a demand-based and Bas et al., 2017, for a supply-based alternative). In the case of the agricultural sector, Heerman (2020) and Heerman et al. (2015) point to reasons specific to the structure of comparative advantage in this sector which are susceptible to generation of non-constant trade elasticities. Agricultural production is dependent on countries' respective ecologies, implying that countries with similar climate and soil endowments are more likely to be competitors because they are more likely to produce the same varieties. To account for this insight, Heerman and Heerman et al. develop Eaton-Kortum models which consider this heterogeneity in ecological endowments through a mixed CES approach[29] with non-trivial effects on trade and welfare. Because this approach allows to account for more heterogeneity between countries compared to a standard Eaton-Kortum model, it increases a lot the gains from trade in agriculture, at least four-fold for the considered countries (Heerman, 2020).

Comparative advantage and structural transformation

So far this section discusses works on the importance of domestic and international trade costs in determining agricultural specialization and the gains from trade in certain and uncertain settings. However, this overlooks an important determinant of agricultural specialization: the level of development. In poor countries, a large share of workers tends to be employed in agriculture, which is paradoxical since the relative productivity of agriculture compared to non-agriculture sectors is lower in poor countries compared to rich countries (Tombe, 2015).[30] This observation implies that the force of comparative advantage is counteracted by other forces related to structural transformation. For reasons of space, we do not review the stream of work on the interaction between comparative advantage and structural transformation but below we provide a discussion of some key mechanisms (see Barrett et al., forthcoming, and Dercon and Gollin, 2014, for more on this issue).

Tombe (2015) provides a model to explain the high level of agricultural specialization in developing countries despite the absence of apparent comparative advantage. This is a three-sector Eaton-Kortum model featuring non-homothetic demand (see section 3.4), which increases the budget share of food in poor countries; higher trade costs in poor countries especially in the agricultural sector, which contributes to explaining their low relative imports of agricultural products; and labor market distortions, which amplify the first two mechanisms explaining high agricultural specialization. Through the same mechanisms, the level of development also affects specialization within agricultural sectors: within the agricultural sector, developing countries tend to specialize excessively in staple crops with lower value-added per worker rather than cash crops. Rivera-Padilla (2020) explains this as due to the combination of the food problem modeled by Tombe (2015) and high domestic trade costs. Lower domestic trade costs would increase employment in

[29]See also Adão et al. (2017) for another use of mixed CES in trade.

[30]Gollin et al. (2014) use micro-data to confirm the productivity gap in the macro-data, and McCullough (2017) shows that it is explained to a large extent by the tendency to supply fewer hours to agriculture.

cash crops and would increase overall productivity. So an additional benefit of reducing trade costs is reducing the food problem which limits the expression of comparative advantage.

Comparative advantage and endogenous tastes

The works reviewed previously assume that tastes are given. However, tastes evolve with time and trade may play a role in their evolution. Globalization and international trade affect food intake through at least two channels: taste and price, with strong interactions between them which must be analyzed. Here we consider the question of the determination of food preferences and their evolution with the environment. This provides a strong link to the economics of trade and culture (Bisin and Verdier, 2014) where the interactions between cultural transmission and international trade are central.

One mechanism through which trade can affect taste is the idea that tastes evolve but have persistence, formalized as habits. The evolution of tastes may be based on what was consumed in the past, for example during childhood, which itself was determined by past tastes and prices. Aizenman and Brooks (2008) provide an illustration of this interaction between price and taste using the global wine and beer markets. They show that in 1963 grape production and latitude explained consumption of wine relative to beer. This applies much less in 2000: production and consumption have been partially decoupled due to globalization. However, despite some convergence consumption patterns remain different while relative prices have become closer. The authors rationalize this observation using a dynamic model of consumption with habits: past consumption of a variety defines a habit and creates a cost to deviate from this consumption level. This implies that two agents with different consumption histories would take time to converge to similar consumption patterns despite facing the same prices.

Building on a similar idea of tastes which evolve endogenously based on past consumption, Atkin (2013) goes further and shows how to estimate the evolution of tastes and analyze the welfare effects of such endogenous preferences in the context of an open economy. He formalizes tastes formation using an overlapping generations model where people learn to love the food (rice and wheat in the model) they were fed in childhood. Over the generations, under high trade costs conditions this implies development of preferences for food products adapted to local agro-climatic conditions since they imply lower prices for these products. So local tastes are biased toward the comparative advantages of the food. This bias has strong implications for evaluating the gains from trade. Tastes toward comparative-advantaged food erode the caloric gains from trade liberalization because it implies higher prices for the preferred food, with nutritional costs for poor households. Atkin (2013) estimates food tastes in a survey of Indian households as a component of the AIDS food budget shares which cannot be explained by prices, total food expenditure, or demographic and seasonal controls, and shows that they can be explained by relative resources endowments.[31] Using the estimated demand system, he conducts counterfactual simulations of price equalization across India and confirms a reduction in the caloric gains from trade caused by taste for the comparative advantage food.

The body of work reviewed here illustrates that some of the conclusions related to the gains from trade in food products should be qualified after considering the indirect effects of trade on nutrition, particularly in relation to the assumption of exogenous preferences for these products.

5 Firm-level analysis

The developments in trade theory from the 2000s emphasize that it is individual firms not countries that are involved in exporting and importing. 1980s and 1990s trade theory aimed at explaining intra-industry trade among similar countries (one of the most important trends in world trade at the end of the 20$^{\text{th}}$ century) and its implications for welfare and income distribution. Studies analyzing this international trade pattern are based on models initiated by Nobel prize-winner Paul Krugman in which fixed production costs and taste for different varieties are the key parameters.

[31] See also Colson-Sihra et al. (2020) for an application of the same estimation of taste preferences to analyze the homogenization of tastes within France over time and the contribution of cultural integration to this process.

However, this literature builds on a workhorse model where all firms export to all destinations. This runs counter to the observation that only a fraction of the firms in developed and developing economies are involved in international trade (Bernard et al., 2007). Only 12% of US food manufacturing firms export. In France, 31% of firms in the food industry were involved in exporting in 2017 (see table 1). Also, table 1 reports that exporting firms located in France with 500 or more employees represent 3% of exporters and account for 54% of the value of food exports (while accounting for only around 35% of French firms' domestic market sales). Furthermore, large exporters (more than 500 employees) on average serve more destinations than smaller exporters. Melitz (2003) provided the first convincing explanation for the so-called "zero" problem and the high concentration of exports in a few firms by positing that the productive capacities of firms are heterogeneous and that only firms that are productive enough can overcome fixed export costs.

Table 1: French food firms

Firm size class (employees) (1)	# of firms (2)	# of exporters (3)	Exports distribution (4)	Average # of destinations (5)	Labor cost share (%) (6)	Material inputs share (%) (7)
1 to 49	9,165	2,353	9.9%	4	25	35
50 to 249	969	717	24.9%	16	18	36
250 to 499	162	138	11.4%	16	18	49
500 or more	121	112	53.8%	33	16	46
Total	10,417	3,320	€36 bn			

Source: Own calculations based on BRN (Bénéfices réels normaux) firm data compiled by the French Statistical Institute which provides annual firm balance-sheet data (total sales, export sales, labor cost, intermediate consumption, etc.) and French customs data which provide export data by firm, destination country and year. The share of labor cost (resp. material inputs) is the sum of the wages paid to all employees and the cost of employee benefits and payroll taxes (resp. total intermediate consumption) paid by the firm relative to its variable costs.

Modern approaches of international trade based on sunk costs, product differentiation, and firm heterogeneity prompted the emergence of a new research agenda which is particularly relevant to the food industry (Gaigné et al., 2015; Gopinath et al., 2007; Sexton, 2013). As highlighted in Sexton (2013), food markets are no longer characterized by firms selling homogeneous products under perfect competition. In contrast, the applicability of new trade models to primary agriculture is not clear since most farms operate as price takers and do not export directly (when they choose their level of production farmers do not know whether or not their products will be exported). Primary products can be considered homogeneous but many processed products are not (Gopinath et al., 2007). In addition, the literature focusing on firm behaviors sheds light on key microeconomic determinants of export performance linked to industry strategies (e.g., choice of products, quality choice, degree of vertical integration). Firm/plant level databases are rich and allow investigation of the impact of firm characteristics (productivity, size, exports, imports, prices, etc.) and their export sales strategies for each destination. For a given macroeconomic context, export performance can differ greatly across firms. However, international comparisons are limited since few countries offer the same level of information on their companies.[32]

In what follows, we provide an overview of developments in this direction. We focus on the role of the prices set by firms and their components as well as the quality of the products on trade margins: the number of firms (the extensive margin) and export sales per firm (the intensive margin).

[32]Nevertheless, some trade databases aim to fill this gap and contain data about trade in goods broken down by different categories of enterprises. The OECD Trade by Enterprise Characteristics (TEC) database details the export and import values by sector and size class and the number of exporting and importing enterprises for 28 EU member states plus Canada, Norway, Israel, Turkey, and the United States. Firm size (the number of employees) is identified according to four intervals: up to 9; 10 to 49; 50 to 249; more than 250. Drawing from confidential firm-level balance sheets in 19 European countries, the Competitiveness Research Network (CompNet) dataset includes a set of micro-aggregated indicators (trade, productivity, labor, finance) computed at firm-level by national data providers (those indicators are harmonized to allow cross-country comparability). For each indicator, the dataset provides different moments including percentiles, mean, standard deviation, skewness, kurtosis, and number of observations. In both databases, industries are classified in all countries at the 2-digit NACE level, including "Manufacture of food products" and "Manufacture of beverages".

5.1 Theory: main ingredients and applicability to food industry

We start by introducing the main ingredients of the supply side of the canonical model proposed by Melitz (2003) and augmented by Chaney (2008) (hereafter MC model), which provides the framing for many of the trade articles written during the last two decades (see Melitz and Redding, 2014).

Within each industry k, there is a competitive fringe of potential firms. Each variety v is produced by a single firm, after paying a sunk entry cost of $\mathcal{F}_i^{k,e}$ units of the composite input, with a productivity $z_i^k(v)$ drawn from a known distribution. Thus, firms are ex-post heterogeneous. The mass of entering firms in each country $\mathcal{M}_i^{k,e}$ is endogenously determined so that the expected profit is equal to $c_i^k \mathcal{F}_i^{k,e}$ (free entry condition). The mass of varieties of good k produced in country i is equal to the mass of surviving firms $\mathcal{M}_i^k$. Firms are assumed to produce under monopolistic competition. This type of framework is a relatively good fit with the food industry. On the one hand, the food industry is composed of a large number of firms with heterogeneous productivity (Blanchard et al., 2012; Gopinath et al., 2007). On the other hand, these food firms operate under imperfect competition and supply differentiated products (McCorriston, 2002).

Product markets are internationally segmented, meaning that the price of a variety varies across destination countries. The profit of a firm located in country i producing a variety of good k is $\pi_i^k(v) = \sum_j \pi_{ij}^k(v)$ where $\pi_{ij}^k(v)$ is the profit associated with export to country j given by $\pi_{ij}^k(v) = [p_{ij}^k - c_i^k \tau_{ij}^k / z_i^k(v)] q_{ij}^k(v) - c_i^k F_{ij}^k$ where F_{ij}^k is the fixed distribution cost that is specific to each origin-destination country pair. This fixed cost corresponds to the costs of maintaining a presence in the destination market (e.g., maintaining a distribution and service network and monitoring foreign customs procedures and product standards).[33]

Being negligible in the market, each firm sets its price while accurately treating the market aggregates (price index and expenditures) as given. The profit-maximizing prices are given by (6) where $m_{ij}^k(v) = m^k$ given the CES demand system and $\theta_{ij}^k(v) = 1$ as there is no vertical differentiation. Using (3) and (6), the profit associated with export to country j is

$$\pi_{ij}^k(v) = \mathcal{A}_{ij}^k \left[z_i^k(v)\right]^{\varepsilon^k - 1} - c_i^k F_{ij}^k, \tag{18}$$

where $\mathcal{A}_{ij}^k \equiv E_j^k (P_j^k)^{\varepsilon^k - 1} (m^k c_i^k \tau_{ij}^k)^{1-\varepsilon^k} / \varepsilon^k$ is an index of market demand from country j for product k supplied by firms located in country i. A firm enters a new market as long as $\pi_{ij}^k(v) \geq 0$, i.e.

$$z_i^k(v) \geq \left[\frac{c_i^k F_{ij}^k}{\mathcal{A}_{ij}^k}\right]^{1/(\varepsilon^k - 1)} \equiv z_{ij}^k, \tag{19}$$

where z_{ij}^k is the productivity cutoff above which a firm can profitably serve a market. It follows that fixed export costs play a key role in the export decision. Empirical evidence shows that exporters face sunk costs on entry into foreign agricultural and food markets in addition to the typical per unit trade costs. Although such sunk costs have declined, Kandilov and Zheng (2011) find they are still important for trade in major agricultural commodities. The food market remains fragmented between OECD countries despite reduced tariff barriers (Olper and Raimondi, 2008), and remains so even between EU countries despite controlling for country characteristics, bilateral variables (distance, common language, common currencies, colonial ties, etc.), and distance to foreign countries (Chevassus-Lozza and Latouche, 2012; Rau and Tongeren, 2009). The results of these studies suggest that trade barriers significantly shape the food product trade patterns in Europe despite EU countries applying mutual recognition of products.

In this context, the sorting of firms into export markets depends mainly upon their productivity: only the most productive firms generate sufficient revenue abroad to cover the fixed costs related to serving foreign markets. Using reduced-form approaches, different empirical studies confirm this self-selection mechanism based on food firm-level data. It has been shown that more productive food firms are larger, more likely to export, and serve more and more

[33] The composite factor is used for all productive activities within the industry, including both variable and fixed costs incurred for overhead production and for entry and market access. Note also that extending the MC model to the case of multi-product firms is trivial if there are no fixed trade costs at firm level.

distant markets (Chevassus-Lozza and Latouche, 2012; Gaigné et al., 2018; Gullstrand, 2011). From a structural perspective, Chevassus-Lozza and Latouche (2012) compute productivity thresholds z_{ij}^k (given in (19)) above which a French food firm could profitably serve a EU country. Assuming a Pareto productivity distribution, they find that productivity thresholds increase with the distance to the foreign country, and decrease with foreign market size as predicted by the theory.

In the MC framework, productivity is the only determinant of the export sales distribution. Additional features have to be introduced in trade models to reconcile the MC model with the data. It can be extended in different ways to study the challenges food firms face and to deliver predictions from theory which can be tested with firm-level data. In what follows, we consider the role of backward linkages with the agricultural sector and the role of end consumers in the export performance of food firms. Forward linkages with wholesalers and retailers are discussed in section 6.1.

5.2 Role of the agricultural sector: backward linkages and biased technology

Since agricultural primary products are processed mainly by food companies, several works study the impact of agricultural prices on trade in food products at firm level. In this subsection we show that lower agricultural prices can lead to unexpected implications, e.g. agricultural trade liberalization may exacerbate revenue inequalities across food processors and may lead to the exit of the less efficient food firms. The effects of agricultural prices depend on the production technology used by food processors, as shown in Gaigné and Le Mener (2014) in a trade model. In contrast to the MC model, they assume that the unit cost of using a composite input c_i^k is also specific to each firm and has the form

$$c_i^k(v) = \left[\left(\gamma_i^{k,\text{labor}}\right)^{\kappa_i^k} \left(\frac{w_i^{k,\text{labor}}}{z_i^{k,\text{labor}}(v)} \right)^{1-\kappa_i^k} + \left(\gamma_i^{k,\text{input}}\right)^{\kappa_i^k} \left(\frac{w_i^{k,\text{input}}}{z_i^{k,\text{input}}(v)} \right)^{1-\kappa_i^k} \right]^{1/(1-\kappa_i^k)}, \tag{20}$$

where $z_i^{k,\text{labor}}(v)$ and $z_i^{k,\text{input}}(v)$ denote (firm-specific) labor-augmenting and input-augmenting technology processes.[34] We fall back on standard trade models if $z_i^{k,\text{labor}}(v) = z_i^{k,\text{input}}(v) = 1$ so that firms differ only in their Hicks-neutral efficiency parameter $z_i^k(v)$. This standard assumption implies that the elasticity of the marginal cost to a change in the input price $(\partial \ln \text{mc}_i^k(v)/\partial \ln w_i^{k,\text{input}})$ does not differ across firms since they exhibit the same factor cost ratio and the same share of labor costs in their production costs which contradicts the evidence of a negative relationship between labor cost share and firm size, and a positive relationship between input expenditures share and firm size (see table 1). To reconcile this contradiction, Gaigné and Le Mener (2014) consider that firms differ mainly in $z_i^{k,\text{labor}}(v)$ and the conversion rate of raw material to final product (captured by $z_i^{k,\text{input}}(v)$) does not vary across firms.[35] Given the production function (20) and $z_i^{k,\text{input}}(v) = z_i^{k,\text{input}}$, the factor cost ratio (the ratio of intermediate good's cost to labor costs) is given by

$$r_i^k(v) = \left(\frac{\gamma_i^{k,\text{input}}}{\gamma_i^{k,\text{labor}}} \right)^{\kappa_i^k} \left(\frac{w_i^{k,\text{input}}}{w_i^{k,\text{labor}}} \right)^{1-\kappa_i^k} \left(\frac{z_i^{k,\text{labor}}(v)}{z_i^{k,\text{input}}} \right)^{1-\kappa_i^k}, \tag{21}$$

and does not vary with the efficiency parameter $z_i^k(v)$. However, the cost share of input expenditures increases with $z_i^{k,\text{labor}}(v)$ when $\kappa_i^k < 1$, i.e. when labor and material inputs are gross complements. This condition is in line with the empirical evidence presented in table 1 (see columns 6 and 7). Food producers cannot easily substitute extra workers for agricultural materials. More generally, the ratio of the purchase cost of intermediate consumption to the total production costs increases with the labor productivity of firms belonging to the same industry (see Gaigné and Le Mener, 2014).

[34] We could also consider firms using specialized workers and process horizontally differentiated across agricultural products, aggregated through a CES function.

[35] The conversion rate is strongly constrained by the technology. Food goods are manufactured according to recipes with more or less fixed proportions of ingredients. For example, the quantity of milk required to produce a type of cheese does not differ significantly across producers.

Using equations (6) and (20), the impact of changes in the price of factors on the output price is given by

$$\mathrm{d}\ln p_{ij}^{k}(\nu) = s_i^k(\nu)\,\mathrm{d}\ln w_i^{k,\text{labor}} + (1 - s_i^k(\nu))\,\mathrm{d}\ln w_i^{k,\text{input}}, \tag{22}$$

where $s_i^k(\nu) = 1/(1+r_i^k(\nu))$ is the labor cost share. Hence, more productive food processors gain more from lower prices for a common agricultural raw material (due to agricultural trade liberalization or productivity gains in the agricultural sector). In this context, the fall in output prices is higher for firms exhibiting higher labor productivity and could lead to the exit of less productive firms (see Gaigné and Le Mener, 2014). The main reason for this selection process is that the cost of the intermediate input is higher for high productivity firms because the cost share of intermediate inputs increases with labor productivity.[36] The most productive firms gain market share in their domestic and foreign markets if the prices of common inputs fall. The market shares of low-productivity firms may decline as their relative price increases and forces some of them to exit the market due to the fixed costs of production and exports. In contrast, a tax credit proportional to the wage bill paid by firms should increase the market share of less efficient firms.

Using firm-level data of the French food sector, Chevassus-Lozza et al. (2013) find that lower input tariffs increase the export sales of high-productivity firms at the expense of low-productivity firms, and decrease the probability of firms entering foreign markets. Based on more consistent index of upstream import penetration and a large micro-dataset of more than 20,000 French and Italian food firms, Olper et al. (2017) confirm that more productive firms gain more from input trade liberalization. Hence, agricultural and trade policies aimed at lowering the prices of agricultural products seem to benefit large food companies more.

In addition, the unequal effects of agricultural trade liberalization on food firms are magnified when the fixed costs of importing become significant. In this case, processors endogenously sort themselves into importers and non-importers of raw materials. Only the most efficient food firms become importers and process agricultural products which are cheaper and/or of better quality (Gaigné and Le Mener, 2014; Gibson and Graciano, 2011). Gibson and Graciano show that for plausible parameters the model can replicate the observed difference in size between Chilean importers and non-importers.

