Fair Trade or Trade Fair? International Food Trade and Cross-border Macronutrient Flows

Abstract

This study examines global food trade from a nutritional perspective, paying particular attention to its implications for food security in low-income countries. By describing food trade in terms of the quantities of three essential macronutrients (carbohydrates, lipids, and proteins) embedded in food, the analysis goes beyond a simple description of trade values, quantities, or caloric content, as is common in the literature. Furthermore, the study provides estimates of the implicit price of each macronutrient, their evolution over time, and their implications in terms of North-South food trade. The data show that, over the 1996–2014 period, the volume of macronutrients exchanged on international markets has more than doubled, with carbohydrates accounting for over 60% of trade flows, but proteins and lipids growing at a faster pace. Proteins were found to be the most expensive macronutrient, followed by lipids and carbohydrates. In general, macronutrients embedded in animal and processed products are more expensive than those in vegetal and unprocessed food. The results also suggest that the participation in international food trade has positive effects on low-income countries' aggregate food availability and food access, two pillars of food security. Indeed, low-income countries register a net inflow of all macronutrients and take advantage of "nutritional arbitrages" available on international food markets due to macronutrients' price differentials.

Keywords: Food security; International food trade.

JEL codes: F14, F63, Q17.

1 Introduction

The last three decades have witnessed the emergence of a truly global food system. Technological developments and international agreements, such as the conclusion of the Uruguay Round, paved the way for a remarkable and steady rise in the volumes and the value of trade in food products.[1] Indeed, even though soft and hard barriers to trade remain higher for food products than for industrial goods, the amount of food exchanged on international markets has increased almost three times faster than food production and, today, one in four food products is sold on export markets (D'Odorico et al., 2014). As a result, a growing number of countries (and an increasing share of the world population) relies on international trade to satisfy their domestic food demand.

Well-integrated markets can contribute to food security by promoting a more efficient use of resources and generating economic development and income growth. For example, economic integration allows countries characterized by relatively unfavorable conditions, such as those that are land- or water-scarce, to meet part of their food demand through imports, while specializing in sectors and goods in which they have a comparative advantage (Anderson, 2016; Martin, 2017). Moreover, trade can hedge a country against the risk of adverse domestic food supply shocks that may be due to extreme natural events, for example (Dorosh, 2001).

However, the claim that international trade is beneficial is not undisputed, especially when it comes to food trade. On the one hand, some authors maintain that free trade is harmful to poor rural households (Madeley, 2000; Gonzalez, 2004; Rosset, 2008). On the other hand, it has been argued that the benefits of free trade agreements may have been overestimated, in particular for those developing countries that do not have a comparative advantage in agricultural production (Bouët et al., 2005; Pyakuryal et al., 2010). With specific reference to fisheries and seafood products, other authors have underlined the lack of robust evidence on the beneficial effects of trade on developing countries' food security (Ruddle, 2008; Béné et al., 2010). Finally, a recent strand of literature has focused on the systemic fragilities associated with an increasingly interconnected international food trade network and on its potential adverse effects on global food security (Puma et al., 2015; Sartori and Schiavo, 2015; Davis et al., 2016; Distefano et al., 2018). In addition to the academic controversies, since the early 1990s, the process of liberalization of trade in agricultural goods has also met with opposition from movements such as *La Via Campesina*, which aims at "taking agriculture out of the WTO" and advocates food sovereignty (Clapp, 2014; 2017; Edelman et al., 2014; Díaz-Bonilla, 2015; Noll and Murdock, 2020).

[1] Within the WTO framework, the Agreement on Agriculture and the Sanitary and Phytosanitary Measures Agreement have been particularly relevant on the topic.

This study examines the dynamics of international food trade from a nutritional perspective. More specifically, by looking at the cross-border flows of macronutrients (i.e., carbohydrates, lipids, and proteins), it provides an original description of international food trade that contributes to the understanding of its consequences for countries' aggregate food and nutrition security. Indeed, macronutrients represent the bulk of human diet and an adequate intake of carbohydrates, lipids, and proteins is key to food security (FAO, 1996; 2013; Hawkesworth et al., 2010; Luan et al., 2018). Within such framework, the analysis pays particular attention to food security in low-income countries (LICs) and it is therefore closely related to the work of Asche et al. (2015), who examine the effects of North-South trade of fish and seafood products. However, the scope of the present study extends to all food products and the empirical analysis presents estimates of the implicit prices of the macronutrients exchanged in international markets. As such, the study sheds further light on the nexus between food trade and food access.

The characterization of trade flows in terms of macronutrients allows us to present a comprehensive description of food trade which, at the same time, conveys meaningful information on nutrition. In fact, it can be seen as an attempt to overcome the trade-off between coverage and specificity that characterizes the literature on international food trade, which focuses either on the aggregate quantity and/or monetary value of international food trade flows (Ercsey-Ravasz et al., 2012) or on specific food categories, for example fisheries (Béné et al., 2010; Asche et al., 2015) and main staples such as corn, wheat, and rice (Puma et al., 2015; Distefano et al., 2018). In the former case, the analysis may be exhaustive (as it covers all food items) but not very insightful regarding the nutritional dimension (as it lumps very different products together). In the latter, it can be highly informative on nutrition but it can offer only partial/limited coverage since the nutritional properties of the selected foods are known but they only account for a non-representative share of food trade. Importantly, other studies have analyzed international food trade in terms of the amount of calories (e.g., Porkka et al., 2013; Torreggiani et al., 2018) and "virtual water" embedded in trade flows (Sartori and Schiavo, 2015). However, despite looking at food trade from innovative and insightful perspectives, these studies are not suitable to thoroughly grasp its nutritional implications. Conversely, our approach allows us to take proper account of the dimension of nutrition without sacrificing representativeness.