It is also worth stressing that agricultural trade liberalization may reduce the labor share in value added (labor cost plus profit) in the food industry. Indeed, it is straightforward to check that the labor share decreases with firm size. In our context, the value added at firm level is given by $p_i^k(\nu)Q_i^k(\nu) - [1 - s_i^k(\nu)]\mathrm{TC}_i^k(\nu)$ where $p_i^k(\nu) = m^k c_i^k(\nu)/z_i^k$ is the factory-gate price, $Q_i^k(\nu) = \sum_j \tau_{ij}^k q_{ij}^k(\nu)$ is total output of variety ν, and $\mathrm{TC}_i^k(\nu)$ is the total cost of producing and distributing this variety (which includes variable costs $c_i^k(\nu)Q_i^k(\nu)/z_i^k(\nu) \equiv \mathrm{VC}_i^k(\nu)$ and fixed costs). Hence, the labor cost $(s_i^k(\nu)\mathrm{TC}_i^k(\nu))$ expressed as a share in value added is given by

$$\mathcal{S}_i^k(\nu) = s_i^k\,(\nu)\left[m^k\frac{\mathrm{VC}_i^k(\nu)}{\mathrm{TC}_i^k(\nu)} - \left(1 - s_i^k(\nu)\right)\right]^{-1} \tag{23}$$

and decreases with firm efficiency (and, in turn, with firm size). By increasing the market share of more efficient firms and the exit of the less efficient firms, agricultural trade liberalization tends to decrease the labor share in value added in large firms due to (i) scale economies and firm heterogeneity (through a rise in $\mathrm{VC}_i^k(\nu)/\mathrm{TC}_i^k(\nu)$) and (ii) biased technical (through a rise in $r_i^k(\nu)$). Future empirical works are needed to better understand the effects of trade policies on labor share in the food industry.

5.3 Role of the end consumer: product quality and taste

We now discuss work focused on the role of product quality in trade, as quality has become a key driver of market share in food markets (Sexton, 2013). In the previous subsections, market shares differ among producers due to differences

[36] With a Cobb-Douglas technology, this effect disappears as the elasticity of the marginal cost to a change in the raw material price $w_i^{k,\text{input}}$ does not differ across firms. Hence, a Cobb-Douglas function does not fit the data well since it implies that $r_i^k(\nu)$ does not vary across firms.

in marginal costs. In this subsection, the allocation of final demand across varieties is driven by quality-adjusted prices ($p_{ij}^k(\nu)/\xi_{ij}^k(\nu)$ where $\xi_{ij}^k(\nu)$ is given by (5)). A small firm can export provided that the product quality is sufficiently high. For example, Champagne and Cognac producers that supply higher quality varieties charge higher prices, export to more markets, and sell more in each market (Crozet et al., 2012; Emlinger and Lamani, 2020). This is the so-called Alchian-Allen effect which makes trade costs relatively less important for high-quality (higher priced) products compared to lower quality ones. Building on Melitz's (2003) framework, several papers consider vertical differentiation to explain the quality sorting found in international trade (Gaigné and Larue, 2016; Hallak and Sivadasan, 2013; Kugler and Verhoogen, 2012). Concerning the choice of product quality, the trade literature considers that the characteristics of the different varieties are customized for each foreign market, and therefore the quality of the varieties is adjusted by the firms as often as prices are adjusted.[37] Under these circumstances, product quality depends on the characteristics of the destination country (market size, trade cost) and firm features (productivity, ability to produce quality). Firms have an incentive to improve the quality of their varieties if demand increases with a better quality of products perceived by consumers. However, a higher product quality induces additional variable and fixed costs of production in line with the industrial organization literature. The impact of quality on firm profits depends on the foreign consumers' attitude to quality (ζ_j^k and $\bar{\xi}_{ij}^k$) relative to the cost elasticities of quality.

The production of quality has been modeled in different ways. Some authors consider that product quality is a function of the quality of inputs (Verhoogen, 2008). In our context, producing higher-quality food products requires higher-quality workers in each occupational category, and higher-quality agricultural raw materials. The technology is assumed to be supermodular, implying complementarity in the quality of inputs.[38] In other words, higher output quality requires high quality of all inputs. In addition, since labor and agricultural markets are competitive, firms are assumed to face upward-sloping worker quality-wage schedules and agricultural raw material quality-price schedules. Hence, the price of inputs increases with their quality. Higher-quality workers must be paid higher wages and farmers supplying higher-quality agricultural products must receive higher prices. In this approach, firms strategically set labor and raw material prices. It is expected that exporters exhibiting higher productivity pay higher input prices, sell goods that are of higher quality, have higher market shares, and export to more destinations (Tseng and Sheldon, 2015).

Some authors make a simplifying assumption when modeling quality production technology. They directly parameterize the cost function to avoid the technical complexity associated with endogenous input prices. It is assumed that better quality yields lower productivity shifters so that the marginal cost is given by equation (7). Furthermore, firms must also incur an additional fixed cost which is quality-specific $c_i^k[\theta_{ij}^k(\nu)]^{\eta^k}/a_i^k(\nu)$ where $\eta^k \geq 0$ is the quality-elasticity of fixed costs and $a_i^k(\nu)$ is the firm's ability to produce quality.[39] In the food industry, higher marginal costs can be caused by a more thorough selection of ingredients and/or additional production tasks. In accordance with the industrial organization literature, fixed costs are also increasing with quality (Sutton, 2007). Firms have to buy new equipment, train workers, and make other adjustments to their production process before producing a single unit of a higher-quality product. For example, firms selling perishable products such as fresh fruits and vegetables may have to invest in better storage facilities to meet quality standards over an extended period. Animal welfare is a growing concern and many farms and processing firms have invested in new equipment and facilities to meet new stricter public regulations in some cases or to differentiate their products. In addition, the ability of firms to produce quality $a_i^k(\nu)$ can vary across firms, as in Hallak and Sivadasan (2013). In this context, following Gaigné and Larue (2016) and assuming that $a_i^k(\nu) = a_i^k$, first order conditions imply

$$p_{ij}^k(\nu) = m^k \frac{c_i^k[\theta_{ij}^k(\nu)]^{\alpha^k}}{z_i^k(\nu)}\tau_{ij}^k,\ x_{ij}^k(\nu) = \frac{\varepsilon^k\eta^k}{\Lambda_j^k}\frac{c_i^k[\theta_{ij}^k(\nu)]^{\eta^k}}{a_i^k},\ \text{and}\ \pi_{ij}^k(\nu) = \frac{\eta^k - \Lambda_j^k}{\Lambda_j^k}\frac{c_i^k[\theta_{ij}^k(\nu)]^{\eta^k}}{a_i^k} - c_i^k F_{ij}^k \tag{24}$$

with $\Lambda_j^k \equiv (\varepsilon^k - 1)(\zeta_j^k - \alpha^k)$ and $\eta^k > \Lambda_j^k > 0$ (the second-order condition) so that the level of quality adopted by a

[37] This assumption implies that firms do not need any adjustment time before starting to customize quality for each foreign market.

[38] Such a quality production function belongs to the "O-Ring" production functions class proposed by Kremer (1993).

[39] So that the profit is given by $\pi_{ij}^k(\nu) = \{p_{ij}^k - c_i^k[\theta_{ij}^k(\nu)]^{\alpha^k}\tau_{ij}^k/z_i^k(\nu)\}q_{ij}^k(\nu) - c_i^k F_{ij}^k - c_i^k[\theta_{ij}^k(\nu)]^{\eta^k}/a_i^k(\nu)$ and $q_{ij}^k(\nu)$ is given by (3).

firm in equilibrium can be expressed as

$$\theta_{ij}^k(\nu) = \underline{\theta}_{ij}^k \left(\frac{z_i^k(\nu)}{z_{ij}^k}\right)^{\rho_j^k} \quad \text{with} \quad \underline{\theta}_{ij}^k = \left(\frac{a_i^k \Lambda_j^k F_{ij}^k}{\eta^k - \Lambda_j^k}\right)^{1/\eta^k} \quad \text{and} \quad z_{ij}^k = \frac{1}{\bar{\xi}_{ij}^k}\left(\frac{\eta^k c_i^k}{\Lambda_j^k a_i^k \mathcal{A}_{ij}^k}\right)^{1/(\varepsilon^k-1)} \left(\underline{\theta}_{ij}^k\right)^{1/\rho_j^k}, \qquad (25)$$

where $\rho_j^k \equiv (\varepsilon^k - 1)/(\eta^k - \Lambda_j^k) > 0$ and $\underline{\theta}_{ij}^k$ is the quality cutoff above which a firm can profitably serve a market ($\pi_{ij}^k(\nu) \geq 0$).[40] Hence, the sorting of firms into export markets depends upon the quality of their varieties: only high-quality firms generate sufficient revenue in foreign markets to cover the fixed export costs. Product quality is increasing with firm efficiency $z_i^k(\nu)$, the ability to produce quality a_i^k, the intensity of the preference for quality by country j ζ_j^k, and trade liberalization. Hence, lower variable trade costs encourages quality upgrading in the food industry which is in line with the empirical evidence (Curzi and Pacca, 2015). Further, for two firms 1 and 2, the spread in their quality ($\theta_{ij}^k(1)/\theta_{ij}^k(2)$) increases with the spread in their productivity and the elasticity of substitution. Highly productive firms have more incentives to vertically differentiate when the degree of horizontal differentiation is limited. In addition, the export sales and profits of a firm serving a foreign market increase unambiguously with productivity (see (24)).

Although the MC model without vertical differentiation performs well in terms of explaining productivity sorting, it is less efficient at explaining the spatial variation in prices. Indeed, in the MC model, the difference in prices set by a firm across destinations ($p_{ij}^k(\nu)/p_{ij'}^k(\nu)$) is affected only by the relative trade costs ($\tau_{ij}^k/\tau_{ij'}^k$) and does not vary across firms located in the same country. Trade models with endogenous quality perform better because they consider that the quality of varieties depends on the characteristics of firms and foreign demand. In addition, if ζ_j^k increases with importer income per capita, then exporters charge higher prices for identical products in richer destinations in accordance with the empirical evidence (Simonovska, 2015). It is worth stressing also that as the consumer price rises with product quality improvements, higher productivity could lead to higher prices, and in turn, to lower quantities. Formally, prices increase with productivity if and only if $\alpha^k \rho_j^k > 1$ or, equivalently, $\zeta_j^k > \eta^k/(\varepsilon^k - 1)$ (see (24) and (25)). Hence, prices (resp. quantity) are positively (resp. negatively) correlated with productivity for a high level of consumer appreciation of quality (high ζ_j^k) and if varieties are not close substitutes (low ε^k). This suggests that highly productive exporting firms need not be large in terms of output size.

Quantification of the role of quality for explaining trade outcomes has received much attention. However, quality is unobservable and measuring it is not straightforward. By focusing on products of the alcoholic beverage industry, we can exploit direct measures of product quality. For example, Crozet et al. (2012) identify the quality by using well-known experts ratings from wine guides while Emlinger and Lamani (2020) use the amount of time the *eau de vie* used to produce Cognac spend in oak. Unfortunately, there are numerous products for which no direct measures of product quality exist. This is why much of the literature uses prices or unit values computed from trade statistics to proxy for quality. However, higher unit values may also reflect lower efficiency. In addition, using (24), we have $\mathrm{d}\ln p_{ij}^k(\nu) = \alpha^k \,\mathrm{d}\ln\theta_{ij}^k(\nu) - \mathrm{d}\ln z_i^k(\nu)$. Also, according to (25), the level of quality depends positively on firm productivity with $\mathrm{d}\ln\theta_{ij}^k(\nu) = \rho_j^k \,\mathrm{d}\ln z_i^k(\nu)$ so that $\mathrm{d}\ln p_{ij}^k(\nu) = (\alpha^k - \rho_j^k)\,\mathrm{d}\ln\theta_{ij}^k(\nu)$. It follows that price and product quality are negatively correlated if appreciation of quality (ζ_j^k) is sufficiently high.

As a result, several researchers use alternative approaches. In Curzi and Olper (2012) product quality is proxied by investment intensity, R&D expenditure, product and process innovations, and quality standard certifications (ISO 9000). Applying this methodology to a sample of 750 Italian food exporting firms, they find that more efficient firms sell higher-quality goods at higher prices and serve more distant markets, confirming the positive relationship between productivity, product quality, and export performance. Other works compute an index of food product quality at the firm-destination-product level using the methodology developed in Khandelwal (2010) and Khandelwal et al. (2013).

[40] Some authors (Baldwin and Harrigan, 2011; Johnson, 2012) adopted a reduced-form relationship linking product quality and productivity: $\theta_i^k(\nu) = (z_i^k)^{\alpha^k}$. In this case, the quality of variety supplied by a firm varies only with its productivity draw. However, such a modeling strategy implies that quality of each variety is invariant over destinations.

For a given price in a firm-destination-product triplet, a variety with a higher quantity is attributed higher quality. Following Khandelwal et al. (2013), $\xi^k_{ij}(\nu)$ can be estimated for each firm-destination-product observation as the residual of equation (3) which can be rewritten as $\ln q^k_{ij}(\nu) + \varepsilon^k \ln p^k_{ij}(\nu) = \text{FE}^k_j + \epsilon^k_{ij}(\nu)$ where $\epsilon^k_{ij}(\nu)$ is the error term and $\text{FE}^k_j \equiv \ln E^k_j (P^k_j)^{\varepsilon^k - 1}$ represents product-by-destination fixed effects which capture expenditure and the price index of product k in destination j and which are common to all exporters serving the same destination country (for a discussion of identification strategies to estimate product quality at the firm level, see Piveteau and Smagghue, 2019). For the elasticity of substitution ε^k, we can rely on the elasticities reported in the empirical literature. Hence, the estimated quality is defined as $\ln \widehat{\xi}^k_{ij}(\nu) = \widehat{\epsilon}^k_{ij}(\nu)/(\varepsilon^k - 1)$. Conditional on price, a variety with a higher quantity is assigned higher quality. Using this methodology, Curzi et al. (2015) find that in Europe lower prices of imported food products can be accompanied by higher quality.

The demand residuals approach confounds taste $\bar{\zeta}^k_{ij}$ with other demand shifters such as product quality $[\theta^k_{ij}(\nu)]^{\zeta^k_j}$. In some recent contributions, the role of consumer taste in import demand is analyzed separately from the role of product quality in import demand. To identify unobserved consumer taste heterogeneity, Aw-Roberts et al. (2020) construct a bilateral indicator of closeness in the ingredients of the national dishes of any two countries which reflects the similarity in food tastes ($\bar{\zeta}^k_{ij}$), and apply a control function approach to estimate import demand. Using firm-level Belgium data, they find that consumer taste for food produced in Belgium differs substantially across countries. Disentangling the role of taste vs. product quality in export performance is a promising area for future studies.

5.4 Aggregate implications

In order to derive quantitative predictions for trade flows and welfare, most of trade literature assumes a Pareto productivity distribution with shape parameter h^k and scale parameter/lower bound $\underline{z}^k_i$, as this assumption yields closed form solutions for productivity cutoffs, the gravity equation, and welfare. The ex-post productivity distributions in the destination markets are truncations of the ex-ante productivity distribution at the cutoff productivities. In this subsection, we consider a trade model in which product quality is endogenous as developed above (and assuming $\zeta^k_j = \zeta^k$ so that $\Lambda^k_j = \Lambda^k$ and $\rho^k_j = \rho^k$).

Average export, average quality, and gravity

Bilateral aggregate trade can be decomposed into the extensive (mass of exporters $\mathcal{M}^k_{ij}$) and intensive (average firm exports $\bar{x}^k_{ij} = E^k_j (P^k_{ij}/P^k_j)^{1-\varepsilon^k}/\mathcal{M}^k_{ij}$) margins where $\mathcal{M}^k_{ij}$ is the mass of firms in i serving j. Following Gaigné and Larue (2016), the price index of imported varieties from i can be expressed as follows $P^k_{ij} = m^k c^k_i \tau^k_{ij}/Z^k_{ij}$ with

$$Z^k_{ij} = \left(\frac{h^k}{h^k - \eta^k \rho^k} \mathcal{M}^k_{ij} \right)^{1/(\varepsilon^k - 1)} \bar{\xi}^k_{ij} (\underline{\theta}^k_{ij})^{\zeta^k - \alpha^k} z^k_{ij} \quad \text{and} \quad \mathcal{M}^k_{ij} = \mathcal{M}^{k,E}_i \left(\frac{\underline{z}^k_i}{z^k_{ij}} \right)^{h^k}, \tag{26}$$

where $h^k > \eta^k \rho^k$ must hold for average firm size to be finite. Higher productivity cutoffs decrease the bilateral price index for a given mass of producers due to the exit of less efficient producers (selection effect). However, by reducing the mass of producers/varieties, a rise in the productivity cutoff increases the bilateral index price (entry effect).

Using (25) and (26), average firm exports and the average quality supplied by exporters given by $\bar{\theta}^k_{ij} = \int_{\Omega^k_{ij}} \theta^k_{ij}(\nu)\, \mathrm{d}\nu$ are

$$\bar{x}^k_{ij} = \frac{h^k \varepsilon^k}{h^k - \eta^k \rho^k} \frac{c^k_i [\underline{\theta}^k_{ij}(\nu)]^{\eta^k}}{a^k_i} \quad \text{and} \quad \bar{\theta}^k_{ij} = \underline{\theta}^k_{ij} \frac{h^k}{h^k - \rho^k} \left(z^k_{ij} \right)^{-h^k}. \tag{27}$$

Note that, although quality is endogenous and depends on destination characteristics, average firm exports are independent of variable trade costs and market size (as in the standard MC model). Hence, lower variable trade costs and higher market size increase bilateral trade solely through the extensive margin. However, the effect of fixed and variable export costs and market size on average quality can be decomposed into two offsetting effects. Freer trade or higher demand decreases the minimum productivity threshold required for firms to survive allowing low-quality firms to enter the market. Nevertheless, equation (25) shows that a lower minimum productivity induces incumbent firms to boost their quality. Thus, the downward pressure on quality stemming from the entry of low-quality firms following increased market size is more than offset by the increase in the quality chosen by existing firms. This implies that consumers living in large economies or open economies should consume products of higher average quality compared to consumers in smaller and less open countries. Curzi et al. (2015) find that lower import tariffs imply quality upgrading, provided that the quality of varieties is close to the world frontier.

The trade model based on firm-level behaviors with endogenous quality can generate a structural gravity-type trade equation which can be estimated from aggregate trade data. Inserting the expression of productivity threshold (25) and equation (26) in equation (9) and using $Y_i^k = \sum_j X_{ij}^k$ imply

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left(\frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right)^{-h^k} \left(E_j^k \right)^{h^k/(\varepsilon^k - 1) - 1} \left(F_{ij}^k \right)^{1 - h^k/(\varepsilon^k - 1) + h^k(\zeta^k - \alpha^k)/\eta^k} \chi_{ij}^k, \tag{28}$$

where $(\Pi_i^k)^{h^k} = \sum_j (\tau_{ij}^k / P_j^k)^{-h^k} (E_j^k)^{h^k/(\varepsilon^k-1)} (F_{ij}^k)^{1-h^k/(\eta^k \rho^k)} \chi_{ij}^k / Y^k$ and $\chi_{ij}^k > 0$ is a function of exogenous parameters distinct from trade costs. The firm-level trade elasticity, given by $\partial \ln x_{ij}^k(v) / \partial \ln \tau_{ij}^k = -\rho^k \eta^k$, depends on the elasticity of substitution ε^k as well as the cost elasticities of quality (α^k and η^k) and appreciation for quality (ζ^k). The elasticity of aggregate trade with respect to variable trade costs (aggregate trade elasticity) does not depend on parameters associated with product differentiation and are determined by the Pareto shape parameter as in Chaney (2008). The elasticity of trade with respect to fixed export costs are driven by the extensive margin as in the MC model. However, this elasticity depends on both the degree of horizontal differentiation through $1 - h^k/(\varepsilon^k - 1)$ (a negative effect) and the scope for vertical differentiation through $h^k(\zeta^k - \alpha^k)/\eta^k$ (a positive effect). As quality increases with $(\zeta^k - \alpha^k)/\eta^k$, the negative impact of fixed trade barriers on trade is weakened in industries selling high quality varieties.

Estimating the gravity model is subject to different econometric issues. One of them is that in the trade data, there are many zeros ($X_{ij}^k = 0$) which can be considered as an endogenous component of the data generating process while the use of CES demand, a continuum of producers and untruncated probability distributions imply there cannot be zero trade flows between any pair of countries.[41] To explain zeros in the data, Helpman et al. (2008) start from the MC model developed in section 5.1 but they consider truncated Pareto distribution so that their gravity model is given by equation (9) in which Z_{ij}^k can be equal to zero. Helpman et al. (2008) employ a Heckman-like correction to account for zero trade flows and consider religion overlap as exclusion restriction. As pointed out in Anderson (2010) they "use common religion, a specification that many find dubious." Unfortunately, it is difficult to find a valid exclusion restriction (a variable explaining the export status which can be excluded from the gravity equation). However, the most robust statistical criticism of Helpman et al. (2008) is laid out in Santos Silva and Tenreyro (2015). They show that the results of the two-stage estimation method proposed in Helpman et al. (2008) are very sensitive to the presence of heteroskedasticity. Feenstra (2016) and Head and Mayer (2014) discuss different methods of estimation to allow for consistent estimates in the presence of frequent zeros.

Welfare

To compute welfare, we first determine the change in Z_{jj}^k, which combines an entry effect and a selection effect. Indeed, equation (26) implies $\ln \hat{Z}_{jj}^k = \ln \hat{\mathcal{M}}_j^k / (\varepsilon^k - 1) + \ln \hat{z}_{jj}^k$ where $\hat{\mathcal{M}}_j^k$ is the change to the mass of surviving domestic firms (the entry effect), which depends on the change in productivity cutoff. Some standard, but tedious, calculations (see our

[41] The pareto distribution without upper truncation used to obtain equation (28) implies there exists some infinitely productive firm. Hence, there must be some firms whose productivity exceeds the productivity threshold for exporting and, in turn, serve all destinations

online Appendix) show that

$$\ln \hat{z}_{jj}^k = \frac{1}{h^k}\left[-\ln \hat{\lambda}_{jj}^k + \ln(\hat{Y}_j^k/\hat{E}_j^k)\right], \tag{29}$$

and

$$\ln \hat{\mathcal{M}}_j^k = \ln \hat{\lambda}_{jj}^k + \ln \hat{E}_j^k - \ln \hat{c}_j^k. \tag{30}$$

For example, if labor is the unique production factor and $P_j^O = \hat{w}^{\text{labor}}$ (the share of expenditure on domestic varieties of the aggregate outside good is kept constant), then $\hat{c}_j^k = \hat{E}_j^k = \hat{R}_j = \hat{w}_j^{\text{labor}}$ and equation (10) reduces to $\ln \hat{V}_j = \sum_{k=1}^K \beta_j^k \ln \hat{z}_{jj}^k$.

The nature of the gains from trade differs in trade models under imperfect competition. First, there is an entry (variety) effect. Trade liberalization implying more import competition (or lower input prices) forces low productive domestic firms to exit.[42] Globalization allowing the introduction of new foreign varieties in domestic countries destroys some domestic varieties by making them unprofitable. This is a spatial version of the process of creative destruction described by Joseph Schumpeter. This entry effect is due to demand-side changes of substitutability among varieties, and the existence of fixed costs: consumers exploit the fall in the price of imports by expanding the number of imported varieties and consuming the same set of domestic varieties but in lower amounts. For some low-productivity domestic firms, their operating profits become lower than their fixed costs forcing them to exit. In the model with a single production factor, the positive effect of import variety on welfare (captured by a lower $\hat{\lambda}_{jj}^k$ in equation (10)) just cancels with the welfare losses due to a lower number of domestic varieties (as $\ln \hat{\mathcal{M}}_j^k = \ln \hat{\lambda}_{jj}^k$).

The gains from trade arise mainly from a selection effect (through an increase in the domestic productivity threshold z_{jj}^k). Indeed, trade liberalization induces expansion of more efficient incumbents at the expense of less productive producers within each sector. It follows that aggregate productivity increases through either market share shifts to more efficient firms or the exit of low productivity producers. Hence, a greater spread of productivities leads to higher proportional gains from trade liberalization. Ruan and Gopinath (2008) find food industry average productivity increases with liberalized international trade. Olper et al. (2014) confirm this finding for a sample of 25 European countries and 9 food industries over the period 1995–2008.

In a one-sector model, the gains from trade are the same with or without selection effect (Arkolakis et al., 2012). However, in a multi-sector economy with firm-level scale economies, the selection effect due to foreign shocks can be magnified or weakened due to changes in the allocation of resources and income across sectors within a country (through a change in $\hat{Y}_j^k/\hat{E}_j^k$) with consequences for the number of varieties that can be produced due to a reallocation of primary factors across sectors.[43] To assess the contribution of this reallocation mechanism in welfare, we quantify the cost of food autarky in France when the heterogeneous food firms operate under imperfection competition while perfect competition prevails in the agricultural sector. In this case, $\ln \hat{V}_j = -(\beta_j^A/\varkappa^A)\ln \hat{\lambda}_{jj}^A + \beta_j^F \ln \hat{z}_{jj}^F$.[44] If France moved to food autarky (${\lambda_{jj}^k}' = 1$ with $k = A, F$), real income would decline by 1.09% when we account for the reallocation of resources across sectors. Under these circumstances, the return to food autarky in France would be equivalent to a decrease in per household annual income of €460 (instead of €415). As the French food industry is a net exporter of goods with firm-level scale effects, the predicted costs from food autarky are higher than those predicted by the same model without imperfect competition in the food industry.

The cost of food autarky is magnified when we consider input-output linkages due to a rise in production costs, but also to a fall in the mass of domestic varieties. To illustrate how vertical linkages operate, unit costs in the food sector are expressed as a simplified version of equation (20): $c_j^F = (w_j^{\text{labor}})^{\gamma_j^{F,\text{labor}}}(P_j^F)^{\gamma_j^{F,F}}(P_j^A)^{\gamma_j^{F,A}}$ with $\gamma_j^{F,\text{labor}} + \gamma_j^{F,F} + \gamma_j^{F,A} = 1$. Production of processed food combines labor, processed food products, and agricultural primary products with constant

[42]To be precise, freer trade results in more productive firms enjoying higher revenues and profits in each destination market; some firms continue to serve only the domestic market and the least productive firms are forced to exit the industry.

[43]As $\hat{w}_j^{\text{labor}} = \hat{E}_j^k$ and $\ln \hat{Y}_j^k = \ln \hat{w}_j^{\text{labor}} + \ln \hat{L}_j^k$ where $\hat{L}_j^k$ is the change in the mass of labor of country j used in industry k, $\hat{Y}_j^k/\hat{E}_j^k = \hat{L}_j^k$.

[44]We assumed that $\mathcal{Z}_j^k$ is constant and labor is the unique input. In this case, $Y_j^k/E_j^k = 1$ under autarky and $Y_j^k/E_j^k = \mu_j^k/\beta_j^k$ where $\mu_j^k = Y_j^k/Y_j$ is the share of revenue in country j generated by sector k. According to the French national account in 2018, $Y_j^F/E_j^F = 1.4$. In addition, like in sections 3.3 and 4.2.2, $\varkappa^A = h^F = 5$ as they correspond to the trade elasticities.

shares. Agricultural production is assumed to use only labor so that $\hat{P}_j^A = (\hat{\lambda}_{jj}^A)^{1/\varkappa^A} \hat{w}_j^{\text{labor}}$ according to equation (15) ($\mathcal{Z}_j^A$ is kept constant). Under these assumptions, as shown in our online Appendix, the welfare change (10) associated with a move to food autarky when food sector operates under monopolistic competition and uses agricultural and food products as intermediate inputs becomes

$$\ln \hat{V}_j = -\frac{1}{\varkappa^A}\left(\beta_j^A + \beta_j^F \frac{\gamma_j^{F,A} m^F}{1-\gamma_j^{F,F} m^F}\right) \ln \hat{\lambda}_{jj}^A + \beta_j^F \left(1 + \frac{\gamma_j^{F,F} m^F}{1-\gamma_j^{F,F} m^F}\right) \ln \hat{z}_{jj}^F. \quad (31)$$

If France moved to food autarky (${\lambda_{jj}^k}' = 1$ with $k = A, F$), real income would decline by 1.77%, equivalent to a decrease in per household annual income of €747.[45] Because of its selection and entry effects, the introduction of tradable intermediate goods processed by food firms dramatically increases the cost of food autarky.

5.5 Discussion

We discuss three strong restrictions in heterogeneous-firm trade models: (i) invariant markup and a continuum of firms, (ii) constant marginal cost, and (iii) uncertainty.

Variable markup, granular firms, and welfare

The combination of monopolistic competition and CES demand systems implies that markups do not vary across destinations and firms, and the pass-through of trade cost shocks into firm prices is complete. Hence, this combination excludes any welfare effects of lower trade costs which derive from changes in profit margins. Trade models with variable markups show that this feature can be crucial for shaping the gains from trade. Indeed, the gains from trade shrink if lower trade costs induce higher market shares for dominant, high-markup producers. This markup dispersion gives rise to misallocation of resources across firms, shrinking the gains from trade liberalization. We lack evidence on how firm-level markup adjusts to freer trade in the food industry. Vancauteren (2013) and Curzi et al. (2021) are two notable exceptions. Vancauteren finds that EU harmonization of regulations, i.e. measures that facilitate trade, generates pro-competitive effects in the Dutch food industry. Using French food firm data over the 2001–13 period and the methodology developed by De Loecker and Warzynski (2012), Curzi et al. (2021) document that more import competition lowers average markup while more input imports raise the average markup, the two effects taken together tend to offset each other. However, markup adjustments to trade vary greatly across firms. Indeed, the markup of firms belonging to the top decile of the markup distribution in the first year of the period covered increases with import competition.[46] In addition, large firms gain much more from a higher availability of intermediate inputs than smaller firms. This suggests an incomplete pass-through of (inputs) cost reductions to prices, which is lower for large firms compare to smaller firms. Hence, empirical evidence suggests that trade liberalization implying higher competition from foreign food firms or lower agricultural price is likely to induce a reallocation of market share from low-markup food firms to high-markup food firms. These empirical findings yield some interesting avenues for further research.

To generate variable markups in trade models, we have to consider either demand systems implying variable demand elasticity (demand side) or oligopolistic competition (supply side). Variable markup under monopolistic competition can be generated with different classes of preferences. For example, preferences can be represented by an additively separable indirect utility function (or indirectly additive preferences - indirect utility is additive in prices) which implies that demand elasticities are variable and the price of each variety depends positively on per-capita income (Bertoletti et al., 2018). Using a model featuring this class of preferences, Bertoletti et al. show that for more productive firms

[45] According to the French national account in 2018, $\gamma_j^{F,F}$ was 0.21 and $\gamma_j^{F,A}$ was 0.24. As $m^F = \varepsilon^F/(\varepsilon^F - 1)$ and $h^F > \varepsilon^F - 1$, we assume that $m^F = 1.2$.

[46] These results are consistent with works on firm-level markup. More productive Slovenian firms enjoy higher markups (De Loecker and Warzynski, 2012) and the markup of US firms belonging to the upper percentiles of the markup distribution have increased sharply (De Loecker et al., 2020).

prices are lower but markups are higher, in line with the empirical evidence that more productive firms have lower pass-through into their prices, and the welfare gains are less than one half of the gains under CES preferences.

Alternatively, a finite number of firms instead of a continuum of firms implies variable markup under a CES demand system as "granular" firms consider the aggregate price index when making pricing decisions. In the case of a CES subutility nested into a Cobb-Douglas utility and oligopolistic competition, the perceived price elasticity of demand $\mathcal{E}^k_{ij}(\nu)$ is no longer a constant ε^k but equals $\varepsilon^k - (\varepsilon^k - 1)\lambda^k_{ij}(\nu)$ where $\lambda^k_{ij}(\nu)$ denotes the market share in country j of the firm producing variety ν.[47] It follows that large firms face lower demand elasticity and enjoy high markup, given by $m^k_{ij}(\nu) = [m^k - \lambda^k_{ij}(\nu)]/[1 - \lambda^k_{ij}(\nu)]$ (which increases with $\lambda^k_{ij}(\nu)$ and falls to m^k when $\lambda^k_{ij}(\nu)$ tends to zero). As a consequence, the distribution of markups adjusts to the changes in trade costs. Hence, more import competition or lower input prices are associated with an increase in aggregate productivity and also aggregate markups since less-efficient firms exit.[48]

Nevertheless, trade models with variable markup ignore important features of food industry. First, market structures are rather mixed for some food industries, which involve a few big firms which are able to manipulate the market, and a large number of small firms each of which has a negligible impact on the market. Food trade models should consider this type of "mixed" structure and their consequences on trade and welfare. For example, assuming coexistence of multi-product oligopolists and a continuum of single-product firms, Parenti (2018) shows that the consumer surplus declines with the entry to the domestic market of a large foreign firm because the exit of small firms implies fewer varieties and a higher price index. However, we are not aware of applications of Parenti's approach to the food sector.

Second, trade models consider market power arises mainly from the ability of firms to manipulate prices and neglects vertical coordination in the food chain (contracts, two-part tariffs, vertical integration) and bargaining power exerted by processing firms with respect to atomistic input suppliers (farmers) or by retailers to small food firms. For example, the impact of contracts between food exporters and importers merits more attention because of cross-country differences in contractual enforcement (Antràs and Foley, 2015).

Third, aggregate food trade is shaped by the individual behavior of multinational enterprises. Although multinational activity appears to be relatively high in the food industry (Scoppola, 2021, documents that multinational food companies account for about 50% of production), we lack economic research on their organizational choices, and their impacts in the agri-food global value chain, on overall welfare, and on income distribution at home and in the host country. Scoppola provides an excellent discussion on challenges and prospects of research in this area.

Variable marginal cost and export duration

Most trade models share a strong restriction: physical output is produced under constant marginal costs. This assumption is practical because it allows firms to make decisions about exports to a given destination independently of decisions about other destinations. Higher exports to one market have no impact on the marginal cost or export performance in all markets. However, agricultural production is characterized by cost convexity: many primary agricultural products take a long time to produce and are perishable. This results in an extreme form of convexity since in the short run capacity is fixed. Also, processing plants may face capacity constraints due to investment lags. In standard trade models, a shock in a foreign market has only an indirect impact on the export sales of other firms in other markets through changes in price indices and national income both of which are treated as given in the optimization of monopolistic firms.

Firm's optimization is more complex under variable marginal cost since all markets must be considered simultaneously as shown in Zongo et al. (2021). The authors assume that the total amount of composite input required to serve markets is given by $[Q^k_i(\nu)]^{\mu^k}/z^k_i(\nu) + \sum_j F^k_{ij}$ where $\mu^k > 0$ and $Q^k_i(\nu) = \sum_j \tau^k_{ij} q^k_{ij}(\nu)$ is the total production of a firm located in country i selling a variety of product k. In this configuration, the marginal costs are given by $\mathrm{mc}^k_i(\nu) = c^k_i \mu^k [Q^k_i(\nu)]^{\mu^k - 1}/z^k_i(\nu)$. Cost convexity is governed by the extent to which μ^k exceeds 1. When $\mu^k = 1$, we

[47] $\mathcal{E}^k_{ij}(\nu) = \varepsilon^k - (\varepsilon^k - 1)(\partial \ln P^k_j / \partial \ln p^k_{ij}(\nu))$ with $\partial \ln P^k_j / \partial \ln p^k_{ij}(\nu) = \lambda^k_{ij}(\nu)$.

[48] Note that if producers are homogeneous, then $\lambda^k_{ij}(\nu) = 1/N^k_j$ where N^k_j is the number of firms serving destination j so that trade openness reduces markup.

revert to the MC trade model. If the marginal costs increase with output size, the authors show that a higher demand in one country implies higher prices in all destinations, and increased exports to the first country at the expense of the other destinations

Variable marginal costs may explain why firm entries and exits in export markets are frequent, and export spells are of a short duration. Empirical evidence on agricultural and food trade shows that exit rates are high in the first few years of exporting (Peterson et al., 2018; Zongo et al., 2021). Standard trade models show that the presence of fixed exporting costs favors highly productive firms with higher probability of export survival. Although exporters face negative transitory shocks, they may prefer to maintain their export activities in order to avoid payment of fixed re-entry costs. In other words, the MC model cannot explain small-scale exporting episodes and the surge in shipments among a small set of successful new exporters. Allowing for convex variable costs has important implications for export duration because the export volume of a firm in one market impacts its marginal costs and survival in all markets whereas under constant marginal costs markets are segmented and independent of each other.

Uncertainty and margins of trade

In standard trade models, once firms are able to enter the export markets they face no additional uncertainty. Although uncertainty is part of Melitz-Chaney-type models, the uncertain parameter (productivity) is revealed before the firm supplies any destination. The trade literature has witnessed a revival of interest in studying the uncertainty realized after the firm enters an export destination (Nguyen, 2012). Firms face uncertain destination-specific demands and/or uncertain origin-specific supply which materialize only after they enter the market.[49] However, this literature stream assumes that uncertainty is resolved before firms set their prices (or quantities) for each destination which in turn means export prices and quantities (thus export sales) are not affected by demand uncertainty. In reality, some random shocks may not be observable by exporters before the time-strategic variables (prices or quantities) are chosen. Although food consumption has low income elasticity, the volatility of household food consumption is relatively high at the household (Gorbachev, 2011) and at the country (De Sousa et al., 2020) levels. Numerous factors including climatic conditions, changes in consumer tastes/incomes, opinion leader attitudes, competing product popularity, and industrial policy are beyond the producer's control and influence realization of expenditure. De Sousa et al. find that if all destination countries exhibit the lowest volatility observed across destinations, then total French exports of dairy products would increase by approximately 40% driven primarily by the extensive margin, i.e., the number of exporters in each destination. Surprisingly, the effects of uncertain agricultural supply/price on trade in food products have received little attention in the literature despite the fact that the vertical relationship between these sectors should imply that the uncertainty upstream should affect the decisions taken downstream. More generally, the impact of demand and supply uncertainty on decisions of food firms to export and to import should be an important avenue of future research.

6 Trade costs: origin and consequences

In the two previous sections, we analyzed the determinants and implications of trade in agricultural and food products. Trade costs play a crucial role but their nature was left unspecified in the analyses (they mostly took the textbook form of iceberg trade costs). In the present section, we attempt to characterize trade costs: their nature and specific consequences. Trade costs depend on product distribution costs and the costs imposed by policies (tariff and non-tariff measures). There is a rich literature on the impact of standard tariffs/subsidies on trade and welfare surveyed elsewhere (Bagwell and Staiger, 2016), therefore, in this section we discuss instead works on the major actors involved in the distribution of agricultural and food products (wholesalers and retailers), on non-tariff measures, and on trade costs in relation to agricultural price volatility.

[49] This uncertainty in demand may also reconcile the high rate of exit seen in the first years of exporting (see e.g. Peterson et al., 2018).

6.1 Distribution cost

In the standard trade models, it is assumed that the firms distribute their products and the costs related to serving foreign markets are common across firms.[50] In reality, global export costs depend on the organization of distribution adopted by producers. To reach the end consumer, instead of distributing directly its varieties a producer can trade either through an independent intermediary, or through an intermediary that it has acquired. The food manufacturing sector is characterized by the use of specialized wholesalers/retailers with various degrees of partial vertical integration to reach the end consumers (Reardon and Timmer, 2007). Wholesalers in the French food industry account for roughly 30% of agri-food product purchases and 35% of food sectors sales (Gaigné et al., 2015). In the rest of this subsection, we review the literature on the role of intermediaries in trade in agricultural and food products. Their role in trade deserves special attention since a fraction of the gains associated with road and productivity improvements or lower tariffs can be captured by the wholesalers and the retailers.