The results show that not only has the total amount of macronutrients exchanged on international markets more than doubled between 1996 and 2014, but also that the composition of food trade has changed, with proteins and lipids growing faster than carbohydrates. Proteins are found to be the most expensive macronutrient, followed by lipids and carbohydrates. In general, macronutrients coming from products with animal origin ("animal" or "non-vegetal" food hereafter) and those derived from processed products tend to be more expensive than those embedded in vegetal and unprocessed food.

Our findings provide indirect evidence on the effects of international food trade on food security in LICs. On the one hand, LICs import more macronutrients than they export, meaning that trade increases the amount of food available on their domestic markets.[2] On the other hand, since the implicit price of the macronutrients they export is higher than the respective price of imports, LICs can increase their income through trade without reducing the total amount of nutrients available domestically. In other words, LICs benefit from "selling high and buying low" on macronutrients. From an aggregate perspective, we interpret these two stylized facts, the LICs' nutritional trade deficit and the "nutritional arbitrage", as a sign that trade has a positive effect on food availability (because it increases the amount of macronutrients available domestically) and food access (because of the net income gains), two pillars of food security.[3]

The remainder of the paper is organized as follows. Section 2 discusses data and methods. Section 3 describes international food trade from a nutritional perspective and estimates the implicit price of each macronutrient. Section 4 focuses on LICs and illustrates how food trade contributes to country-level food availability and food access. Section 5 concludes.

2 Data and methods

2.1 Data

The empirical analysis is based on a panel containing trade flows of 385 different food products between 1996 and 2014, which was built by combining FAO and CEPII data. Specifically, FAO trade matrices report bilateral trade flows of about 400 food and agricultural products, from which we drop all the non-edible entries (e.g., animal feed, tallow, cotton) as well as products used for herbal infusions such as tea, coffee, and mate. However, FAO data do not include information on fisheries, which we take from the CEPII-BACI dataset (Gaulier and Zignago, 2010).[4]

[2] We consider LICs as a group, but the result holds for the majority of individual countries.

[3] We refer to an aggregate perspective to stress that the analysis does not consider any of the distributional issues associated to trade. Albeit very important, these issues lie beyond the scope of the present study.

[4] We couldn't use data from FAO Fisheries and Aquaculture database (FishStat) because it does not provide bilateral trade flows. Importantly, however, the simultaneous presence of two different product classifications, namely the FAO classification and the 6-digit Harmonized System used by CEPII-BACI, is not an issue for the analysis. In fact, they refer to non-overlapping food categories and are characterized by an equivalent level of aggregation. Moreover, as discussed in the following, we match each traded product with nutritional data on the basis of product description.

The dataset covers 236 countries and territories and is therefore representative of the entire international food trade network. To identify LICs, we refer to those that are eligible for the Poverty Reduction and Growth Trust (PRGT) program by the IMF; the list of the 71 economies that we consider as LICs for the purpose of this study is reported in the Appendix.[5] The monetary value of trade flows is expressed in constant 2010 US dollars and is free on board (FOB), meaning that it includes the value of the goods plus the value of the services performed to deliver them to the border of the exporting country.[6]

To convert the aggregate quantity of each bilateral trade flow into its content of carbohydrates, lipids, and proteins we match each food category present in the trade data with the appropriate item(s) in the Food Composition Databases, a repository provided by the United States Department of Agriculture (USDA) that contains a large amount of information on food products available on the US market. In particular, it reports nutritional information on more than 3,400 generic food items (Standard Reference, or SR, database), and about 8,800 branded products (Branded Food Products, or BF, database). First, we manually match every food category in the trade data with entries from the SR database. When more than one SR entry is compatible with the product description, we averaged their nutritional content. We do not find a proper match within the SR database for about 20 food categories and, in this case, we rely on the BF database.[7]

Importantly, the conversion of trade flows relies on USDA data because the adoption of country-specific tables, which would have been our preferred option, was found to be unfeasible. In fact, even the local conversion tables made available by the FAO International Network of Food Data Systems (INFOODS) are characterized by substantial heterogeneity both in terms of product classification (e.g., different levels of aggregation, different classification standards) and details regarding nutritional properties. In addition, the tables refer to the food varieties consumed within the country, which are not necessarily representative of those that are exported.[8] As a result, we prefer to rely only on the USDA conversion table, and also because the US is a very large market where several varieties of each product are likely to coexist. As such, potential biases stemming from variety-specific nutritional content should (at least partially) average out.

[5]The results hold if the analysis is performed on the subsample of countries and territories with a population of at least 200,000 and that are present in all the years considered in the analysis (174 countries and territories).

[6]We use the World Bank's implicit deflator of world GDP to transform current values into real ones.

[7]The conversion table is available upon request.

[8]Furthermore, the level of aggregation of trade data does not allow us to distinguish between different varieties of the same food category. For example, there are several wheat varieties, but trade data aggregate them in a single food category.

2.2 Methodology

We describe international food trade referring to the cross-border flows of macronutrients, that is, carbohydrates, lipids, and proteins. Macronutrients, which need to be consumed in large amounts and on a daily basis, represent the basic components of a healthy diet and are necessary to sustain every body function and to fuel human activities. Specifically, carbohydrates represent the main source of energy and are critical for metabolism and homeostasis, proteins constitute the building blocks of human cells, and lipids play a key role for the central nervous system and in child development (WHO, 2007; FAO, 2010; Hawkesworth et al., 2010).