6.1.1 Intermediaries: distribution technology and market structure

Producers can use intermediation to avoid having to set up their own distribution networks. Intermediaries are viewed as agents that facilitate the matching between foreign buyers and sellers. By offering their network of contacts, intermediaries reduce the buyers' and sellers' matching frictions and search costs but are able to exert market power over the food supply chain (Kopp and Sexton, 2021).

Several authors recast the standard models of trade with heterogeneous firms such that domestic manufacturers can choose between two distribution methods: either exporting directly which implies variable and fixed export costs (as in section 5), or contracting with an intermediary which takes responsibility for the selling activities. Indirect exporting requires the firm to pay a wholesale unit price to reach its markets but frees it from distribution costs. The intermediaries incur fixed and variable distribution costs and maximize their profit by choosing final prices. By handling large product portfolios, intermediaries are able to spread the fixed costs of distribution over several products (economies of scope), and thus, are able to offer cheaper access to foreign markets (Ahn et al., 2011). However, this advantage is countered by lower producer operating profits due to higher consumer prices. In this case, only more productive firms can export directly and behave (approximately) as in the MC model. In addition, by controlling the distribution networks of their varieties, large firms enjoy higher foreign demand and hurts small firms, which lose market share or exit from the foreign markets (Gaigné et al., 2018).

The MC model can be easily extended by assuming that the distribution costs required to reach foreign markets depend on the strategic behaviors of intermediaries and the market structure. Gaigné et al. (2018) assume that intermediaries buy in bulk from producers and then sell the products to end consumers, act strategically (in a vertical manner), and operate under imperfect competition. They study price-setting behavior in vertical structures which include upstream manufacturers that can sell their products through downstream retailers/wholesalers within a multi-country model under general equilibrium. CES demand implies the equilibrium price paid by the consumer (6) becomes $p^k_{ij}(v) = (m^k)^2 c^k_i \tau^k_{ij} / z^k_i(v)$. Hence, we obtain the so-called double-marginalization problem, the markup is $(m^k)^2$, since both manufacturers and intermediaries set prices at a markup over the marginal cost.[51] Using data on French exporters of food products, Gaigné et al. (2018) find that export prices of firms that own their distribution networks are

[50]Note that Arkolakis (2010) assumes that the fixed export costs vary endogenously with the supplier's choice of what fraction of consumers in a market it will serve $e^k_{ij}(v) \in [0, 1]$. Under this configuration, the firm must pay a fixed cost equal to $F^k_{ij}[1 - (1 - e^k_{ij}(v))^{1-\mu}]$ which increases with e, while its operating profit is given by $e^k_{ij}(v)\mathcal{A}^k_{ij}[z^k_i(v)]^{\varepsilon^k - 1}$. The MC model corresponds to the particular case in which $\mu = 0$. When $\mu \in (0, 1)$, exporters can easily find a few customers in a destination market but the costs of building a clientele increases more than proportionately with export sales. This implies that low-productivity firms can reach foreign markets by exporting low volumes.

[51]To reduce the double marginalization, a manufacturer contracting with an intermediary to sell its variety can use different pricing schemes such as two-part tariffs instead of a linear tariff. It charges its intermediary one unit-price for its variety and another price for the right to sell it, i.e. a franchise fee. Under this configuration, as expected, manufacturers set the wholesale price at the marginal cost to avoid the double marginalization problem, and then recoup a share of the intermediary's profit via a fixed fee which increases with the manufacturer's bargaining power. For more details, see the online supplementary appendix of Gaigné et al. (2018).

lower (11% on average), conditional on the firm, product, and destination characteristics. Bergquist and Dinerstein (2020) study the impact of the behaviors of intermediary traders in agricultural markets in developing countries on the prices paid by end consumers. They find evidence of a high degree of intermediary market power in Africa and reveal that traders act consistently with joint profit maximization. Traders pass through to customers only 22% of the reduction in production costs.

Food firms can also be motivated by a strategy of vertical integration to reduce global distribution costs. Among the 14,000 French food firms identified in France in 2012, about 1,500 have equity shares in a wholesaler or in a retailer (Gaigné et al., 2018). According to the industrial organization literature, forward integration takes place to reduce double marginalization and transaction and coordination costs, to enhance market power through foreclusion, or to transfer intangible inputs within firms. Owning distribution networks may help the firm to reduce the fixed distribution costs associated with exports, or to acquire information on foreign markets. Since producers and intermediaries do not necessarily have the same information on foreign markets, owning an intermediary enables the firm to manage the distribution network more efficiently. The MC model with intermediaries can be extended by assuming that wholesalers/retailers may be either independent or controlled by manufacturers (Gaigné et al., 2018). Upstream suppliers may buy a fraction $f(v) \in [0, 1]$ of the intermediary at price $b(f)$. By explicitly allowing manufacturers to modify the nature of the vertical relationship with intermediaries, the double marginalization issue is accounted for and markups become firm-specific. Indeed, under this configuration, Gaigné et al. (2018) show that the price paid by the end consumer is $p_{ij}^k(v) = [\varepsilon^k/(\varepsilon^k + f(v) - 1)]m^k c_i^k \tau_{ij}^k / z_i^k(v)$. It follows that a higher fraction of equity in its intermediary $f(v)$ reduces the negative effect of the double marginalization (no double marginalization if $f(v) = 1$) but increases the cost of acquiring an intermediary, $b(f)$. The authors show that only the most productive firms choose to integrate forward. The costs associated with product distribution are not only specific to the destination but also depend on whether the firm producing the traded variety controls its intermediary. Using firm-level data for the French food industry, Gaigné et al. (2018) confirm that firms self-select to acquire equity shares in intermediaries based on their productivity. The combination of lower marginal costs and lower markups due to intermediary acquisition enables food manufacturers to serve a larger set of destinations. Moreover, the authors show that for a given destination, food firms owning intermediaries enjoy lower market entry costs. The advantage of an own distribution network is magnified if the firm serves foreign countries with low market potential and important market entry costs.

6.1.2 Multinational retailers: network effect and private (voluntary) standards

At the end of the food value chain are the supermarkets which have come to dominate the retail distribution of food, especially in major developed countries. One explanation for this is the scale economies and supply chain efficiencies achievable by big retail companies. In addition, supermarket retailers can be viewed as multi-product platforms which connect consumers with suppliers (Richards and Hamilton, 2013). The large number of products available in supermarkets attracts a large number of consumers. The high number of varieties and products increases the probability that the consumer will find her preferred brand, and allows for "one-stop" shopping which reduces the per-unit costs of filling an entire shopping basket. Hence, food suppliers benefit by selling through a supermarket retailer able to reach a large number of consumers.

A small group of transnational retailers have expanded their overseas activities rapidly beyond the core markets of North America and Western Europe (Cheptea et al., 2019). They have increased their market shares in many countries in Asia, Eastern Europe, and South America. The increased international activities of major retailers are having significant impacts on food supply networks. Retailers investing abroad may continue to source from their suppliers in their origin country. Indeed, retailers continue to contract with their domestic suppliers to save on transaction costs, or because some products are not available locally or are not of the appropriate quality. Information barriers (information on consumers' tastes, etc.) are another obstacle faced by exporters. Hence, domestic producers may benefit from network effects and information externalities generated by the foreign activities of retailers. Thus, the international expansion of retailers may reduce the trade costs of domestic food producers, and in turn, increase their exports.

Some contributions have investigated the impact of multinational retailers on trade in food products. They examine whether international expansion by retailers boosts their home countries' exports. Using bilateral food exports for a large panel of countries over 2000–10, Cheptea et al. (2015) find a positive effect of overseas presence of retailers from a given country on their food exports to those markets. Emlinger and Poncet (2018) focus on the activities of the five largest global retailers in China (Auchan, Carrefour, Metro, Tesco, and Walmart), and confirm these positive spillovers. This effect is due mainly to the presence of European retailers in China which has a strong effect on food imports from the EU.

Based on their market power and the increasing need for quality control over supply chain, retailers are the driving force behind private standards. Fulponi (2006) reports that major food retailers in the OECD countries have responded to sanitary crises by imposing minimum quality standards on increasingly wide sets of food products. Retailers commonly impose private standards on upstream suppliers. The trade effects of these private standards are ambiguous. Private standard implying high compliance and certification costs (Colen et al., 2012) can reduce trade flows by eliminating less efficient producers (compliance costs act as fixed costs). However, private standards reduce the search costs borne by retailers, and in turn, boost import demand.

Latouche and Chevassus-Lozza (2015) analyze the export performance of food firms certified with two European private standards: the International Food Standard and/or the British Retail Consortium standard (BRC). Certified firms are able to supply some European retailers with products sold under their retailers' own private label. The authors show that certified firms are among the biggest and most productive firms in the sample suggesting high compliance costs.[52] In addition, after controlling for firm size and productivity, Latouche and Chevassus-Lozza (2015) show that French firms that adopt the BRC standard and enter the corresponding network enjoy lower access cost to serve foreign markets in the EU compared to other firms. Different empirical studies confirm the network effects on trade. For example, French firms with the private International Featured Standard certification are more likely to export, and mode likely to export larger volumes to markets where French retailers have established outlets compared to noncertified firms (Cheptea et al., 2019). GlobalGAP certification which is now accepted by many main food buyers around the world has a positive effect on imports of fruits and vegetables into the EU15 (Andersson, 2019). Andersson shows also that buyers are more likely to start importing a product from an exporting country with many certified producers. More generally, GlobalGAP certifications involve extra costs for the producers but result in higher import demand (Fiankor et al., 2020).

6.2 Standard-like non-tariff measures

Non-tariff measures cover a large set of policies including technical measures and quantitative restrictions (Disdier and Fugazza, 2020). In this subsection, we discuss some NTMs that are contentious issues in trade negotiations, affect most traded agricultural and food products, and are playing an increasing role in international trade (see stylized fact #2). Mainly involved are quality-related NTMs in the agreements on SPS, on TBT, and on Trade Related Aspects of Intellectual Property Rights (TRIP) which covers "Geographical Indications" (GI) labels.[53] Regulatory measures such as SPS and TBT measures are not per se trade obstacles. They are dedicated to protecting the health of a country's human, animal, or plant populations, and they apply equally to domestic products. So they can be viewed as correctives for market failures due to mainly asymmetric information and externalities. However, they could also be protectionist if governments use technical measures as a trade policy.

These agreements deal with the quality attributes of food products and their production methods. There is a fraction of consumers who show increasing concern for some food characteristics which go beyond quantity, price, and taste and are linked to additional arguments in their utility function, such as health, safety, pollution, and moral aspects.[54]

[52] This sorting effect can be explained also by the model developed in Rauch and Watson (2003). They assume that buyers engage in costly search for suppliers which are heterogeneous in terms of their productivity and their capabilities to deliver specialized products (e.g., own-brand products). If only productivity is costlessly observable, then buyers reject low-productivity sellers, place small trial orders with medium-productivity sellers to learn about the seller's capabilities, and invest in training sellers and place major orders with high-productivity firms.

[53] We do not cover in this chapter the economics of tariff rate quotas.

[54] In our context, moral concerns are related to situations where consumers feel guilt about their responsibility for the externalities imposed on

However, many food products exhibit credence characteristics, i.e. the consumers know what they do or do not want but they cannot observe all of the product's attributes even after consumption (Dulleck et al., 2011; Sheldon, 2017). For example, consumers lack the technical expertise to obtain information on the presence of pesticide residues, genetic modifications, animal welfare, and location and method of production. As a result, credence characteristics create asymmetric information problems. The introduction of quality labels and standards can be used to address the credence good problem.

6.2.1 Information asymmetry and standards in trade theory

To discuss the economic effects of standards-like measures, the MC model is extended by considering an economy with asymmetric information on product quality and heterogeneous firms. Although the producer knows its product quality, this may not be observable by consumers. In this context, $\xi^k_{ij}(\nu)$ depends on the information available to consumers. Disdier et al. (2021) consider two polar cases. The first corresponds to the framework developed in section 5.3. If credible and truthful disclosure is feasible, consumers know the exact attributes of any variety and $\xi^k_{ij}(\nu)$ is given by (5). Second, if this quality cannot be precisely observed by the consumers, consumers—who are risk-neutral—do not consider the quality of each variety but rather the average quality so that $\xi^k_{ij}(\nu) = \bar{\xi}^k_{ij}$.

If the quality of the varieties sold by firms is not observed by consumers (they know only the average quality of the product), this provides incentives for producers to pass off low-quality goods as high-quality ones. However, consumers account for these incentives by judging the quality of goods as uncertain. In this case, exports are increasing with average quality ($\bar{\xi}^k_{ij}$) and the firm's productivity. Hence, if the average quality in the destination market increases, consumers are willing to pay more for all goods imported from country i. Under these circumstances, high-quality producers share their benefits with low-quality producers. Nevertheless, information asymmetry implies $\partial x^k_{ij}(\nu)/\partial\theta^k_{ij}(\nu) < 0$ for a given productivity because the price increases as the marginal costs rise with quality while $\xi^k_{ij}(\nu) = \bar{\xi}^k_{ij}$ does not adjust (treated as an exogenous variable by firms under information asymmetry due to the assumption of a continuum of firms). As a consequence, under information asymmetry, the best strategy for all firms whatever their productivity level is to reduce the quality of its varieties. Since consumers only know the average quality of the product, their demand for (expensive) top-quality products is lower. Although they are preferred by consumers, high-quality products are driven out of the market by low-quality products (Akerlof's lemons principle). Thus, the quality supplied by firms is lower under information asymmetry than under perfect information. Also, $\bar{\xi}^k_{ij}$ shrinks so that demand for the varieties supplied by firms decreases, and some firms exit the market because of fixed costs.

Firms may decide to invest in quality signaling and choose strategically to disclose information to uninformed consumers about the quality of their product. Disdier et al. (2021) assume that truthful and credible disclosure is feasible whereas misrepresentation is impossible. Quality disclosure can take different forms. Sellers may make the quality of their products known to the purchaser through a guarantee issued by an independent third party (certification). Formally, if a firm located in country i producing product k invests in quality signaling for consumers living in country j, then the quality of the variety supplied by the firm ($\theta^k_{ij}(\nu)$) is perfectly observed by foreign consumers and is given by (25). However, quality-signaling activities imply a sunk cost for the firm and this cost varies across origin countries, destination markets, and products (e.g., the cost of obtaining certification of product quality from an independent third party). It follows that a firm invests in quality signaling and exports if and only if its productivity is sufficiently high. However, the productivity cutoff above which a firm can profitably export is higher under information asymmetry than under perfect information due to the additional cost associated with the signaling activity.

While small firms may be unable individually to invest in quality signaling, there is scope for producers to act cooperatively. As in Moschini et al. (2008), GIs can be interpreted as a common brand allowing sharing of the marketing, promotion, and certification costs required for a credible GI. In a MC model with endogenous quality and information asymmetry, GI membership is driven by two opposite forces. Producers form a coalition and adopt a common label (a common quality) in order to decrease the fixed costs associated with signaling activity. However, the common

citizens (or living beings) located in the trading partners.

quality-adjusted price imposed by the coalition deviates from the optimal quality-adjusted prices of individual members which implies lower operating profits. The number, size, and composition of the coalition in this economic context merit more research.

Alternatively, each country could introduce a standard setting a minimum quality ($\underline{\theta}_j^k$). The concept of a "minimum standard" makes sense in the context of vertically differentiated products. It implies that only products reaching a certain or higher level of "quality or attainment" are considered to meet the relevant standard. A firm can serve foreign market j if and only if $\theta_{ij}^k(\nu) \geq \underline{\theta}_j^k$. Gaigné and Larue (2016) extend the MC model to study the impact of minimum public standards when firms choose strategically the quality of their product. Under perfect information, Gaigné and Larue show that $\theta_{ij}^k(\nu) = \underline{\theta}_j^k[z_i^k(\nu)/z_{ij}^k]^{\rho^k}$ instead of (25) where z_{ij}^k depend negatively on $\underline{\theta}_j^k$ instead of $\underline{\theta}_{ij}^k$. For instance, a stricter quality standard (inducing higher fixed and variable production costs for all domestic and foreign producers) benefits highly productive firms which gain from the quality-induced exit of less productive domestic and foreign firms. Macedoni and Weinberger (2022) extend the framework developed in Gaigné and Larue (2016) by accounting for variable markup and confirms this finding. As in Marette and Beghin (2010), quality standards are not protectionist if foreign producers are more efficient than domestic producers at complying with them. However, under information asymmetry, Disdier et al. (2021) show that only firms with a high enough productivity can export but that the quality of exported varieties is equal to the minimum quality $\theta_{ij}^k(\nu) = \underline{\theta}_j^k$ without quality signaling activity. As in the standard literature, quality standards can solve "lemons" type problems in markets with asymmetric information by increasing the average quality of products (Ronnen, 1991). Hence, under information asymmetry, the introduction of a quality standard tends to increase the number of varieties available in market j and increases average quality.

The effects of quality standard on welfare is ambiguous. On the one hand, quality standard can facilitate trade and improve welfare when consumers can neither correlate product quality with price nor perfectly judge it even after consumption. As mentioned above, the demand for foreign products may increase due to a better quality of products or due to a reduction in informational asymmetries between domestic consumers and foreign producers. In addition, a stricter quality standard yields a better reallocation of resources from low-productivity low-quality firms to high-productivity high-quality firms. On the other hand, there are two distortions associated with the introduction of a minimum quality when imperfect competition prevails: (i) a distortion on the distribution of the quality-adjusted prices (some firms have to adopt the minimum standard while the optimal quality for those firms without quality standard differs); and (ii) an entry distortion implying less varieties available in the country. Even if the public mandatory standards imposed by national governments are applied in a non-discriminatory way (between domestic and foreign firms), standards can be "post-discriminatory" agreements and eliminate trade because of additional variable and fixed costs of production (compliance costs and the lack of transparency). This effect is exacerbated when standards differ among countries, which significantly increases the cost of doing business internationally.[55] Such measures may remove product varieties that consumers demand but which do not satisfy the standard.

Hence, the relationships between standard-like measures and welfare are complex. Although standard-like non-tariff may alleviate market failures (negative externalities and information asymmetry), they can also create distortions.

6.2.2 Geographical indications and trade: empirical evidence

Geographical indications are a contentious issue in trade negotiations and disputes. These tensions arise from the significant differences in the EU, US, Canadian, and Australian approaches (Josling, 2006). The EU's efforts to promote GIs in multilateral and bilateral negotiations conflict with the view of Anglo-Saxon countries which historically prefer to rely on trademarks. Although GIs are protected by the WTO Agreements on TRIPS which oblige WTO members to recognize and protect GIs as intellectual property, some countries such as the US consider some GIs to be generic terms. For example, the US consider feta to be the generic name for a type of cheese, whereas it is protected as a GI in Europe. As a result, cheese produced in the US may not be exported for sale as feta cheese in the EU, since feta is produced only

[55] In the presence of switching costs and network externalities, consumers welfare maximizing governments may have no incentive to force its producers to comply with the international standard (Barrett and Yang, 2001).

in EU regions. More than 1,500 food product names are registered and protected in the EU (Duvaleix et al., 2021). The inclusion of GI protection is increasing in various regional and bilateral trade pacts. The protection of GIs was very controversial in the negotiation between the EU and Canada (and Japan). Canada has agreed to recognize a list of 143 EU GIs (Japan more than 200 EU GIs). According to the US, these GI protections could reduce US exports of food products to Canada and Japan.

Studies have tried to identify the empirical impact of GIs on trade. Quantifying the effects of GIs on trade flows is challenging since information on trade in varieties that are GI-protected is not recorded in a database, and therefore, indirect measures are needed. Empirical studies use the number of GIs per product category to identify the flows that include potential GI varieties. Sorgho and Larue (2014) was the first study to quantify the effect of GIs on bilateral trade within the EU using a structural gravity equation. They use information on the number of GIs in force for agricultural products in each country. They document that these effects vary according to whether or not the importing country has GI-protected products. Bilateral trade in agricultural and food products is higher if both the exporting and importing countries have GIs. In a more disaggregated analysis (2-digit level), Sorgho and Larue (2017) find that the effect of GIs on European trade is ambiguous, due to international heterogeneity in consumer preferences. Raimondi et al. (2020) use a dataset with trade flows at the country and product (6-digit level) levels to estimate the effect of GIs on intra- and extra-EU trade margins. They show that having GIs in an HS6 line has a positive effect on trade and prices in both European and non-European countries.