In order to provide an overall description of world food trade, the original data matrix representing bilateral trade flows of all food products is converted into a lower-dimensional matrix in which all the trade flows from country i to country j are collapsed according to their content of macronutrients. This returns the total amount of carbohydrates, lipids, and proteins exported by every country in the sample to each destination, thus reducing food trade to a set of three bilateral trade matrices per year.[9]

Breaking down food trade flows according to their content of macronutrients also allows us to estimate their implicit prices on international food markets. To do so, following a classical hedonic price (HP) framework, we assume that the value of trade flows is related to the amount of macronutrients they convey. Accordingly, we estimate different versions of the following model:

$$y_{ijft} = \beta_1 carbohydrates_{ijft} + \beta_2 lipids_{ijft} + \beta_3 proteins_{ijft} + \boldsymbol{x}'_{if}\boldsymbol{\gamma} + \boldsymbol{z}'_{ij}\boldsymbol{\delta} + \boldsymbol{\tau}'_t\boldsymbol{\eta} + \varepsilon_{ijft} \quad (1)$$

where y_{ijft} represents the value (in thousands of constant 2010 US dollars) of the trade flow of food f from country i to country j at time t, while the variables $carbohydrates_{ijft}$, $lipids_{ijft}$, and $proteins_{ijft}$ indicate the quantity (in metric tons) of macronutrients embedded in the total amount of food f exported by country i to country j in year t. We also include a wide set of fixed effects. In particular, $\boldsymbol{x}_{if}$ is a vector of exporter × product fixed effects controlling for time-invariant unobservable characteristics of the country from which each food item is exported, $\boldsymbol{z}_{ij}$ are country-pair fixed effects accounting for time-invariant unobservables related to the ties between bilateral trade partners, and $\boldsymbol{\tau}_t$ is a vector of time fixed effects meant to capture annual fluctuations of food prices. The main coefficients of interest are β_1, β_2, and β_3, which we interpret as the (FOB) implicit export price of a kilogram of carbohydrates, lipids and proteins, expressed in constant 2010 USD.[10]

[9] Considering that there are 385 food items, the dimensionality of the problem is reduced by two orders of magnitude.

[10] The use of exporter × product fixed effect reduces possible biases stemming from the adoption of a

It is worth noting that, in general, HP theory is agnostic with respect to the actual functional form linking products' price and attributes. While several applications assume a nonlinear function (e.g., Costanigro et al., 2007), in his seminal contribution Rosen (1974) highlights that in the special case in which buyers can "repackage" the characteristics of different products at no cost, the price function takes a linear form. This condition is naturally compatible with the case of macronutrients embedded in food products. In fact, the desired nutritional (and caloric) intake can be obtained with several different combinations of food items available to consumers at different prices.

Even though all the products included in the analysis can be properly classified as food, it is important to highlight that we do not have exact information regarding their final use. A share of certain products such as cereals and pulses, for example, will likely be used as animal feed or seeds. In addition, products such as rapeseed, corn, wheat, and sugar cane may be used to produce non-edible products such as biofuels, while some others will end up as waste. Since the food products used for human nutrition are probably more expensive than those used for other purposes, our price estimates should be considered a lower bound of the actual price of macronutrients. For the very same reason, our estimates of the cross-border flows of macronutrients represent an upper bound of the actual quantity of macronutrients exchanged on international markets *and* used for human nutrition.[11]

3 The international trade of food: from value, quantities, and calories to a (macro)nutritional perspective

3.1 The evolution of international food trade: value, quantities and calories

We provide a brief description of the evolution of international food trade in Table 1. Between 1996 and 2014, regardless of the unit of measure (dollars, tons, kilocalories), food trade has more than doubled, registering a compound annual growth rate of about 4.8%. By splitting the period into two nine-year intervals, it can be seen that while quantities and calories have grown faster in the first sub-period (5.0% *vs.* 4.3% and 5.2% *vs.* 4.7% per year, respectively), the aggregate monetary value of international food trade has grown considerably faster between 2005 and 2014 (3.4% *vs.* 6.0% per year, respectively). This difference may be partially explained by the change in the aggregate composition of trade flows, and partly by price dynamics, even though the level of aggregation of data prevents us from fully grasping the underlying dynamics. For example, the exchanged

common nutritional content conversion table (see Section 2.1) as it controls for country-product specific differences.

[11] However, this concern is mitigated by the use of exporter×product fixed effects.

quantity of food with animal origin, which is more costly than vegetal food, is found to have grown faster between 2005 and 2014 than over the previous nine years. However, the opposite is true for the dynamics of processed food, whose traded quantities grew faster during the 1996–2005 period.

The difference between the growth rates of the dollar value and the caloric content of trade flows provides insights on the evolution of the unit price of calories. In particular, between 1996 and 2005, the price of calories exchanged on international markets decreased at a rate of about 1.7% per year while it grew at a 1.3% yearly rate in the second period. The same trend emerges after splitting trade flows according to products' biological origin (vegetal *vs.* animal) and processing stage (unprocessed *vs.* processed).

The overview of international food trade provided in Table 1, however, is not very informative with regards of nutrition. Indeed, despite the distinctions that may be drawn on the basis of biological origin and processing stage of food, panels A and B lump very heterogeneous products together. For example, "animal food" includes products as diverse as herring, beef, honey, shrimps, and chicken eggs, while the category of "processed food" groups together food products such as macaroni, orange juice, dried eggs, and fish liver oils. On the other hand, the aggregation of food trade flows on the basis of their caloric content (panel C), presents the nutritional dynamics of food trade from a relevant but still narrow perspective.

3.2 Cross-border flows of macronutrients: steady growth, stable sources

Looking at global food trade from the viewpoint of macronutrient flows allows us to grasp the nutritional implications of international food trade without the need of focusing on specific food categories. The evolution of the aggregate amount of nutrients exchanged on international markets is reported in Table 2. In the years considered, carbohydrates retain the lion's share in terms of traded quantities. However, it also emerges that the trade of proteins and lipids has grown faster (overall 1996–2014 growth: +131% and +194% *vs.* +110%). Notably, even though the combined quantity of proteins and lipids traded in 2014 represents only 55% of the carbohydrates exchanged in that same year, it is higher than the total amount of carbohydrates exchanged in 1996 in absolute terms.

Table 2 also provides a disaggregation of macronutrient flows on the basis of their biological origin and of processing stage of the food products in which they are embedded. For each macronutrient, the growth rates of the subcategories have been roughly balanced and therefore, even though the overall quantity of macronutrients exchanged on international markets has more than doubled, the relative composition of trade flows has not undergone substantial changes. Indeed, the relative importance of animal proteins and carbohydrates has remained roughly unchanged (about 18% and 2%, respectively), while the percentage of animal lipids has decreased by little more than three percentage points, dropping to 10% in 2014. In addition, the proportion of macronutrients coming from processed food has remained stable, with about 22%, 73%, and 21% of internationally traded carbohydrates, lipids, and proteins originating from processed food, respectively.

Shifting the focus to specific products, Table 3 shows that staples such as wheat, maize, rice, barley, and soybeans account for more than 60% of the total amount of carbohydrates and proteins exchanged on international markets, while more than 40% of traded lipids originate from palm, sunflower, soybean, and rapeseed oils. Narrowing the analysis to non-vegetal food (Table 4), milk products represent the most important source of carbohydrates, while most proteins and lipids originate from meat. However, the distribution is less concentrated in these two latter cases.

3.3 The implicit price of macronutrients on international food markets

Table 5 reports the results of the estimation of the baseline empirical model (1) for the full sample (column 1) and different partitions of the data: products with animal and vegetal origin (columns 2 and 3), and processed vs. unprocessed food (columns 4 and 5). The regressions underlying Table 5 are not weighted, meaning that each trade flows carries equal weight, but results from weighted regressions are qualitatively similar in terms of sign, significance, and magnitude of the coefficients. Moreover, the results are found to be robust to the inclusion of different sets of fixed effects that are meant to saturate all the heterogeneity in the trade flows and thus reduce possible identification issues linked to omitted variables (see Table A1 in the Appendix).[12]

As expected, the estimated price of macronutrients displays significant variations across the different subsamples. Generally speaking, we find that carbohydrates are the cheapest macronutrient, while proteins tend to be the most expensive. When the model is estimated for the full sample, all three nutrients are highly significant and yield an average implicit price of about 0.06 USD/Kg for carbohydrates, 0.75 USD/Kg for lipids, and 1.41 USD/Kg for proteins.

The implicit price of macronutrients displays significant variations across the different subsamples. For example, by comparing the price of nutrients on the basis of their biological origin (Columns 2 and 3), animal proteins and lipids are found to be much more expensive than their vegetal counterparts. Indeed, the average international price of animal proteins is 6.72 USD/kg, while animal lipids cost 6.86 USD/Kg. Carbohydrates, on the other hand, do not contribute to explaining the price of animal food. Similar

[12]The fixed effects used in Table A1 allow us to control for comparative advantages, specialization patterns and "trade resistance" factors, as is commonly done in the gravity literature (Head and Mayer, 2014).

differences emerge by comparing the unit price of macronutrients embedded in processed food with those embedded in unprocessed products (Columns 4 and 5). In this latter case, however, the content of lipids are not significant in explaining the price of unprocessed food products.

The presence of non-significant coefficients indicates that, in some cases, not all macronutrients contribute to the determination of trade flows' value. In economic terms, it means that the implicit price of the associated macronutrient is zero. However, macronutrients are conveyed by food products and most foods contains at least some quantity of each macronutrient. Therefore, since macronutrients cannot be disentangled from food, even when the implicit price of a given macronutrient is found to be zero, importers have to "pay" for the other macronutrients embedded in the same food products. In fact, in every regression at least two out of three macronutrients have positive and significant coefficients.

Finally, Figure 1 illustrates the year-by-year evolution of the price of macronutrients on international markets. It shows that the period between the second half of the 1990s and the first half of the 2000s was characterized by low and somehow declining prices (at least regarding proteins and lipids), while the markets have become more volatile since 2006 and prices have increased, on average. Notably, the price dynamics that we estimate are fully consistent with the FAO Food Price Index (see Figure A1 in the Appendix) that, as expected, are mainly driven by the price of carbohydrates.

4 International food trade and food security in low-income countries

4.1 Fair trade or trade fair?

Food security is usually defined as a condition in which *"all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"* (FAO, 1996). As anticipated in the introduction, the merits of international food trade as a tool to promote food security are intensely debated both in academia and policy circles (Burnett and Murphy, 2014; Matthews, 2014; Jarosz, 2014; Clapp, 2015; 2017; Díaz-Bonilla, 2015; Farsund et al., 2015; Noll and Murdock, 2020). In particular, the awareness of the ambivalent effects that an increasing reliance on food trade may produce on countries' food security has increased after the 2008 food crisis (Headey, 2011). Such concerns are particularly relevant for LICs, where the largest share of world food insecure households live, and in the light of the warning signals from the recent reversal in the trends of undernourishment at the global level (FAO, 2018).