The studies cited above analyze the effect of GIs at the aggregate level (country imports of HS2 or HS6 products). To identify the impact of GI on trade requires more precise information. The 8-digit level product classification allows this more precise identification. For example, studying trade in wine, Agostino and Trivieri (2014) use the official product 8-digit classification since wines are defined at this level as GI or not. Similarly, Curzi and Huysmans (2022) build a rich dataset on trade in cheeses using 235 EU cheese GIs registered up to 2018 which they match manually to the corresponding 8-digit category. They find that legal protection of GIs in trade agreements does not generally lead to significant additional exports (the effect is not any higher than the general export-promoting effects of trade agreements), with the exception of higher quality GI products. To obtain information on trade in varieties with a GI protection, Duvaleix et al. (2021) consider exports at the firm-product level. The authors exploit a unique exhaustive list of firm-(8-digit)product pairs with protected designation of origin (PDO) certification in France. Since only certain firms are authorized to handle GI products, GI flows can be identified from trade datasets which account for firm-product (8-digit) pairs. By exploiting the differences between PDO and non-PDO firm-product pairs, for a given destination and a given 8-digit product, they find that GI varieties are perceived by consumers as being of higher quality than non-GI varieties, and that the prices of GI varieties are 11.5% higher than those for non-PDO varieties.

6.2.3 Public standards and trade: empirical evidence

NTMs include a wide set of measures: non-tariff barriers (discriminatory policies such as price and quantity controls) and measures which address regulatory standards aimed at correcting for market failure (e.g., health and consumer safety, and pollution and the environment). The mandatory public standards established by national governments such as SPS measures and TBTs have become increasingly important in global food chains (see figure 2b).[56] Agricultural and food products are more affected by NTMs than manufactured products (Beghin et al., 2015b). Countries develop their own sets of standards with some guidance from the Codex Alimentarius and the WTO Sanitary and Phytosanitary Agreement. Although quality standards are not a priori discriminatory measures (since they must be respected by both foreign and domestic firms), it is not surprising that public standards are at the heart of many trade disputes at the WTO,[57] and there has been much concern about the misuse or mischaracterization of public standards as non-tariff barriers. The incidence of those public quality standards on trade and welfare has received growing interest in agricultural economics (Beghin et al., 2015a).

[56]For example, national policy makers set rules on additives and contaminants in the food and drink sector.

[57]Between 1995 and 2017, 470 SPS-related and 549 TBT-related trade concerns were raised (source: WTO, http://spsims.wto.org/ and http://tbtims.wto.org/).

Most of the evidence on the impact of quality standard on trade flows are based on product level observations. The trade effect of quality standards has been studied mainly using a gravity model framework. Results suggest that agricultural and food products are more affected by NTMs than manufactured products. Disdier et al. (2008) find a negative effect of SPS and TBT measures on trade in agri-food products. However, they highlight that those measures have no significant impact on OECD country exports but have a negative and significant effect on developing country exports. Curzi et al. (2018) and Xiong and Beghin (2012) confirm this finding focusing on maximum pesticide residue levels and veterinary drugs levels allowed by the EU for agri-food imports. Disdier and Marette (2010) and Winchester et al. (2012) found also that trade is significantly reduced if the importing country has stricter maximum residue limits (MRLs) for plant products than exporting countries.

The effects of quality standards on the intensive and extensive margins also differ. For example, Ferro et al. (2015) found that stricter pesticide residue limits tend to increase fixed export costs and that the effect of stricter standards is mainly at the extensive margin. Once exporters adjust their production to comply with the standards of the destination country, those have no impact on the intensity of their exports to that market. These results confirm also that developing country exporters are more constrained by those standards than their rivals in developed countries. In addition, Traoré and Tamini (forthcoming) find that the imposition of strict MRLs for pesticides in developed countries reduced total production of mangoes in African countries. Fernandes et al. (2019) study the impact of pesticide standards on firm exports of agricultural products across countries and time. They conclude that imposing a lower legally-tolerated level of pesticide residues in products lowers the probability that the firms will export and also reduce their export values and quantities. They find that smaller exporters are affected more negatively by the relative stringency of standards than are larger firms.

In contrast, measures requiring trading partners to adopt a common NTM (harmonization) or reciprocal acceptance of NTMs (mutual recognition) can be trade-enhancing. Since the early 2000s, the deep trade agreements which aim at regulating the use of SPS and TBT measures by favoring mutual recognition or harmonization have increased (Mattoo et al., 2020). Frahan and Vancauteren (2006) suggest that although the harmonization of standards has a positive and significant impact on intra-European trade, the effect is small for meat and dairy industries. More research evaluating the effects of deep trade agreements is needed to better understand the impacts of SPS and TBT measures on food trade and real income.

Furthermore, the diffusion of standards tends to have positive effects on product quality. Using data on French food firms, Disdier et al. (2021) document that the introduction of SPS measures and TBTs in foreign markets increase the probability of exporting and the value of exports for the most productive French exporters supplying high-quality products but reduce exporting probability for the least productive French firms regardless of the quality of their varieties. In an investigation of firm-level exports from Peru, Curzi et al. (2020) report that only the most restrictive standards have a significantly effect on limiting agri-food exports but they result in product quality upgrading. In contrast, regular SPSs are found only to enhance trade. In a study of food-processing firms in Ukraine in 2008–13, Movchan et al. (2020) found that more SPS regulations on inputs in upstream industries lead to exports of better-quality products. One exception in this literature strand is Fiankor et al. (2021). They estimate different gravity-type models which exploit the bilateral differences in MRLs for 145 products over 2005–14 and across 59 countries and report that cross-country differences in MRLs restrict trade and increase product prices but do not affect product quality.

We lack empirical evidence regarding the effects of NTMs on the price index and food production of agricultural and food products. The welfare evaluations in Disdier and Marette (2010) show that stricter standards related to MRLs can be welfare enhancing. Cheptea et al. (2021) quantify the potential effects of post-Brexit regulatory divergence between the UK and the EU on trade flows and real incomes, and find that, were the UK to adopt different SPS measures and TBTs, the effect would be limited.

6.3 Trade costs and agricultural price volatility

Section 4.3 showed that the gains from trade in agricultural products materialize also through lower price volatility thanks to the partial smoothing of idiosyncratic shocks. These gains emerge in the absence of barriers limiting the transmission of price incentives. In this section, we consider two kinds of trade costs that can limit this transmission: (i) trade policy adjustments that are contingent to border prices, and (ii) information flows that are complementary to trade flows when information travels faster than goods.

6.3.1 Trade policy adjustments

The existence of idiosyncratic shocks is both a reason for countries to participate in the world market in order to benefit from a more stable market, and to isolate from the world market if the local shock is more favorable than the global aggregate shock. This applies to several instances in the last two decades and particularly between 2007 and 2012 in relation for example to export restriction in Russia and Ukraine (Götz et al., 2013), numerous export bans applied in Sub-Saharan African countries (Porteous, 2017), and a series of interventions affecting most of the major rice market players (Headey, 2011). These repeated interventions and the important volatility of agricultural markets between 2007 and 2012 caused renewed academic interest in the issue following decades of little attention.

In the literature, the economic motivations behind trade policy interventions in relation to world volatility are of the second-best kind. Gouel and Jean (2015) propose that one motivation for trade policy interventions countercyclical to world prices is the presence of risk-averse consumers if risk markets are incomplete. In this setting, stabilizing domestic prices can improve welfare in the domestic economy. However, the optimal policy in this setting would be to put in place countercyclical safety nets to mimic the effect of the missing markets for risk. Pieters and Swinnen (2016) extend Gouel and Jean's framework by also accounting for producers' risk aversion. They show that the optimal trade policy of a small-open economy is to smooth world price variations, the domestic price being a weighted average of the world price and its mean, with a weight function of the agents' risk aversion. Such behavior is similar to what is practiced by many countries with large populations relying on staple foods: long-run variations in the world price are followed but trade policies are adjusted to insulate the domestic price from short-run variations (Anderson and Nelgen, 2012; Ivanic and Martin, 2014).

Giordani et al. (2016) propose an alternative explanation for these interventions by considering that agents, consumers, and producers are loss averse (following the framework developed in Freund and Özden, 2008), so are more sensitive to a reduction in their utility from consumption below a reference point than to a corresponding increase. In this setting, the interventions are aimed not at mitigating price volatility but limiting the downside risk for each agent category, but as in Gouel and Jean (2015) and Pieters and Swinnen (2016) it leads to a policy offsetting world price movements. Giordani et al. (2016) confirm the empirical validity of these theoretical predictions. Regressing trade policy utilization on price deviation from its recent trend instrumented by climatic conditions, they show that positive deviations in prices cause more trade policy utilization in the form of export restrictions and reduction of import protection.

Another contribution by Giordani et al. (2016) shows theoretically that if many countries apply the same countercyclical trade policies this has a multiplier effect: a given world price increase is amplified by all the policies trying to offset it (a result provided also by Gouel, 2016, and Martin and Anderson, 2012). A corollary to this is that trade policies are strategic complements: a country's trade policy adjustments (increasing export taxes or decreasing import tariffs when prices increase) incite the other countries to adjust their own policies in the same direction due to the effect on world prices. Both results are important because they highlight that although it makes sense for a single country to isolate itself from world price fluctuations, this behavior collectively becomes self-defeating if generalized. If when world prices increase all importing countries decrease their tariffs and all exporting countries put in place export taxes, these policies will tend to compensate for each other and will raise world prices.[58] Giordani et al. (2016) confirm empirically

[58] It should be noted that substituting trade policies by direct transfers to the poor, which is the first-best intervention, would not avoid price rises because of the existence of non-homothetic preferences (Do and Levchenko, 2017). However, direct transfers would not alter the incentives of the other economic agents, such as producers and storers.

the presence of a multiplier effect by regressing world price changes on global trade restrictions instrumented by past price changes, expected elections in the top trading countries, and prevalence of non-tariff barriers. They find that these trade reactions explain between 22% and 56% of the price spikes in 2008–11. Martin and Anderson (2012) suggest a similar order of magnitude based on a back-of-the-envelope calculation and a simple supply and demand model.

The reality is far from perfect offsetting of the exporters' policies by the importers, because the interventions are heterogeneous. Countries have different incentives depending on their level of development, their trade situation, and their fiscal space. For example, an important difference between the 1972/3 and the 2007/8 food crises was that in the latter case high-income countries abstained from the extreme policy interventions such as export restrictions and import subsidies which they imposed in 1972/3. Another asymmetry is related to enforcement. Porteous (2017) shows that in several East and Southern African countries, export bans were ineffective to create price gaps at the borders due most likely to the importance of informal trade in these countries. These asymmetries mean that the burden of the adjustments to high prices shifts to those countries that do not adjust their policies as much, or cannot adjust them to the same extent as the other countries. An illustration is provided by Götz et al. (2013) using the case of the Russian and Ukrainian wheat export restrictions in 2007/8. They show that while the policies were in force these markets displayed a reduced degree of integration with the world market accompanied by lower producer prices, in contrast with Germany and the US which did not intervene in their markets. To understand the overall food security and poverty impacts of these countercyclical protections, we need to combine the relative level of a country's price insulation with respect to the rest of the world, with its relative level of poverty. If countries with higher shares of poor population are also those which insulate more, then these policies may contribute to reducing global poverty. This is the finding of Anderson et al. (2014) who combined Martin and Anderson's supply and demand model with household survey data.

Despite this eventually fortunate combination of policies, concerns have been raised that by destabilizing world markets, these policies could push countries toward costly self-sufficiency policies. So disciplining them has been an important policy objective following the 2007/8 food crisis. However, the prospects for improving this prisoner's dilemma situation are small. Coordination problems such as these tend to be dealt with within the framework of the WTO. Notwithstanding the stalled WTO negotiations, these issues are unlikely to find agreement. The first problem is related to the incentives. To be incentive-compatible in all situations, trade agreements usually include rule exceptions (Bagwell and Staiger, 1990) such as special protections which can be applied in the case of high import volumes or low import prices. When considering the issue of food price volatility, these exceptions risk being asymmetrical because of the skewed distribution of food prices (Gouel, 2016). Storable agricultural products have a positively skewed distribution because speculative storage tends to reduce the occurrence of low prices but cannot reduce the occurrence of high prices to the same extent. According to Gouel, this implies that to accept an agreement disciplining countercyclical trade policies food-exporting countries must retain the right to special protection in times of high prices because high prices create strong incentives to deviate from agreements, incentives that are much higher than those faced by importing countries in times of low prices, because the skewed distribution implies that these low prices will never fall far below the mean. A second problem is enforcement (Cardwell and Kerr, 2014). International agreements require enforcement mechanisms, and according to Cardwell and Kerr, the WTO dispute settlement system cannot enforce such disciplines because export restrictions are of short duration compared to the time taken to settle disputes, and because the potential complainant countries, which would be mostly poor net-food-importing countries, may not be in a position to retaliate owing to insufficient bilateral trade levels with the offending countries.

6.3.2 Information flows

Trade can stabilize agricultural prices and increase welfare but, over long distances or in the case of poor infrastructure, trade is costly and takes time which could limit its effectiveness to do so. If the local situation has changed since the order was place, when shipments finally arrive, they may be too small or too large. So trade can be complemented by information transmission. If information travels faster than goods, shipments can be re-ordered as the situations evolve. The immediacy of information is taken for granted today; a production shock in Argentina and Brazil has a contemporaneous effect on US commodity futures markets with no need to wait for the harvest to be completed or for the trade flows to occur (Lybbert et al., 2014; Merener, 2015). So we may neglect the important role played by information in enabling the stabilizing role of trade. Old and recent historical episodes of faster information transmission can provide good natural experiments to study the interactions between trade and information flows.

An interesting event for our purpose is the development of the telegraph. Before the telegraph, over long distances information barely traveled faster than goods. Steinwender (2018) studies the case of the establishment of the transatlantic telegraph in 1866 and its effect on the United States–United Kingdom cotton market. She shows that the faster information transmission allowed by the telegraph reduced the price difference between New York and Liverpool by 35%, despite the fact that there was already regular trade between them.[59] The information flows had also real effects: they increased exports and their variance since they were more responsive to news from Liverpool. These empirical results are consistent with the prediction of a stylized two-country rational expectations storage model extended to account for information delays. The results refer to an efficient ocean shipping context but can be found in other contexts. The telegraph was important also within countries; for instance, in the case of colonial India, transport costs could be very heterogeneous and before railroads could be prohibitive over long distances (Andrabi et al., 2021). Andrabi et al. show that the implementation of the telegraph reduced price gaps in rice and wheat trade but that this reduction was mediated by distance: the effect of the telegraph declines with the distance between two districts.

This complementarity between trade and information to achieve price stability and convergence has been highlighted by the literature on cellphone availability (Aker, 2010; Jensen, 2007) which finds an additional benefit for perishable goods since timely information reduces spoilage. One formalization of information friction in a trade context is provided by Allen (2014). Allen develops an alternative setting to Eaton and Kortum (2002) to represent Ricardian trade, and applies it to crops, emphasizing the interactions between heterogeneity of producer size and search costs under incomplete information about the selling prices in the various regions. He shows that information frictions help to explain trade and price data patterns which are inconsistent with a complete information framework. By preventing price differences from being arbitraged among regions, information frictions play the role of additional trade costs above freight costs. Mobile phone access contributes to reducing these frictions but does not eliminate them.

7 Conclusions

This chapter provides an overview of the last two decades of economic literature analyzing international trade in agricultural and food products. A summary of what has driven progress in this field would emphasize the convergence of various innovations: new theories accounting for economic heterogeneity (Eaton-Kortum and Melitz), new data (archive, firm-level, rich spatial data such as yields and transport networks), new multidisciplinary questions (climate change, nutrition), and new approaches (credibility revolution, parsimonious quantitative trade models). This chapter also identifies in each section various directions for continued research effort.

These innovations have led to a very different field. In the previous survey conducted by Karp and Perloff (2002) the authors note that "government policy has been the *raison d'être* for the discipline". Our more limited coverage of agricultural and trade policies in this chapter shows that this no longer applies and new questions have emerged related for instance to the mechanisms driving comparative advantage in agriculture and analysis of food industry firms' decisions. Nevertheless, trade policies are still important and have evolved beyond tariffs and quantitative restrictions to include standards that are at the heart of negotiations in modern trade agreements. This new landscape calls for more attention to be devoted to deep trade agreements, whose goals are beyond traditional trade policies. Trade agreements have been deepening since the 2000s to include trade-related regulatory issues such as mutual recognition or harmonization of standards, but also policy areas that are not directly related to trade such as environmental and labor issues. Future contributions should quantify the impacts of such deep trade agreements on agri-food trade and welfare.

A lot of the literature reviewed in this chapter focuses on the size of the gains from trade with three limits we

[59] A result confirmed in the case of wheat trade between Chicago and Liverpool by Ejrnæs and Persson (2010).

would like to evoke in this conclusion. First, although aggregate gains are positive due mainly to lower quality-adjusted prices, agri-food trade liberalization generates winners and losers. More research should document the impact of globalization on the distribution of gains and losses along the food value chain and within each stage, which involves farmers, food processors, distributors, and consumers. In particular, we lack theoretical and empirical analysis on the role of multinational food companies and agricultural trade policy on the sharing of value added among stakeholders and among countries. Second, the quantification of the gains from trade discussed in this chapter are variations of a "simple" exercise that considers long-run responses to foreign shocks and trade costs. In this exercise, there are no obstacles to the reallocation of resources across sectors. Yet, factors used in agricultural production face high adjustment costs in the short run due to sector-specific skills and capital. Some owners of specific resources initially employed in agricultural sectors would lose from trade-related changes in the short run and this issue is too often neglected. Third, such modeling exercises focus on standard economic mechanisms, which are easy to model, neglecting the fact that the agri-food sectors are activities generating economy-wide externalities in production or consumption. Agricultural and food sectors provide productive spillovers, ecosystem services, and consumption amenities (natural amenities, food security, cultural amenities). If included in quantitative trade models, such amenities could have the potential to drastically alter standard conclusions.

The gravity model and the quantitative trade models which are built on it are central in this survey and are great unifying tools in the trade literature allowing simple links between models and data. However, this simplicity has some limitations and it is important also to pursue alternative approaches when studying agri-food trade. For example, some issues such as the study of uncertainty and price volatility in relation to trade made little use of these frameworks and rely on other more adapted tools. Finally, the parsimony of the new generation of quantitative trade models used, while fostering model mechanism transparency, can also contribute to a disconnection of the field from the rest of the agricultural economics profession by neglecting the micro-econometrics evidence generated by the latter (e.g., use of Cobb-Douglas functions everywhere unless elasticities can be estimated easily). To avoid this outcome, trade economists should practice what they preach by recognizing the value of the division of labor so that not all trade papers should include new estimations of demand and supply elasticities or unfounded assumptions about them.

References

Adamopoulos, T. (2020). *Spatial Integration and Agricultural Productivity: Quantifying the Impact of New Roads*. Working paper (cit. on p. 21).

Adão, R., A. Costinot, and D. Donaldson (2017). "Nonparametric Counterfactual Predictions in Neoclassical Models of International Trade". *American Economic Review*, 107(3), 633–689. doi: 10.1257/aer.20150956 (cit. on p. 26).

Aggarwal, S. (2018). "Do rural roads create pathways out of poverty? Evidence from India". *Journal of Development Economics*, 133, 375–395. doi: 10.1016/j.jdeveco.2018.01.004 (cit. on p. 21).

Aggarwal, S., B. Giera, D. Jeong, J. Robinson, and A. Spearot (2018). *Market Access, Trade Costs, and Technology Adoption: Evidence from Northern Tanzania*. Working paper 25253. NBER. doi: 10.3386/w25253 (cit. on pp. 17, 21).

Agostino, M. and F. Trivieri (2014). "Geographical indication and wine exports. An empirical investigation considering the major European producers". *Food Policy*, 46, 22–36. doi: 10.1016/j.foodpol.2014.02.002 (cit. on p. 45).

Ahn, J., A. K. Khandelwal, and S.-J. Wei (2011). "The role of intermediaries in facilitating trade". *Journal of International Economics*, 84(1), 73–85. doi: 10.1016/j.jinteco.2010.12.003 (cit. on p. 40).