In this section, we provide insights on the effects of international food trade on the first two dimensions of LICs' aggregate food security, that is, food availability and food access. In doing so, we acknowledge that the aggregate perspective of the study prevents us from grasping the micro-level dynamics that link food trade to household food security (Burchi and De Muro, 2016). For example, the analysis is agnostic regarding the within-country distributive effects of food trade (Dorosh, 2001; Dorosh and Rashid, 2013; Houssa and Verpoorten, 2015), which determine the actual winners and losers and that largely depend on the peculiarities of the local context. Keeping this in mind, aggregate measures such as per capita income and food supply are both premises and predictors of household food security (Timmer, 2000; Smith and Haddad, 2001; Soriano and Garrido, 2016), and a macro-level analysis of this kind can therefore contribute to meaningfully frame the discussion on food trade policies in developing countries. Indeed, any rise in aggregate food security creates the conditions for Pareto improvements.

Generally speaking, the results presented below are qualitatively consistent with those discussed by Asche et al. (2015), who, focusing on seafood trade, find that developing countries profit from international trade by exporting high-price seafood and importing cheaper products. In addition, they also find that LICs' surplus in the trade of seafood almost disappears if measured in terms of quantities rather than in monetary values, hence mitigating the concerns that fish trade may reduce food security in developing countries. By directly taking nutritional aspects into account, considering trade in all products, and using bilateral trade data, our study increases both the depth and the scope of the analysis, thereby shedding further light on the link between trade and food security.

4.2 Food trade and food availability

The first question we address concerns the impact of international food trade on food availability. When we look at trade flows in terms of aggregate quantities, trade value, or caloric content, LICs are found to run a trade deficit with the rest of the world (RoW, i.e., middle- and high- income countries).[13] Such net inflow of food indicates that international trade increases the total amount of macronutrients available in those countries. However, this does not reveal much about the type and the nutritional properties of the food that is traded. For example, LICs may predominantly export products rich in proteins, which (at least in poor countries) are usually associated with a healthy diet (Kirkpatrick and Tarasuk, 2008; FAO, 2018), thus worsening the nutritional balance of their average diet. A similar argument applies to the distinction between fresh or unprocessed products

[13] In calculating export and import flows, we only take the trade flows from LICs to RoW and *vice versa* into account, without considering intra-LICs and intra-RoW trade.

versus processed food, which might represent lower-quality food.

This issue is not new in the literature although, to the best of our knowledge, it has never been investigated has never been investigated with the level of granularity adopted here. For example, Asche et al. (2015) observe that LICs export more seafood than they import and investigate the implications of such trade surplus. In fact, this unbalanced flow of seafood could signal that trade deprives poor countries of high-quality, locally-produced proteins, but also represent a useful poverty alleviation tool due to the income gains associated with positive net exports (Béné et al., 2010).

Table 6 shows that LICs run trade deficits for each of the three fundamental macronutrients. Such deficits increase over time and, among them, the higher increase is registered among proteins (+482% between 1996 and 2014). The result is the same if we further divide the macronutrients' flows according to the biological origin of the food in which they are embedded. This represents an important aspect to control for, since the average household diet in several developing countries is characterized by a low share of animal food, and of animal proteins in particular, the consumption of which is highly correlated with an adequate and healthy diet (FAO, 2013). Notably, between 1996 and 2014, LICs' net inflow of animal proteins increased faster than the corresponding inflow of vegetal proteins (+752% *vs.* +456%).

The general picture remains unchanged when we distinguish between unprocessed and processed food. In this regard, it is worth noting that LICs' exports of processed lipids and proteins have grown faster than their unprocessed counterparts, possibly indicating an increasing involvement of LICs in downstream activities of the global food value chain (e.g., see Balié et al., 2018). It may also be worth noting that, even though the macronutrient deficits have widened in absolute terms, they have remained roughly stable in relative terms. Indeed, over the period considered, both imports and exports have grown at similar rates. This finding may in turn be seen as a clue supporting the conclusion that the opening to international food markets did not have a disruptive effect on LICs' domestic agricultural production.[14]

If we look at individual countries, rather than LICs as a group, it is possible to better appreciate how the adoption of different units of measurement uncover different phenomena. For example, when trade flows are evaluated in dollar terms, the data reveal that 17% of LICs run a food trade surplus. However, this number almost halves if we look at kilocalories and it further falls to less than 4% if we look at macronutrients. Interestingly, this implies that some LICs simultaneously run a monetary surplus and a

[14]According to the World Bank (2019), between 1996 and 2014 the aggregate cereal production in LICs increased at an annual compound rate of 3.72%, against the 2.20% and 1.23% rates registered in middle- and high- income countries, respectively. On the other hand, the growth rates of cereal yields were 1.72%, 1.87%, and 1.69%, respectively.

caloric or nutritional deficit. This is the case for countries such as Bolivia, Ivory Coast, and Moldova, which, in most of the years considered in the analysis, are net exporters in monetary terms and net importers in terms of calories.