Aizenman, J. and E. Brooks (2008). "Globalization and Taste Convergence: the Cases of Wine and Beer". *Review of International Economics*, 16(2), 217–233. doi: 10.1111/j.1467-9396.2007.00659.x (cit. on p. 27).

Aker, J. C. (2010). "Information from Markets Near and Far: Mobile Phones and Agricultural Markets in Niger". *American Economic Journal: Applied Economics*, 2(3), 46–59. doi: 10.1257/app.2.3.46 (cit. on p. 49).

Allen, T. (2014). “Information Frictions in Trade”. *Econometrica*, 82(6), 2041–2083. doi: 10.3982/ecta10984 (cit. on p. 49).

Allen, T. and D. Atkin (2016). *Volatility and the Gains from Trade*. Working paper 22276. NBER. doi: 10.3386/w22276 (cit. on p. 25).

Anderson, J. E. and E. van Wincoop (2003). “Gravity with Gravitas: A Solution to the Border Puzzle”. *American Economic Review*, 93(1), 170–192. doi: 10.1257/000282803321455214 (cit. on pp. 3, 11).

Anderson, J. E. (2010). *The Gravity Model*. Working paper 16576. NBER. doi: 10.3386/w16576 (cit. on p. 35).

Anderson, K., M. Ivanic, and W. J. Martin (2014). “Food Price Spikes, Price Insulation and Poverty”. In: *The Economics of Food Price Volatility*. Ed. by J.-P. Chavas, D. Hummels, and B. D. Wright. National Bureau of Economic Research conference report. University of Chicago Press. Chap. 8, pp. 311–339. url: http://www.nber.org/chapters/c12818 (cit. on p. 48).

Anderson, K. and S. Nelgen (2012). “Trade Barrier Volatility and Agricultural Price Stabilization”. *World Development*, 40(1), 36–48. doi: 10.1016/j.worlddev.2011.05.018 (cit. on p. 47).

Anderson, K., G. C. Rausser, and J. F. Swinnen (2013). “Political Economy of Public Policies: Insights from Distortions to Agricultural and Food Markets”. *Journal of Economic Literature*, 51(2), 423–477. doi: 10.1257/jel.51.2.423 (cit. on pp. 3, 22).

Anderson, S. P., A. de Palma, and J.-F. Thisse (1992). *Discrete Choice Theory of Product Differentiation*. Cambridge, MA: The MIT Press. doi: 10.7551/mitpress/2450.001.0001 (cit. on p. 9).

Andersson, A. (2019). “The trade effect of private standards”. *European Review of Agricultural Economics*, 46(2), 267–290. doi: 10.1093/erae/jby027 (cit. on p. 42).

Andrabi, T., S. Bharat, and M. Kuehlwein (2021). *Information and Price Convergence: Telegraphs in British India*. Working paper 04/2021. BASE University. repec: p/alj/wpaper/04-2021 (cit. on p. 49).

Antràs, P. and D. Chor (2018). “On the measurement of upstreamness and downstreamness in global value chains”. In: *World Trade Evolution*. Ed. by L. Y. Ing and M. Yu. London: Routledge. Chap. 5, pp. 126–194. doi: 10.4324/9781351061544-5 (cit. on p. 9).

Antràs, P. and C. F. Foley (2015). “Poultry in Motion: A Study of International Trade Finance Practices”. *Journal of Political Economy*, 123(4), 853–901. doi: 10.1086/681592 (cit. on p. 38).

Arkolakis, C. (2010). “Market Penetration Costs and the New Consumers Margin in International Trade”. *Journal of Political Economy*, 118(6), 1151–1199. doi: 10.1086/657949 (cit. on p. 40).

Arkolakis, C., A. Costinot, and A. Rodríguez-Clare (2012). “New Trade Models, Same Old Gains?” *American Economic Review*, 102(1), 94–130. doi: 10.1257/aer.102.1.94 (cit. on pp. 12, 36).

Asher, S. and P. Novosad (2020). “Rural Roads and Local Economic Development”. *American Economic Review*, 110(3), 797–823. doi: 10.1257/aer.20180268 (cit. on p. 19).

Atkin, D. (2013). “Trade, Tastes, and Nutrition in India”. *American Economic Review*, 103(5), 1629–1663. doi: 10.1257/aer.103.5.1629 (cit. on p. 27).

Atkin, D. and D. Donaldson (2015). *Who’s Getting Globalized? The Size and Implications of Intra-national Trade Costs*. Working paper 21439. NBER. doi: 10.3386/w21439 (cit. on p. 19).

Bagwell, K. and R. W. Staiger (1990). “A Theory of Managed Trade”. *American Economic Review*, 80(4), 779–795. JSTOR: 2006707 (cit. on p. 48).

— eds. (2016). *Handbook of Commercial Policy*. Amsterdam: Elsevier. url: https://www.sciencedirect.com/handbook/handbook-of-commercial-policy (cit. on pp. 3, 39).

Baldos, U. L. C. and T. W. Hertel (2015). “The role of international trade in managing food security risks from climate change”. *Food Security*, 7(2), 275–290. doi: 10.1007/s12571-015-0435-z (cit. on p. 23).

Baldos, U. L. C., T. W. Hertel, and F. Moore (2019). “Understanding the Spatial Distribution of Welfare Impacts of Global Warming on Agriculture and Its Drivers”. *American Journal of Agricultural Economics*, 101(5), 1455–1472. doi: 10.1093/ajae/aaz027 (cit. on pp. 23, 24).

Baldwin, R. and J. Harrigan (2011). “Zeros, Quality, and Space: Trade Theory and Trade Evidence”. *American Economic Journal: Microeconomics*, 3(2), 60–88. doi: 10.1257/mic.3.2.60 (cit. on p. 33).

Barrett, C. B., T. Reardon, J. F. Swinnen, and D. Zilberman (forthcoming). “Agri-food Value Chain Revolutions in Low- and Middle-Income Countries”. *Journal of Economic Literature*. doi: 10.1257/jel.20201539 (cit. on p. 26).

Barrett, C. B. and Y.-N. Yang (2001). “Rational incompatibility with international product standards”. *Journal of International Economics*, 54(1), 171–191. doi: 10.1016/S0022-1996(00)00082-9 (cit. on p. 44).

Bas, M., T. Mayer, and M. Thoenig (2017). “From Micro to Macro: Demand, Supply, and Heterogeneity in the Trade Elasticity”. *Journal of International Economics*, 108, 1–19. doi: 10.1016/j.jinteco.2017.05.001 (cit. on p. 26).

Beghin, J. C., M. Maertens, and J. F. Swinnen (2015a). “Nontariff Measures and Standards in Trade and Global Value Chains”. *Annual Review of Resource Economics*, 7(1), 425–450. doi: 10.1146/annurev-resource-100814-124917 (cit. on p. 45).

Beghin, J. C., A.-C. Disdier, and S. Marette (2015b). “Trade restrictiveness indices in the presence of externalities: An application to non-tariff measures”. *Canadian Journal of Economics*, 48(4), 1513–1536. doi: 10.1111/caje.12157 (cit. on p. 45).

Bergquist, L. F. and M. Dinerstein (2020). “Competition and Entry in Agricultural Markets: Experimental Evidence from Kenya”. *American Economic Review*, 110(12), 3705–3747. doi: 10.1257/aer.20171397 (cit. on p. 41).

Bergquist, L. F., B. Faber, T. Fally, M. Hoelzlein, E. Miguel, and A. Rodríguez-Clare (2019). *Scaling Agricultural Policy Interventions: Theory and Evidence from Uganda*. Working paper (cit. on p. 21).

Bergstrand, J. H. (1989). “The Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade”. *Review of Economics and Statistics*, 71(1), 143–153. JSTOR: 1928061 (cit. on p. 14).

Bernard, A. B., J. B. Jensen, S. J. Redding, and P. K. Schott (2007). “Firms in International Trade”. *Journal of Economic Perspectives*, 21(3), 105–130. doi: 10.1257/jep.21.3.105 (cit. on p. 28).

Bertoletti, P., F. Etro, and I. Simonovska (2018). “International Trade with Indirect Additivity”. *American Economic Journal: Microeconomics*, 10(2), 1–57. doi: 10.1257/mic.20160382 (cit. on p. 37).

Bisin, A. and T. Verdier (2014). “Trade and Cultural Diversity”. In: *Handbook of the Economics of Art and Culture*. Ed. by V. A. Ginsburgh and D. Throsby. Vol. 2. Amsterdam: Elsevier. Chap. 17, pp. 439–484. doi: 10.1016/B978-0-444-53776-8.00017-9 (cit. on p. 27).

Blanchard, P., J.-P. Huiban, and C. Mathieu (2012). “The determinants of firm exit in the French food industries”. *Review of agricultural and environmental studies*, 93(2), 193–212. doi: 10.22004/ag.econ.188225 (cit. on p. 29).

Boppart, T. (2014). “Structural Change and the Kaldor Facts in a Growth Model With Relative Price Effects and Non-Gorman Preferences”. *Econometrica*, 82(6), 2167–2196. doi: 10.3982/ECTA11354 (cit. on p. 14).

Borusyak, K. and X. Jaravel (2021). *The Distributional Effects of Trade: Theory and Evidence from the United States*. Working paper 28957. NBER. doi: 10.3386/w28957 (cit. on p. 15).

Broda, C. and D. E. Weinstein (2006). “Globalization and the Gains from Variety”. *Quarterly Journal of Economics*, 121(2), 541–585. doi: 10.1162/qjec.2006.121.2.541 (cit. on p. 13).

Brooks, W. J. and K. Donovan (2020). “Eliminating Uncertainty in Market Access: The Impact of New Bridges in Rural Nicaragua”. *Econometrica*, 88(5), 1965–1997. doi: 10.3982/ecta15828 (cit. on pp. 21, 25).

Bureau, J.-C., H. Guimbard, and S. Jean (2019). “Agricultural Trade Liberalisation in the 21st Century: Has It Done the Business?” *Journal of Agricultural Economics*, 70(1), 3–25. doi: 10.1111/1477-9552.12281 (cit. on p. 5).

Burgess, R. and D. Donaldson (2010). “Can Openness Mitigate the Effects of Weather Shocks? Evidence from India’s Famine Era”. *American Economic Review, Papers and Proceedings*, 100(2), 449–453. doi: 10.1257/aer.100.2.449 (cit. on p. 25).

Cardwell, R. and W. A. Kerr (2014). “Can Export Restrictions be Disciplined Through the World Trade Organisation?” *The World Economy*, 37(8), 1186–1196. doi: 10.1111/twec.12173 (cit. on p. 48).

Chaney, T. (2008). "Distorted Gravity: The Intensive and Extensive Margins of International Trade". *American Economic Review*, 98(4), 1707–1721. DOI: 10.1257/aer.98.4.1707 (cit. on pp. 29, 35).

Cheptea, A., C. Emlinger, and K. Latouche (2015). "Multinational Retailers and Home Country Food Exports". *American Journal of Agricultural Economics*, 97(1), 159–179. DOI: 10.1093/ajae/aau017 (cit. on p. 42).

— (2019). "Exporting firms and retail internationalization: Evidence from France". *Journal of Economics & Management Strategy*, 28(3), 561–582. DOI: 10.1111/jems.12294 (cit. on pp. 41, 42).

Cheptea, A. and C. Gaigné (2020). "Russian food embargo and the lost trade". *European Review of Agricultural Economics*, 47(2), 684–718. DOI: 10.1093/erae/jbz032 (cit. on p. 13).

Cheptea, A., M. Huchet, and L. Henry (2021). "How will Brexit affect the patterns of European agricultural and food exports?" *European Review of Agricultural Economics*, 48(5), 1031–1073. DOI: 10.1093/erae/jbab037 (cit. on p. 46).

Chetty, R. (2009). "Sufficient Statistics for Welfare Analysis: A Bridge Between Structural and Reduced-Form Methods". *Annual Review of Economics*, 1(1), 451–488. DOI: 10.1146/annurev.economics.050708.142910 (cit. on p. 12).

Chevassus-Lozza, E., C. Gaigné, and L. Le Mener (2013). "Does input trade liberalization boost downstream firms' exports? Theory and firm-level evidence". *Journal of International Economics*, 90(2), 391–402. DOI: 10.1016/j.jinteco.2013.02.004 (cit. on p. 31).

Chevassus-Lozza, E. and K. Latouche (2012). "Firms, markets and trade costs: access of French exporters to European agri-food markets". *European Review of Agricultural Economics*, 39(2), 257–288. DOI: 10.1093/erae/jbr009 (cit. on pp. 29, 30).

Colen, L., M. Maertens, and J. F. Swinnen (2012). "Private Standards, Trade and Poverty: GlobalGAP and Horticultural Employment in Senegal". *The World Economy*, 35(8), 1073–1088. DOI: 10.1111/j.1467-9701.2012.01463.x (cit. on p. 42).

Colson-Sihra, E., J. De Sousa, and T. Mayer (2020). *Market Integration and Cultural Homogenization in Consumption Patterns*. Working paper (cit. on p. 27).

Conte, B. (2021). *Climate change and migration: the case of Africa*. Working paper (cit. on p. 24).

Conte, B., K. Desmet, D. K. Nagy, and E. Rossi-Hansberg (2021). "Local sectoral specialization in a warming world". *Journal of Economic Geography*, 21(4), 493–530. DOI: 10.1093/jeg/lbab008 (cit. on pp. 17, 24).

Costinot, A. and D. Donaldson (2012). "Ricardo's Theory of Comparative Advantage: Old Idea, New Evidence". *American Economic Review, Papers and Proceedings*, 102(3), 453–458. DOI: 10.1257/aer.102.3.453 (cit. on pp. 7, 17).

— (2016). *How Large Are the Gains from Economic Integration? Theory and Evidence from U.S. Agriculture, 1880–1997*. Working paper 22946. NBER. DOI: 10.3386/w22946 (cit. on pp. 7, 18, 19).

Costinot, A., D. Donaldson, and C. B. Smith (2016). "Evolving Comparative Advantage and the Impact of Climate Change in Agricultural Markets: Evidence from 1.7 Million Fields around the World". *Journal of Political Economy*, 124(1), 205–248. DOI: 10.1086/684719 (cit. on pp. 8, 16, 17, 22–24).

Costinot, A. and A. Rodríguez-Clare (2014). "Trade Theory with Numbers: Quantifying the Consequences of Globalization". In: *Handbook of International Economics*. Ed. by E. Helpman, K. Rogoff, and G. Gopinath. Vol. 4. Amsterdam: Elsevier. Chap. 4, pp. 197–261. DOI: 10.1016/B978-0-444-54314-1.00004-5 (cit. on pp. 3, 12, 16, 17, 19, 20).

Cramon-Taubadel, S. von and B. K. Goodwin (2021). "Price Transmission in Agricultural Markets". *Annual Review of Resource Economics*, 13(1), 65–84. DOI: 10.1146/annurev-resource-100518-093938 (cit. on p. 3).

Crozet, M., K. Head, and T. Mayer (2012). "Quality Sorting and Trade: Firm-level Evidence for French Wine". *Review of Economic Studies*, 79(2), 609–644. DOI: 10.1093/restud/rdr030 (cit. on pp. 32, 33).

Curzi, D., M. Garrone, and A. Olper (2021). "Import Competition and Firm Markups in the Food Industry". *American Journal of Agricultural Economics*, 103(4), 1433–1453. DOI: 10.1111/ajae.12175 (cit. on p. 37).

Curzi, D. and M. Huysmans (2022). "The Impact of Protecting EU Geographical Indications in Trade Agreements". *American Journal of Agricultural Economics*, 104(1), 364–384. DOI: 10.1111/ajae.12226 (cit. on p. 45).

Curzi, D., M. Luarasi, V. Raimondi, and A. Olper (2018). "The (lack of) international harmonization of EU standards: import and export effects in developed versus developing countries". *Applied Economics Letters*, 25(21), 1552–1556. DOI: 10.1080/13504851.2018.1430327 (cit. on p. 46).

Curzi, D. and A. Olper (2012). "Export behavior of Italian food firms: Does product quality matter?" *Food Policy*, 37(5), 493–503. DOI: 10.1016/j.foodpol.2012.05.004 (cit. on p. 33).

Curzi, D. and L. Pacca (2015). "Price, quality and trade costs in the food sector". *Food Policy*, 55, 147–158. DOI: 10.1016/j.foodpol.2015.06.007 (cit. on p. 33).

Curzi, D., V. Raimondi, and A. Olper (2015). "Quality upgrading, competition and trade policy: evidence from the agri-food sector". *European Review of Agricultural Economics*, 42(2), 239–267. DOI: 10.1093/erae/jbu021 (cit. on pp. 34, 35).

Curzi, D., M. Schuster, M. Maertens, and A. Olper (2020). "Standards, trade margins and product quality: Firm-level evidence from Peru". *Food Policy*, 91, 101834. DOI: 10.1016/j.foodpol.2020.101834 (cit. on p. 46).

Darwin, R., M. E. Tsigas, J. Lewandrowski, and A. Raneses (1995). *World Agriculture and Climate Change: Economic Adaptations*. Agricultural Economic Report 703. USDA, ERS, p. 98. DOI: 10.22004/ag.econ.33933 (cit. on pp. 22, 24).

De Loecker, J., J. Eeckhout, and G. Unger (2020). "The Rise of Market Power and the Macroeconomic Implications". *Quarterly Journal of Economics*, 135(2), 561–644. DOI: 10.1093/qje/qjz041 (cit. on p. 37).

De Loecker, J. and F. Warzynski (2012). "Markups and Firm-Level Export Status". *American Economic Review*, 102(6), 2437–2471. DOI: 10.1257/aer.102.6.2437 (cit. on p. 37).

De Sousa, J., A.-C. Disdier, and C. Gaigné (2020). "Export decision under risk". *European Economic Review*, 121, 103342. DOI: 10.1016/j.euroecorev.2019.103342 (cit. on p. 39).

Deaton, A. S. and J. Muellbauer (1980). "An Almost Ideal Demand System". *American Economic Review*, 70(3), 312–326. JSTOR: 1805222 (cit. on p. 15).

Dekle, R., J. Eaton, and S. Kortum (2007). "Unbalanced Trade". *American Economic Review, Papers and Proceedings*, 97(2), 351–355. URL: http://www.jstor.org/stable/30034474 (cit. on p. 12).

Dercon, S. and D. Gollin (2014). "Agriculture in African Development: Theories and Strategies". *Annual Review of Resource Economics*, 6(1), 471–492. DOI: 10.1146/annurev-resource-100913-012706 (cit. on p. 26).

Desmet, K. and E. Rossi-Hansberg (2015). "On the spatial economic impact of global warming". *Journal of Urban Economics*, 88, 16–37. DOI: 10.1016/j.jue.2015.04.004 (cit. on p. 24).

Dingel, J., K. Meng, and S. Hsiang (2019). *Spatial Correlation, Trade, and Inequality: Evidence from the Global Climate*. Working paper 25447. NBER. DOI: 10.3386/w25447 (cit. on p. 23).

Disdier, A.-C., L. Fontagné, and M. Mimouni (2008). "The Impact of Regulations on Agricultural Trade: Evidence from the SPS and TBT Agreements". *American Journal of Agricultural Economics*, 90(2), 336–350. DOI: 10.1111/j.1467-8276.2007.01127.x (cit. on p. 46).

Disdier, A.-C. and M. Fugazza (2020). *A Practical Guide to the Economic Analysis of Non-Tariff Measures*. New York: United Nations. DOI: 10.18356/b9cc8a8d-en (cit. on p. 42).

Disdier, A.-C., C. Gaigné, and C. Herghelegiu (2021). *Do Standards Improve the Quality of Traded Products?* Working Paper 21-11. SMART-LERECO (cit. on pp. 43, 44, 46).

Disdier, A.-C. and S. Marette (2010). "The Combination of Gravity and Welfare Approaches for Evaluating Nontariff Measures". *American Journal of Agricultural Economics*, 92(3), 713–726. DOI: 10.1093/ajae/aaq026 (cit. on p. 46).