Finally, given the relevance of the so-called "hidden hunger" (von Grebmer et al., 2014), we also check whether the net inflow of macronutrients to LICs may conceal a net outflow of key nutrients and micronutrients. In fact, micronutrient deficiencies affect about two billion people worldwide and may entail serious and long-lasting consequences on the health and wellbeing of individuals, especially children (FAO, 2013; Beal et al., 2017). Table 7 reports the trade balance between LICs and the RoW with reference to a set of selected vitamins, minerals, and nutrients. The table shows that, as in the case of macronutrients, LICs register a net inflow of micronutrients (with the only partial exception of vitamin C in 1996). The change in the net inflow of vitamin A, which has increased by a factor of 18 in less than two decades, is particularly striking. Indeed, vitamin A deficiency, which is widespread in the developing world, weakens the resistance to infection and is a leading cause of preventable childhood blindness and anaemia (WHO, 2009).

Overall, the above evidence suggests that, at least when we look at country-level food security and we consider the cross-border flows of the three fundamental macronutrients (regardless of their biological origin and of their processing stage), international trade contributes to increasing the (aggregate) availability of food in LICs.[15] In addition, since looking at micronutrients leads to similar conclusions, we are reassured that the result is not driven by our decision to focus on macronutrients only.

4.3 Food trade and food access

A further issue to be investigated is whether international food trade has a positive impact on LICs' food access, a dimension of food security that is positively related to the capacity of purchasing food. While exports generate income, they reduce the total amount of macronutrients available in a country. However, other bundles of food that provide the same amount of macronutrients at a lower price may be available on international markets. We define such circumstance as "nutritional arbitrage", and in this section we provide indirect evidence that LICs take advantage of these market opportunities.

To this end, we re-estimate our empirical model subsampling according to the income

[15] As discussed in Section 2.2, our analysis focuses on the overall cross-border flows of macronutrients, therefore including also those embedded in products that will not be directly used as human food. As a robustness check, we re-calculate LICs' trade balance exploiting information contained in the Food Balance Sheets published by the FAO. For each country, we compute the proportion of macronutrients that are used in human food, and apply this share to trade data, thus correcting for alternative uses of food (such as animal feed, seeds, waste). Results are reported in Table A2 in the Appendix and are qualitatively similar to those presented in Table 6.

level of exporting and importing countries and compare the coefficients. The implicit price of the macronutrients embedded in the food exported by LICs and by the RoW are reported in columns (1) and (2) of Table 8, while the last two columns report the estimated prices of the macronutrients exported from LICs to the RoW and *vice versa*. As before, the quantity of macronutrients contained in food is significant in explaining the price of the products exported by the two groups of countries. However, the export prices of LICs are systematically higher than those of the RoW. For example, the average price of carbohydrates exported by LICs toward middle- and high- income countries is 1.07 $/Kg while the import cost of carbohydrates is about 0.24 $/Kg. Such pattern largely also holds when distinguishing between animal/vegetal and processed/unprocessed products (see Tables 9 and 10).

These results indicate that, by engaging in international food trade and by capitalizing on price differentials, LICs increase their level of income without sacrificing the total amount of macronutrients available on their domestic markets. The presence nutritional arbitrage opportunities in turn yields an improvement of LICs' aggregate food access. The findings are consistent with both the "quality exchange" mechanism described in Asche et al. (2015), and with a pattern that has been observed since the early 1990s, namely the shift of developing countries' agriculture toward products that command a premium price on world markets (Henson and Jaffee, 2006; Didier and Lucie, 2008).[16]

5 Concluding remarks

This study analyzed the link between international food trade and food security, looking at the implicit flows of three essential macronutrients (proteins, lipids, and carbohydrates) embedded in each food item. This original approach is particularly suitable for describing and understanding the consequences of food trade on nutrition and food security because it allows us to by-pass the trade-off between specificity and coverage, that is, between analyzing a few specific food categories with known nutritional properties and looking at aggregate trade flows in terms of value, quantities, or caloric content but ignoring the nutritional dimension.

Looking at the evolution of food trade over about two decades, we find that cross-border flows of macronutrients have increased substantially since the mid 1990s, with the aggregate quantity of proteins and lipids growing faster than that of carbohydrates. We also observe that a large share of total macronutrients exchanged on international markets is conveyed by a relatively low number of food products and that the relative

[16]Positive aggregate effects may well hide an adverse within-country impact on some households or groups. While we are unable to examine the distributional consequences of trade with the data at hand, this remains an important issue that requires more research.

importance of the different items (at least of those in the top positions of the ranking) does not change much. For example, wheat, maize, and barley account for about half of the total traded carbohydrates and a third of the total traded proteins both in 1996 and in 2014. Furthermore, the relative share of macronutrients of animal origin and from processed products is found to be quite stable over time.

With respect to the implicit price of macronutrients, we find that proteins are the more expensive item, followed by lipids and carbohydrates. We also find that the price of macronutrients embedded in non-vegetal and processed food is generally higher than those derived from vegetables or from unprocessed goods.

In the second part of the analysis, we look at nutritional trade balances and average export and import prices to understand how trade affects the availability of macronutrients and access to them. In fact, these aspects represent the first two dimensions of food security.

On the one hand, food availability improved because LICs registered a net inflow of all the three macronutrients (and of micronutrients as well). Such finding remains unchanged if we further split the macronutrients on the basis of their origin, that is, animal *vs.* vegetal. Indeed, not only do proteins represent the macronutrient whose net imports have grown faster, but the net inflow of animal proteins, which in LICs are usually associated with a healthier diet, has increased faster than the imports of vegetal proteins. On the other hand, international trade improves aggregate food access in LICs due to the favorable price differential between exported and imported nutrients. Indeed, our results indicate that the unit prices of macronutrients exported by LICs are higher than of those exported from the RoW. Hence, by engaging international food trade and by capitalizing on such price differentials, LICs can increase their level of income (that can be used to purchase more food from abroad) without reducing the aggregate amount of macronutrients available domestically.