Dixit, A. K. and J. E. Stiglitz (1977). "Monopolistic Competition and Optimum Product Diversity". *American Economic Review*, 67(3), 297–308. JSTOR: 1831401 (cit. on p. 8).

Do, Q.-T. and A. A. Levchenko (2017). "Trade policy and redistribution when preferences are non-homothetic". *Economics Letters*, 155, 92–95. DOI: 10.1016/j.econlet.2017.03.007 (cit. on p. 47).

Donaldson, D. (2018). “Railroads of the Raj: Estimating the Impact of Transportation Infrastructure”. *American Economic Review*, 108(4–5), 899–934. DOI: 10.1257/aer.20101199 (cit. on pp. 7, 18, 25).

— (2019). “Comparative advantage and agricultural trade”. *Agricultural Economics*, 50(S1), 29–40. DOI: 10.1111/agec.12529 (cit. on pp. 16, 18).

Donaldson, D. and R. Hornbeck (2016). “Railroads and American Economic Growth: A “Market Access” Approach”. *Quarterly Journal of Economics*, 131(2), 799–858. DOI: 10.1093/qje/qjw002 (cit. on p. 18).

Dragone, D. and N. R. Ziebarth (2017). “Non-separable time preferences, novelty consumption and body weight: Theory and evidence from the East German transition to capitalism”. *Journal of Health Economics*, 51, 41–65. DOI: 10.1016/j.jhealeco.2016.11.002 (cit. on p. 15).

Dragusanu, R., D. Giovannucci, and N. Nunn (2014). “The Economics of Fair Trade”. *Journal of Economic Perspectives*, 28(3), 217–236. DOI: 10.1257/jep.28.3.217 (cit. on p. 10).

Dulleck, U., R. Kerschbamer, and M. Sutter (2011). “The Economics of Credence Goods: An Experiment on the Role of Liability, Verifiability, Reputation, and Competition”. *American Economic Review*, 101(2), 526–555. DOI: 10.1257/aer.101.2.526 (cit. on pp. 10, 43).

Duvaleix, S., C. Emlinger, C. Gaigné, and K. Latouche (2021). “Geographical indications and trade: Firm-level evidence from the French cheese industry”. *Food Policy*, 102, 102118. DOI: 10.1016/j.foodpol.2021.102118 (cit. on p. 45).

Eaton, J. and S. Kortum (2002). “Technology, Geography, and Trade”. *Econometrica*, 70(5), 1741–1779. DOI: 10.1111/1468-0262.00352 (cit. on pp. 3, 4, 16, 17, 19, 21, 22, 24, 49).

Ejrnæs, M. and K. G. Persson (2010). “The gains from improved market efficiency: trade before and after the transatlantic telegraph”. *European Review of Economic History*, 14(3), 361–381. DOI: 10.1017/s1361491610000109 (cit. on p. 49).

Emlinger, C. and V. Lamani (2020). “International trade, quality sorting and trade costs: the case of Cognac”. *Review of World Economics*, 156(3), 579–609. DOI: 10.1007/s10290-019-00372-z (cit. on pp. 32, 33).

Emlinger, C. and S. Poncet (2018). “With a little help from my friends: Multinational retailers and China’s consumer market penetration”. *Journal of International Economics*, 112, 1–12. DOI: 10.1016/j.jinteco.2018.01.007 (cit. on p. 42).

Fajgelbaum, P. D. and A. K. Khandelwal (2016). “Measuring the Unequal Gains from Trade”. *Quarterly Journal of Economics*, 131(3), 1113–1180. DOI: 10.1093/qje/qjw013 (cit. on p. 15).

Fally, T. (2015). “Structural gravity and fixed effects”. *Journal of International Economics*, 97(1), 76–85. DOI: 10.1016/j.jinteco.2015.05.005 (cit. on p. 12).

Fally, T. and J. Sayre (2018). *Commodity Trade Matters*. Working paper 24965. NBER. DOI: 10.3386/w24965 (cit. on pp. 19, 20).

Farrokhi, F. and H. S. Pellegrina (2021). *Trade, Technology, and Agricultural Productivity*. Working paper (cit. on pp. 7, 16, 19–21).

Feenstra, R. C. (1994). “New Product Varieties and the Measurement of International Prices”. *American Economic Review*, 84(1), 157–177. JSTOR: 2117976 (cit. on p. 13).

— (2016). *Advanced international trade: theory and evidence*. Princeton: Princeton University Press (cit. on pp. 12, 35).

Feenstra, R. C. and C. Hong (2022). “China’s Import Demand for Agricultural Products: The Impact of the Phase One Trade Agreement”. *Review of International Economics*, 30(1), 345–368. DOI: 10.1111/roie.12568 (cit. on p. 14).

Féménia, F. (2019). “A meta-analysis of the price and income elasticities of food demand”. *German Journal of Agricultural Economics*, 68(2), 77–98. URL: https://www.gjae-online.de/articles/a-meta-analysis-of-the-price-and-income-elasticities-of-food-demand/ (cit. on p. 14).

Ferguson, S. M. and J. Gars (2020). “Measuring the Impact of Agricultural Production Shocks on International Trade Flows”. *European Review of Agricultural Economics*, 47(3), 1094–1132. DOI: 10.1093/erae/jbz013 (cit. on p. 25).

Ferguson, S. M. and M. R. Olfert (2016). "Competitive Pressure and Technology Adoption: Evidence from a Policy Reform in Western Canada". *American Journal of Agricultural Economics*, 98(2), 422–446. doi: 10.1093/ajae/aav018 (cit. on p. 21).

Fernandes, A. M., E. Ferro, and J. S. Wilson (2019). "Product Standards and Firms' Export Decisions". *World Bank Economic Review*, 33(2), 353–374. doi: 10.1093/wber/lhw071 (cit. on p. 46).

Ferro, E., T. Otsuki, and J. S. Wilson (2015). "The effect of product standards on agricultural exports". *Food Policy*, 50, 68–79. doi: 10.1016/j.foodpol.2014.10.016 (cit. on p. 46).

Fiankor, D.-D. D., D. Curzi, and A. Olper (2021). "Trade, price and quality upgrading effects of agri-food standards". *European Review of Agricultural Economics*, 48(4), 835–877. doi: 10.1093/erae/jbaa026 (cit. on p. 46).

Fiankor, D.-D. D., I. Flachsbarth, A. Masood, and B. Brümmer (2020). "Does GlobalGAP certification promote agrifood exports?" *European Review of Agricultural Economics*, 47(1), 247–272. doi: 10.1093/erae/jbz023 (cit. on p. 42).

Fieler, A. C. (2011). "Nonhomotheticity and Bilateral Trade: Evidence and a Quantitative Explanation". *Econometrica*, 79(4), 1069–1101. doi: 10.3982/ECTA8346 (cit. on p. 14).

Fontagné, L., H. Guimbard, and G. Orefice (2020). *Product-Level Trade Elasticities: Worth Weighting For*. Working paper 8491. CESifo. repec: p/ces/ceswps/_8491 (cit. on p. 6).

Frahan, B. H. de and M. Vancauteren (2006). "Harmonisation of food regulations and trade in the Single Market: evidence from disaggregated data". *European Review of Agricultural Economics*, 33(3), 337–360. doi: 10.1093/eurrag/jbl015 (cit. on p. 46).

Freund, C. and C. Özden (2008). "Trade Policy and Loss Aversion". *American Economic Review*, 98(4), 1675–1691. doi: 10.1257/aer.98.4.1675 (cit. on p. 47).

Fulponi, L. (2006). "Private voluntary standards in the food system: The perspective of major food retailers in OECD countries". *Food Policy*, 31(1), 1–13. doi: 10.1016/j.foodpol.2005.06.006 (cit. on p. 42).

Gaigné, C., C. Laroche-Dupraz, and A. Matthews (2015). "Thirty years of European research on international trade in food and agricultural products". *Review of Agricultural and Environmental Studies*, 96(1), 91–130. url: https://hal.archives-ouvertes.fr/hal-01884928 (cit. on pp. 28, 40).

Gaigné, C. and B. Larue (2016). "Quality Standards, Industry Structure, and Welfare in a Global Economy". *American Journal of Agricultural Economics*, 98(5), 1432–1449. doi: 10.1093/ajae/aaw039 (cit. on pp. 9, 32, 34, 44).

Gaigné, C., K. Latouche, and S. Turolla (2018). "Vertical Ownership and Export Performance: Firm-Level Evidence from the Food Industry". *American Journal of Agricultural Economics*, 100(1), 46–72. doi: 10.1093/ajae/aax071 (cit. on pp. 30, 40, 41).

Gaigné, C. and L. Le Mener (2014). "Agricultural Prices, Selection, and the Evolution of the Food Industry". *American Journal of Agricultural Economics*, 96(3), 884–902. doi: 10.1093/ajae/aat080 (cit. on pp. 30, 31).

Gaulier, G. and S. Zignago (2010). *BACI: International Trade Database at the Product-level. The 1994–2007 Version*. Working paper 2010-23. CEPII. repec: p/cii/cepidt/2010-23 (cit. on p. 4).

Gibson, M. J. and T. A. Graciano (2011). "The Decision to Import". *American Journal of Agricultural Economics*, 93(2), 444–449. doi: 10.1093/ajae/aaq162 (cit. on p. 31).

Giordani, P. E., N. Rocha, and M. Ruta (2016). "Food Prices and the Multiplier Effect of Trade Policy". *Journal of International Economics*, 101, 102–122. doi: 10.1016/j.jinteco.2016.04.001 (cit. on p. 47).

Giuntella, O., M. Rieger, and L. Rotunno (2020). "Weight gains from trade in foods: Evidence from Mexico". *Journal of International Economics*, 122, 103277. doi: 10.1016/j.jinteco.2019.103277 (cit. on p. 15).

Gohin, A. and F. Féménia (2009). "Estimating Price Elasticities of Food Trade Functions: How Relevant is the CES-based Gravity Approach?" *Journal of Agricultural Economics*, 60(2), 253–272. doi: 10.1111/j.1477-9552.2009.00199.x (cit. on p. 14).

Gollin, D., D. Lagakos, and M. E. Waugh (2014). "The Agricultural Productivity Gap". *Quarterly Journal of Economics*, 129(2), 939–993. doi: 10.1093/qje/qjt056 (cit. on p. 26).

Gopinath, M., I. M. Sheldon, and R. Echeverria (2007). *Firm Heterogeneity and International Trade: Implications for Agricultural and Food Industries*. Trade Issues Papers 9349. International Agricultural Trade Research Consortium. DOI: 10.22004/ag.econ.9349 (cit. on pp. 28, 29).

Gorbachev, O. (2011). "Did Household Consumption Become More Volatile?" *American Economic Review*, 101(5), 2248–2270. DOI: 10.1257/aer.101.5.2248 (cit. on p. 39).

Götz, L., T. Glauben, and B. Brümmer (2013). "Wheat export restrictions and domestic market effects in Russia and Ukraine during the food crisis". *Food Policy*, 38, 214–226. DOI: 10.1016/j.foodpol.2012.12.001 (cit. on pp. 47, 48).

Gouel, C. (2014). "Food Price Volatility and Domestic Stabilization Policies in Developing Countries". In: *The Economics of Food Price Volatility*. Ed. by J.-P. Chavas, D. Hummels, and B. D. Wright. National Bureau of Economic Research conference report. Chicago, IL: University of Chicago Press. Chap. 7, pp. 261–306. URL: http://www.nber.org/chapters/c12816 (cit. on p. 24).

— (2016). "Trade Policy Coordination and Food Price Volatility". *American Journal of Agricultural Economics*, 98(4), 1018–1037. DOI: 10.1093/ajae/aaw020 (cit. on pp. 47, 48).

Gouel, C. and S. Jean (2015). "Optimal Food Price Stabilization in a Small Open Developing Country". *World Bank Economic Review*, 29(1), 72–101. DOI: 10.1093/wber/lht018 (cit. on p. 47).

Gouel, C. and D. Laborde (2021). "The Crucial Role of Domestic and International Marlet-Mediated Adaptation to Climate Change". *Journal of Environmental Economics and Management*, 106, 102408. DOI: 10.1016/j.jeem.2020.102408 (cit. on pp. 22, 23).

Guimbard, H., S. Jean, M. Mimouni, and X. Pichot (2012). "MAcMap-HS6 2007, An exhaustive and consistent measure of applied protection in 2007". *International Economics*, 130, 99–121. DOI: 10.1016/S2110-7017(13)60046-3 (cit. on p. 5).

Gullstrand, J. (2011). "Firm and destination-specific export costs: The case of the Swedish food sector". *Food Policy*, 36(2), 204–213. DOI: 10.1016/j.foodpol.2010.11.017 (cit. on p. 30).

Hallak, J. C. (2006). "Product quality and the direction of trade". *Journal of International Economics*, 68(1), 238–265. DOI: 10.1016/j.jinteco.2005.04.001 (cit. on p. 9).

Hallak, J. C. and J. Sivadasan (2013). "Product and process productivity: Implications for quality choice and conditional exporter premia". *Journal of International Economics*, 91(1), 53–67. DOI: 10.1016/j.jinteco.2013.05.001 (cit. on pp. 9, 32).

Hanoch, G. (1975). "Production and Demand Models with Direct or Indirect Implicit Additivity". *Econometrica*, 43(3), 395–419. JSTOR: 1914273 (cit. on p. 14).

Head, K. and T. Mayer (2014). "Gravity Equations: Workhorse, Toolkit, and Cookbook". In: *Handbook of International Economics*. Ed. by E. Helpman, K. Rogoff, and G. Gopinath. Vol. 4. Amsterdam: Elsevier. Chap. 3, pp. 131–195. DOI: 10.1016/B978-0-444-54314-1.00003-3 (cit. on pp. 3, 6, 35).

Head, K. and J. Ries (2001). "Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade". *American Economic Review*, 91(4), 858–876. DOI: 10.1257/aer.91.4.858 (cit. on p. 6).

Headey, D. (2011). "Rethinking the global food crisis: The role of trade shocks". *Food Policy*, 36(2), 136–146. DOI: 10.1016/j.foodpol.2010.10.003 (cit. on p. 47).

Heerman, K. E. (2020). "Technology, ecology and agricultural trade". *Journal of International Economics*, 123, 103280. DOI: 10.1016/j.jinteco.2019.103280 (cit. on p. 26).

Heerman, K. E., S. Arita, and M. Gopinath (2015). "Asia-Pacific Integration with China versus the United States: Examining Trade Patterns under Heterogeneous Agricultural Sectors". *American Journal of Agricultural Economics*, 97(5), 1324–1344. DOI: 10.1093/ajae/aav038 (cit. on p. 26).

Helpman, E., M. J. Melitz, and Y. Rubinstein (2008). "Estimating Trade Flows: Trading Partners and Trading Volumes". *Quarterly Journal of Economics*, 123(2), 441–487. DOI: 10.1162/qjec.2008.123.2.441 (cit. on p. 35).

Helpman, E., K. Rogoff, and G. Gopinath, eds. (2014). *Handbook of International Economics*. Vol. 4. Amsterdam: Elsevier.

Herrendorf, B., J. A. Schmitz Jr, and A. Teixeira (2012). "The Role of Transportation in U.S. Economic Development: 1840–1860". *International Economic Review*, 53(3), 693–716. DOI: 10.1111/j.1468-2354.2012.00697.x (cit. on p. 19).

Hertel, T. W. (2002). "Applied general equilibrium analysis of agricultural and resource policies". In: *Handbook of Agricultural Economics*. Ed. by B. L. Gardner and G. C. Rausser. Vol. 2, part A. Amsterdam: Elsevier. Chap. 26, pp. 1373–1419. DOI: 10.1016/S1574-0072(02)10008-9 (cit. on pp. 16, 17).

Hummels, D. (2007). "Transportation Costs and International Trade in the Second Era of Globalization". *Journal of Economic Perspectives*, 21(3), 131–154. DOI: 10.1257/jep.21.3.131 (cit. on p. 6).

IIASA/FAO (2021). *Global Agro-ecological Zones (GAEZ v4)*. IIASA, Laxenburg, Austria and FAO, Rome, Italy. URL: https://gaez.fao.org (cit. on p. 7).

Imbs, J. and I. Mejean (2017). "Trade Elasticities". *Review of International Economics*, 25(2), 383–402. DOI: 10.1111/roie.12270 (cit. on p. 13).

Ivanic, M. and W. J. Martin (2014). "Implications of Domestic Price Insulation for Global Food Price Behavior". *Journal of International Money and Finance*, 42, 272–288. DOI: 10.1016/j.jimonfin.2013.08.015 (cit. on p. 47).

Jacks, D. S., K. H. O'Rourke, and J. G. Williamson (2011). "Commodity Price Volatility and World Market Integration since 1700". *Review of Economics and Statistics*, 93(3), 800–813. DOI: 10.1162/REST_a_00091 (cit. on pp. 24, 25).

Jäkel, I. C. (2019). "Product appeal, differences in tastes, and export performance: Evidence for Danish chocolate and confectionery". *International Journal of Industrial Organization*, 63, 417–459. DOI: 10.1016/j.ijindorg.2018.11.002 (cit. on p. 9).

Janssens, C., P. Havlík, T. Krisztin, J. Baker, S. Frank, T. Hasegawa, D. Leclère, S. Ohrel, S. Ragnauth, E. Schmid, H. Valin, N. V. Lipzig, and M. Maertens (2020). "Global hunger and climate change adaptation through international trade". *Nature Climate Change*, 10(9), 829–835. DOI: 10.1038/s41558-020-0847-4 (cit. on p. 23).

Jensen, R. T. (2007). "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector". *Quarterly Journal of Economics*, 122(3), 879–924. DOI: 10.1162/qjec.122.3.879 (cit. on p. 49).

Johnson, R. C. (2012). "Trade and prices with heterogeneous firms". *Journal of International Economics*, 86(1), 43–56. DOI: 10.1016/j.jinteco.2011.09.004 (cit. on p. 33).

Josling, T. (2006). "The war on *terroir*: Geographical indications as a transatlantic trade conflict". *Journal of Agricultural Economics*, 57(3), 337–363. DOI: 10.1111/j.1477-9552.2006.00075.x (cit. on p. 44).

Kandilov, I. T. and X. Zheng (2011). "The impact of entry costs on export market participation in agriculture". *Agricultural Economics*, 42(5), 531–546. DOI: 10.1111/j.1574-0862.2010.00530.x (cit. on p. 29).

Karp, L. S. and J. M. Perloff (2002). "A synthesis of agricultural trade economics". In: *Handbook of Agricultural Economics*. Ed. by B. L. Gardner and G. C. Rausser. Vol. 2, part B. Amsterdam: Elsevier. Chap. 37, pp. 1945–1998. DOI: 10.1016/S1574-0072(02)10024-7 (cit. on pp. 3, 49).

Keeney, R. and T. W. Hertel (2009). "The Indirect Land Use Impacts of United States Biofuel Policies: The Importance of Acreage, Yield, and Bilateral Trade Responses". *American Journal of Agricultural Economics*, 91(4), 895–909. DOI: 10.1111/j.1467-8276.2009.01308.x (cit. on p. 21).

Khandelwal, A. K. (2010). "The Long and Short (of) Quality Ladders". *Review of Economic Studies*, 77(4), 1450–1476. DOI: 10.1111/j.1467-937X.2010.00602.x (cit. on p. 33).

Khandelwal, A. K., P. K. Schott, and S.-J. Wei (2013). "Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters". *American Economic Review*, 103(6), 2169–2195. DOI: 10.1257/aer.103.6.2169 (cit. on pp. 33, 34).

Kopp, T. and R. J. Sexton (2021). "Farmers, Traders, and Processors: Buyer Market Power and Double Marginalization in Indonesia". *American Journal of Agricultural Economics*, 103(2), 543–568. DOI: 10.1111/ajae.12149 (cit. on p. 40).

Kremer, M. (1993). "The O-Ring Theory of Economic Development". *Quarterly Journal of Economics*, 108(3), 551–575. DOI: 10.2307/2118400 (cit. on p. 32).

Kugler, M. and E. A. Verhoogen (2012). "Prices, Plant Size, and Product Quality". *Review of Economic Studies*, 79(1), 307–339. DOI: 10.1093/restud/rdr021 (cit. on pp. 9, 32).