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TABLES AND FIGURES

Table 1: International food trade: value, quantities and calories

Year	Total		Vegetal		Animal		Unprocessed		Processed	
	Level	CAGR	Level	CAGR	Level	CAGR	Level	CAGR	Level	CAGR
					A) Monetary values					
1996	476	.	300	.	176	.	215	.	261	.
2005	645	3.4%	422	3.9%	223	2.7%	277	2.9%	367	3.9%
2014	1,085	6.0%	723	6.2%	362	5.5%	505	6.9%	580	5.2%
					B) Quantities					
1996	526	.	472	.	53	.	357	.	169	.
2005	817	5.0%	739	5.1%	78	4.3%	536	4.6%	281	5.8%
2014	1,197	4.3%	1,076	4.3%	121	5.0%	810	4.7%	387	3.6%
					C) Calories					
1996	1,535	.	1,421	.	114	.	973	.	562	.
2005	2,414	5.2%	2,249	5.2%	165	4.2%	1,411	4.2%	1,003	6.7%
2014	3,645	4.7%	3,390	4.7%	255	4.9%	2,150	4.8%	1,494	4.5%

Notes: the table reports the value of international food trade expressed in billions of 2010 constant 2010 $ (panel A), in millions of metric tons (panel B) and in trillions of kilocalories (panel C); CAGR indicates the compounded annual growth rate. Source: Own calculations based on FAO, CEPII and USDA data.

Table 2: International food trade: flows of macronutrients

Year	Total		Vegetal		Animal		Unprocessed		Processed	
	Level	CAGR	Level	CAGR	Level	CAGR	Level	CAGR	Level	CAGR
					A) Carbohydrates					
1996	230	.	226	.	4	.	181	.	49	.
2005	336	4.3%	330	4.3%	6	4.4%	256	3.9%	81	5.6%
2014	484	4.1%	475	4.1%	9	5.1%	378	4.4%	106	3.1%
					B) Lipids					
1996	51	.	44	.	7	.	15	.	36	.
2005	92	6.9%	83	7.3%	10	4.2%	23	5.1%	69	7.6%
2014	149	5.5%	135	5.6%	15	4.8%	39	5.9%	110	5.3%
					C) Proteins					
1996	51	.	42	.	9	.	40	.	11	.
2005	76	4.7%	63	4.8%	13	4.2%	61	4.7%	16	4.7%
2014	117	4.8%	97	4.8%	20	5.0%	96	5.2%	22	3.5%

Notes: the table reports the international flows of carbohydrates, lipids and proteins (panel A, B and C respectively) in 1996, 2005 and 2014; values in levels are expressed in millions of tons; CAGR indicates the compounded annual growth rate. Source: Own calculations based on FAO, CEPII and USDA data.

Table 3: Food products as vehicles of macronutrients in international food trade

1996		2014	
Carbohydrates			
Wheat	25.2%	Wheat	25.1%
Maize	22.3%	Maize	21.6%
Barley	6.0%	Sugar Raw Centrifugal	6.7%
Sugar Raw Centrifugal	5.5%	Rice	5.8%
Rice	5.3%	Barley	5.1%
Sugar refined	4.9%	Soybeans	5.0%
Soybeans	3.1%	Sugar refined	4.6%
Flour, wheat	2.9%	Flour, wheat	1.7%
Molasses	2.1%	Sorghum	1.3%
Sorghum	2.0%	Cake, soybeans	1.2%
Lipids			
Oil, palm	20.5%	Oil, palm	28.8%
Oil, soybean	9.6%	Soybeans	10.6%
Soybeans	9.2%	Oil, sunflower	8.8%
Maize	6.5%	Oil, soybean	6.8%
Oil, rapeseed	5.2%	Oil, rapeseed	4.6%
Oil, sunflower	5.2%	Maize	4.5%
Wheat	4.0%	Wheat	2.8%
Cake, soybeans	2.3%	Pastry	2.1%
Butter, cow milk	1.9%	Fat, nes, prepared	1.9%
Pastry	1.9%	Oil, palm kernel	1.8%
Proteins			
Wheat	22.0%	Soybeans	25.0%
Soybeans	17.0%	Wheat	20.0%
Maize	12.8%	Maize	11.3%
Cake, soybeans	5.8%	Cake, soybeans	5.1%
Barley	4.6%	Barley	3.6%
Rice	3.3%	Rice	3.3%
Meat, chicken	2.9%	Meat, chicken	3.1%
Flour, wheat	2.4%	Flour, wheat	1.3%
Sorghum	1.3%	Meat, cattle, boneless (beef & veal)	1.1%
Meat, cattle, boneless (beef & veal)	1.2%	Cheese, whole cow milk	0.9%

Note: the table reports the first ten food products that vehicle the largest share of carbohydrates, lipids and proteins traded on international markets in 1996 and 2014. Source: Own calculation based on FAO, CEPII and USDA data.