Latouche, K. and E. Chevassus-Lozza (2015). "Retailer Supply Chain and Market Access: Evidence From French Agri-food Firms Certified with Private Standards". *The World Economy*, 38(8), 1312–1334. DOI: 10.1111/twec.12191 (cit. on p. 42).

Leclère, D., P. Havlík, S. Fuss, E. Schmid, A. Mosnier, B. Walsh, H. Valin, M. Herrero, N. Khabarov, and M. Obersteiner (2014). "Climate change induced transformations of agricultural systems: insights from a global model". *Environmental Research Letters*, 9(12), 124018. DOI: 10.1088/1748-9326/9/12/124018 (cit. on p. 22).

Lenzen, M., K. Kanemoto, D. Moran, and A. Geschke (2012). "Mapping the Structure of the World Economy". *Environmental Science & Technology*, 46(15), 8374–8381. DOI: 10.1021/es300171x (cit. on p. 4).

Liao, J. and W. Wang (2018). "Income elasticity and international income differences". *Economics Letters*, 169, 68–71. DOI: 10.1016/j.econlet.2018.05.019 (cit. on p. 15).

Linder, S. B. (1961). *An Essay on Trade and Transformation*. New York: John Wiley & Sons (cit. on p. 14).

Liu, M. Y., Y. Shamdasani, and V. Taraz (2021). *Climate Change and Labor Reallocation: Evidence from Six Decades of the Indian Census*. Working paper (cit. on p. 24).

Lybbert, T. J., A. Smith, and D. A. Sumner (2014). "Weather Shocks and Inter-hemispheric Supply Responses: Implications for Climate Change Effects on Global Food Markets". *Climate Change Economics*, 5(4), 1450010. DOI: 10.1142/s2010007814500109 (cit. on p. 49).

Macedoni, L. and A. Weinberger (2022). "Quality heterogeneity and misallocation: The welfare benefits of raising your standards". *Journal of International Economics*, 134, 103544. DOI: 10.1016/j.jinteco.2021.103544 (cit. on p. 44).

Magruder, J. R. (2018). "An Assessment of Experimental Evidence on Agricultural Technology Adoption in Developing Countries". *Annual Review of Resource Economics*, 10(1), 299–316. DOI: 10.1146/annurev-resource-100517-023202 (cit. on p. 21).

Marette, S. and J. C. Beghin (2010). "Are Standards Always Protectionist?" *Review of International Economics*, 18(1), 179–192. DOI: 10.1111/j.1467-9396.2009.00856.x (cit. on p. 44).

Martin, W. J. and K. Anderson (2012). "Export Restrictions and Price Insulation During Commodity Price Booms". *American Journal of Agricultural Economics*, 94(2), 422–427. DOI: 10.1093/ajae/aar105 (cit. on pp. 47, 48).

Matsuyama, K. (2019). "Engel's Law in the Global Economy: Demand-Induced Patterns of Structural Change, Innovation, and Trade". *Econometrica*, 87(2), 497–528. DOI: 10.3982/ecta13765 (cit. on p. 14).

Mattoo, A., N. Rocha, and M. Ruta, eds. (2020). *Handbook of Deep Trade Agreements*. Washington, DC: The World Bank. DOI: 10.1596/978-1-4648-1539-3 (cit. on p. 46).

McArthur, J. W. and G. C. McCord (2017). "Fertilizing growth: Agricultural inputs and their effects in economic development". *Journal of Development Economics*, 127, 133–152. DOI: 10.1016/j.jdeveco.2017.02.007 (cit. on p. 20).

McCorriston, S. (2002). "Why should imperfect competition matter to agricultural economists?" *European Review of Agricultural Economics*, 29(3), 349–371. DOI: 10.1093/eurrag/29.3.349 (cit. on p. 29).

McCullough, E. B. (2017). "Labor productivity and employment gaps in Sub-Saharan Africa". *Food Policy*, 67, 133–152. DOI: 10.1016/j.foodpol.2016.09.013 (cit. on p. 26).

Meemken, E.-M., C. B. Barrett, H. C. Michelson, M. Qaim, T. Reardon, and J. Sellare (2021). "Sustainability standards in global agrifood supply chains". *Nature Food*, 2(10), 758–765. DOI: 10.1038/s43016-021-00360-3 (cit. on p. 10).

Melitz, M. J. (2003). "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity". *Econometrica*, 71(6), 1695–1725. DOI: 10.1111/1468-0262.00467 (cit. on pp. 3, 4, 28, 29, 32).

Melitz, M. J. and S. J. Redding (2014). "Heterogeneous Firms and Trade". In: *Handbook of International Economics*. Ed. by E. Helpman, K. Rogoff, and G. Gopinath. Vol. 4. Amsterdam: Elsevier. Chap. 1, pp. 1–54. DOI: 10.1016/B978-0-444-54314-1.00001-X (cit. on p. 29).

Merener, N. (2015). "Globally Distributed Production and the Pricing of CME Commodity Futures". *Journal of Futures Markets*, 35(1), 1–30. REPEC: a/wly/jfutmk/v35y2015i1p1-30 (cit. on p. 49).

Minten, B., B. Koru, and D. Stifel (2013). "The last mile(s) in modern input distribution: Pricing, profitability, and adoption". *Agricultural Economics*, 44(6), 629–646. DOI: 10.1111/agec.12078 (cit. on p. 21).

Moschini, G., L. Menapace, and D. Pick (2008). "Geographical Indications and the Competitive Provision of Quality in Agricultural Markets". *American Journal of Agricultural Economics*, 90(3), 794–812. DOI: 10.1111/j.1467-8276.2008.01142.x (cit. on p. 43).

Movchan, V., O. Shepotylo, and V. Vakhitov (2020). "Non-tariff measures, quality and exporting: evidence from microdata in food processing in Ukraine". *European Review of Agricultural Economics*, 47(2), 719–751. DOI: 10.1093/erae/jbz034 (cit. on p. 46).

Nath, I. (2020). *The Food Problem and the Aggregate Productivity Consequences of Climate Change*. Working paper 27297. NBER. DOI: 10.3386/w27297 (cit. on p. 24).

Nelson, G. C., H. Valin, R. D. Sands, P. Havlík, H. Ahammad, D. Deryng, J. Elliott, S. Fujimori, T. Hasegawa, E. Heyhoe, P. Kyle, M. von Lampe, H. Lotze-Campen, D. M. d'Croz, H. van Meijl, D. van der Mensbrugghe, C. Müller, A. Popp, R. Robertson, S. Robinson, E. Schmid, C. Schmitz, A. Tabeau, and D. Willenbockel (2014). "Climate change effects on agriculture: Economic responses to biophysical shocks". *Proceedings of the National Academy of Sciences*, 111(9), 3274–3279. DOI: 10.1073/pnas.1222465110 (cit. on p. 22).

Newbery, D. M. G. and J. E. Stiglitz (1984). "Pareto Inferior Trade". *Review of Economic Studies*, 51(1), 1–12. DOI: 10.2307/2297701 (cit. on p. 25).

Nguyen, D. X. (2012). "Demand uncertainty: Exporting delays and exporting failures". *Journal of International Economics*, 86(2), 336–344. DOI: 10.1016/j.jinteco.2011.10.007 (cit. on p. 39).

Nigai, S. (2016). "On Measuring the Welfare Gains from Trade Under Consumer Heterogeneity". *Economic Journal*, 126(593), 1193–1237. DOI: 10.1111/ecoj.12192 (cit. on p. 15).

Novy, D. (2013a). "Gravity Redux: Measuring Internation Trade Costs with Panel Data". *Economic Inquiry*, 51(1), 101–121. DOI: 10.1111/j.1465-7295.2011.00439.x (cit. on p. 6).

— (2013b). "International trade without CES: Estimating translog gravity". *Journal of International Economics*, 89(2), 271–282. DOI: 10.1016/j.jinteco.2012.08.010 (cit. on p. 26).

Oberländer, L., A.-C. Disdier, and F. Etilé (2017). "Globalisation and national trends in nutrition and health: A grouped fixed-effects approach to intercountry heterogeneity". *Health Economics*, 26(9), 1146–1161. DOI: 10.1002/hec.3521 (cit. on pp. 10, 16).

Olivier, J., M. Thoenig, and T. Verdier (2008). "Globalization and the dynamics of cultural identity". *Journal of International Economics*, 76(2), 356–370. DOI: 10.1016/j.jinteco.2008.06.009 (cit. on p. 10).

Olper, A., D. Curzi, and V. Raimondi (2017). "Imported Intermediate Inputs and Firms' Productivity Growth: Evidence from the Food Industry". *Journal of Agricultural Economics*, 68(1), 280–300. DOI: 10.1111/1477-9552.12164 (cit. on p. 31).

Olper, A., L. Pacca, and D. Curzi (2014). "Trade, import competition and productivity growth in the food industry". *Food Policy*, 49, 71–83. DOI: 10.1016/j.foodpol.2014.06.004 (cit. on p. 36).

Olper, A. and V. Raimondi (2008). "Agricultural market integration in the OECD: A gravity-border effect approach". *Food Policy*, 33(2), 165–175. DOI: 10.1016/j.foodpol.2007.06.003 (cit. on p. 29).

Ossa, R. (2015). "Why Trade Matters After All". *Journal of International Economics*, 97(2), 266–277. DOI: 10.1016/j.jinteco.2015.07.002 (cit. on p. 13).

Parenti, M. (2018). “Large and small firms in a global market: David vs. Goliath”. *Journal of International Economics*, 110, 103–118. DOI: 10.1016/j.jinteco.2017.09.001 (cit. on p. 38).

Pellegrina, H. S. (forthcoming). “Trade and the Spatial Organization of Agriculture: Evidence from Brazil”. *Journal of Development Economics* (cit. on p. 19).

Peterson, E. B., J. H. Grant, and J. Rudi-Polloshka (2018). “Survival of the Fittest: Export Duration and Failure into United States Fresh Fruit and Vegetable Markets”. *American Journal of Agricultural Economics*, 100(1), 23–45. DOI: 10.1093/ajae/aax043 (cit. on p. 39).

Pieters, H. and J. F. Swinnen (2016). “Trading-off volatility and distortions? Food policy during price spikes”. *Food Policy*, 61, 27–39. DOI: 10.1016/j.foodpol.2016.01.004 (cit. on p. 47).

Piveteau, P. and G. Smagghue (2019). “Estimating firm product quality using trade data”. *Journal of International Economics*, 118, 217–232. DOI: 10.1016/j.jinteco.2019.02.005 (cit. on p. 34).

Porteous, O. (2017). “Empirical effects of short-term export bans: The case of African maize”. *Food Policy*, 71, 17–26. DOI: 10.1016/j.foodpol.2017.07.003 (cit. on pp. 47, 48).

— (2019). “High Trade Costs and Their Consequences: An Estimated Dynamic Model of African Agricultural Storage and Trade”. *American Economic Journal: Applied Economics*, 11(4), 327–366. DOI: 10.1257/app.20170442 (cit. on pp. 19, 25).

— (2020). “Trade and Agricultural Technology Adoption: Evidence from Africa”. *Journal of Development Economics*, 144, 102440. DOI: 10.1016/j.jdeveco.2020.102440 (cit. on pp. 19, 21).

Raimondi, V., C. Falco, D. Curzi, and A. Olper (2020). “Trade effects of geographical indication policy: The EU case”. *Journal of Agricultural Economics*, 71(2), 330–356. DOI: 10.1111/1477-9552.12349 (cit. on p. 45).

Randhir, T. O. and T. W. Hertel (2000). “Trade Liberalization as a Vehicle for Adapting to Global Warming”. *Agricultural and Resource Economics Review*, 29(2), 159–172. DOI: 10.1017/s1068280500005293 (cit. on pp. 22, 23).

Rau, M.-L. and F. van Tongeren (2009). “Heterogeneous firms and homogenising standards in agri-food trade: the Polish meat case”. *European Review of Agricultural Economics*, 36(4), 479–505. DOI: 10.1093/erae/jbp032 (cit. on p. 29).

Rauch, J. E. and J. Watson (2003). “Starting small in an unfamiliar environment”. *International Journal of Industrial Organization*, 21(7), 1021–1042. DOI: 10.1016/S0167-7187(03)00018-3 (cit. on p. 42).

Reardon, T. and C. P. Timmer (2007). “Transformation of Markets for Agricultural Output in Developing Countries Since 1950: How Has Thinking Changed?” In: *Handbook of Agricultural Economics*. Ed. by R. Evenson and P. Pingali. Vol. 3. Amsterdam: Elsevier. Chap. 55, pp. 2807–2855. DOI: 10.1016/S1574-0072(06)03055-6 (cit. on p. 40).

Reilly, J. M. and N. Hohmann (1993). “Climate Change and Agriculture: The Role of International Trade”. *American Economic Review*, 83(2), 306–312. JSTOR: 2117682 (cit. on p. 22).

Reimer, J. J. and M. Li (2010). “Trade Costs and the Gains from Trade in Crop Agriculture”. *American Journal of Agricultural Economics*, 92(4), 1024–1039. DOI: 10.1093/ajae/aaq046 (cit. on p. 19).

Richards, T. and S. F. Hamilton (2013). “Network externalities in supermarket retailing”. *European Review of Agricultural Economics*, 40(1), 1–22. DOI: 10.1093/erae/jbs011 (cit. on p. 41).

Rivera-Padilla, A. (2020). “Crop choice, trade costs, and agricultural productivity”. *Journal of Development Economics*, 146, 102517. DOI: 10.1016/j.jdeveco.2020.102517 (cit. on p. 26).

Aw-Roberts, B. Y., Y. Lee, and H. Vandenbussche (2020). *Consumer Taste in Trade*. Discussion paper DP14941. CEPR. URL: https://cepr.org/active/publications/discussion_papers/dp.php?dpno=14941 (cit. on pp. 9, 34).

Ronnen, U. (1991). “Minimum quality standards, fixed Costs, and competition”. *Rand Journal of Economics*, 22(4), 490–504. JSTOR: 2600984 (cit. on p. 44).

Rosenzweig, C. and M. L. Parry (1994). “Potential impact of climate change on world food supply”. *Nature*, 367(6459), 133–138. DOI: 10.1038/367133a0 (cit. on p. 22).

Ruan, J. and M. Gopinath (2008). "Global productivity distribution and trade liberalisation: evidence from processed food industries". *European Review of Agricultural Economics*, 35(4), 439–460. DOI: 10.1093/erae/jbn034 (cit. on p. 36).

Samuelson, P. A. (1954). "The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments". *Economic Journal*, 64(254), 264–289. DOI: 10.2307/2226834 (cit. on p. 8).

Santos Silva, J. M. C. and S. Tenreyro (2015). "Trading Partners and Trading Volumes: Implementing the Helpman-Melitz-Rubinstein Model Empirically". *Oxford Bulletin of Economics and Statistics*, 77(1), 93–105. DOI: 10.1111/obes.12055 (cit. on p. 35).

Scoppola, M. (2021). "Globalisation in agriculture and food: the role of multinational enterprises". *European Review of Agricultural Economics*, 48(4), 741–784. DOI: 10.1093/erae/jbab032 (cit. on p. 38).

Sexton, R. J. (2013). "Market Power, Misconceptions, and Modern Agricultural Markets". *American Journal of Agricultural Economics*, 95(2), 209–219. DOI: 10.1093/ajae/aas102 (cit. on pp. 28, 31).

Shamdasani, Y. (2021). "Rural road infrastructure & agricultural production: Evidence from India". *Journal of Development Economics*, 152, 102686. DOI: 10.1016/j.jdeveco.2021.102686 (cit. on pp. 19, 21).

Sheldon, I. M. (2017). "Certification Mechanisms for Credence Attributes of Foods: Does It Matter Who Provides Diagnosis?" *Annual Review of Resource Economics*, 9(1), 33–51. DOI: 10.1146/annurev-resource-100516-053630 (cit. on p. 43).

Shiue, C. H. (2002). "Transport Costs and the Geography of Arbitrage in Eighteenth-Century China". *American Economic Review*, 92(5), 1406–1419. DOI: 10.1257/000282802762024566 (cit. on p. 25).

Simonovska, I. (2015). "Income Differences and Prices of Tradables: Insights from an Online Retailer". *Review of Economic Studies*, 82(4), 1612–1656. DOI: 10.1093/restud/rdv015 (cit. on p. 33).

Simonovska, I. and M. E. Waugh (2014). *Trade Models, Trade Elasticities, and the Gains from Trade*. Working paper 20495. NBER. DOI: 10.3386/w20495 (cit. on p. 17).

Sorgho, Z. and B. Larue (2014). "Geographical indication regulation and intra-trade in the European Union". *Agricultural Economics*, 45(S1), 1–12. DOI: 10.1111/agec.12125 (cit. on p. 45).

— (2017). "Do Geographical Indications Really Increase Trade? A Conceptual Framework and Empirics". *Journal of Agricultural & Food Industrial Organization*, 16(1), 20170010. DOI: 10.1515/jafio-2017-0010 (cit. on p. 45).

Sotelo, S. (2020). "Domestic Trade Frictions and Agriculture". *Journal of Political Economy*, 128(7), 2690–2738. DOI: 10.1086/706859 (cit. on pp. 16, 19, 21).

Steinwender, C. (2018). "Real Effects of Information Frictions: When the States and the Kingdom Became United". *American Economic Review*, 108(3), 657–696. DOI: 10.1257/aer.20150681 (cit. on p. 49).

Sutton, J. (2007). "Quality, Trade and the Moving Window: The Globalisation Process". *Economic Journal*, 117(524), F469–F498. DOI: 10.1111/j.1468-0297.2007.02119.x (cit. on p. 32).

Tombe, T. (2015). "The Missing Food Problem: Trade, Agriculture, and International Productivity Differences". *American Economic Journal: Macroeconomics*, 7(3), 226–258. DOI: 10.1257/mac.20130108 (cit. on pp. 6, 26).

Traoré, O. Z. and L. D. Tamini (forthcoming). "African trade of mangoes to OECD countries: disentangling the effects of compliance with maximum residue limits on production, export supply and import demand". *European Review of Agricultural Economics*. DOI: 10.1093/erae/jbab016 (cit. on p. 46).

Tseng, E. and I. M. Sheldon (2015). *Food Processing Firms, Input Quality Upgrading and Trade*. Conference paper. AAEA session, ASSA meetings. DOI: 10.22004/ag.econ.189696 (cit. on p. 32).

Tsigas, M. E., G. B. Frisvold, and B. Kuhn (1997). "Global climate change and agriculture". In: *Global Trade Analysis: Modeling and Applications*. Ed. by T. W. Hertel. Cambridge: Cambridge University Press. Chap. 11, pp. 280–304. DOI: 10.1017/cbo9781139174688.012 (cit. on p. 22).

Vancauteren, M. (2013). "EU harmonisation of regulations and mark-ups in the Dutch food industry". *European Review of Agricultural Economics*, 40(1), 163–189. DOI: 10.1093/erae/jbs009 (cit. on p. 37).

Verhoogen, E. A. (2008). "Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector". *Quarterly Journal of Economics*, 123(2), 489–530. DOI: 10.1162/qjec.2008.123.2.489 (cit. on p. 32).

Winchester, N., M.-L. Rau, C. Goetz, B. Larue, T. Otsuki, K. Shutes, C. Wieck, H. L. Burnquist, M. J. P. de Souza, and R. N. de Faria (2012). "The Impact of Regulatory Heterogeneity on Agri-food Trade". *The World Economy*, 35(8), 973–993. DOI: 10.1111/j.1467-9701.2012.01457.x (cit. on p. 46).

Xiong, B. and J. C. Beghin (2012). "Does European aflatoxin regulation hurt groundnut exporters from Africa?" *European Review of Agricultural Economics*, 39(4), 589–609. DOI: 10.1093/erae/jbr062 (cit. on p. 46).

Xu, K. (2014). "Why Are Agricultural Goods Not Traded More Intensively: High Trade Costs or Low Productivity Variation?" *The World Economy*, 38(11), 1722–1743. DOI: 10.1111/twec.12232 (cit. on pp. 4, 6, 19).

Zongo, W. J.-B., B. Larue, and C. Gaigné (2021). *On Export Duration Puzzles*. Working Paper 21-10. SMART-LERECO (cit. on pp. 38, 39).