Table 4: Food products as vehicles of macronutrients in international food trade (Animal origin)

1996		2014	
		Carbohydrates	
Milk, skimmed dried	18.5%	Whey, dry	19.1%
Whey, dry	16.8%	Milk, skimmed dried	15.4%
Milk, whole dried	14.3%	Milk, whole dried	12.0%
Meal, meat	8.5%	Meal, meat	7.8%
Fish fillets, frozen	6.0%	Fish fillets, frozen	6.2%
Milk, whole fresh cow	4.8%	Honey, natural	5.1%
Honey, natural	4.8%	Milk, whole fresh cow	5.0%
Ice cream and edible ice	3.5%	Infant food	3.8%
Fish meat & mince (no liver, roe, fillets) frozen	2.7%	Ice cream and edible ice	3.6%
Milk, whole condensed	2.6%	Milk, whole condensed	3.4%
		Lipids	
Butter, cow milk	14.3%	Meat, pig	10.2%
Meat, pig	9.6%	Butter, cow milk	8.8%
Cheese, whole cow milk	8.2%	Meat, pork	8.5%
Meat, pork	6.3%	Cheese, whole cow milk	7.7%
Milk, whole dried	5.9%	Milk, whole dried	5.2%
Offals, edible, cattle	5.0%	Offals, edible, cattle	5.0%
Lard	4.8%	Pigs	4.0%
Meat, cattle, boneless (beef & veal)	3.3%	Meat, chicken	3.1%
Meal, meat	3.0%	Meat, cattle, boneless (beef & veal)	3.0%
Meat, sheep	2.9%	Fat, pigs	2.9%
		Proteins	
Meat, chicken	16.1%	Meat, chicken	17.9%
Meat, cattle, boneless (beef & veal)	6.7%	Meat, cattle, boneless (beef & veal)	6.0%
Milk, skimmed dried	5.4%	Cheese, whole cow milk	4.9%
Cheese, whole cow milk	5.2%	Milk, skimmed dried	4.7%
Meat, pig	4.3%	Meat, pig	4.6%
Milk, whole dried	4.2%	Fish nes, frozen, whole	4.0%
Fish nes, frozen, whole	3.5%	Meat, pork	3.8%
Meat, cattle	3.4%	Milk, whole dried	3.7%
Meat, pork	2.9%	Meat, chicken, canned	2.4%
Meal, meat	2.1%	Cattle	2.2%

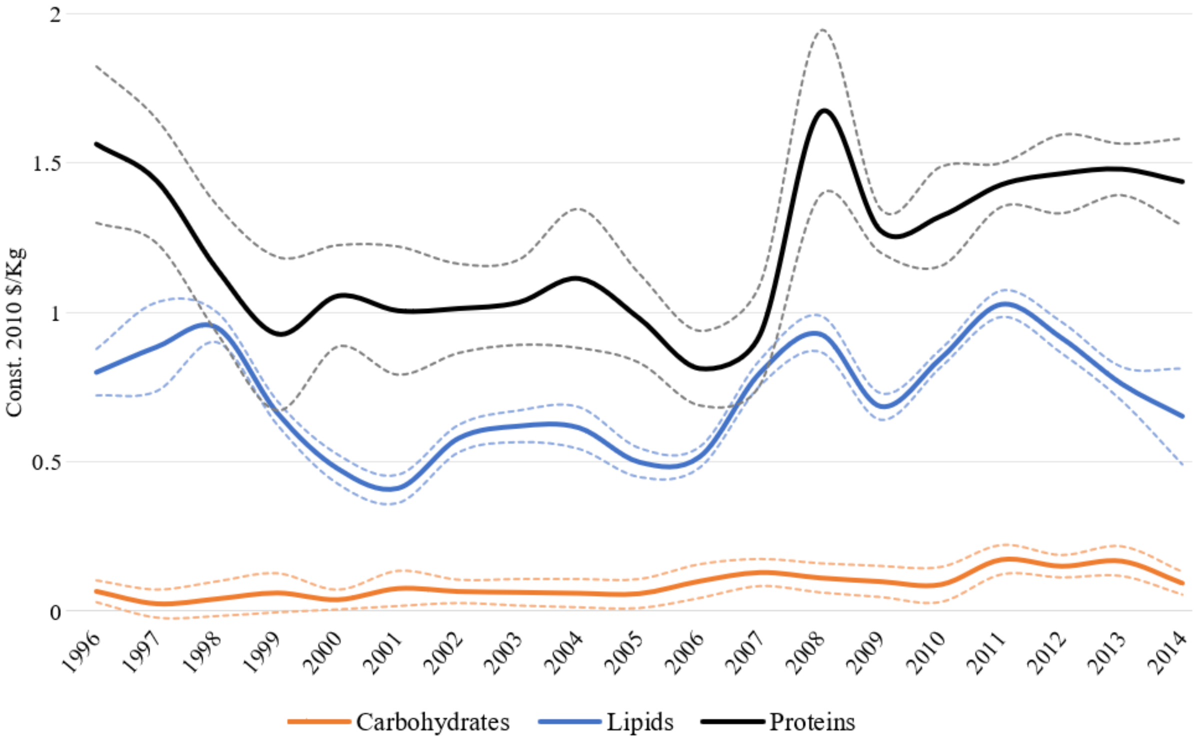
Note: the table reports the first ten animal food products that vehicle the largest share of carbohydrates, lipids and proteins traded on international markets in 1996 and 2014. Source: Own calculation based on FAO, CEPII and USDA data.

Table 5: Implicit prices of macronutrients

	Dep. variable: Trade Value (thousands of const. 2010 $)				
	(1) Full Sample	(2) Animal Origin	(3) Vegetal Origin	(4) Processed	(5) Unprocessed
Carbohydrates	0.0638***	0.5672	0.0765***	0.3411***	0.0185***
	(0.0238)	(0.3967)	(0.0246)	(0.0334)	(0.0082)
Lipids	0.7518***	6.8573***	0.7470***	0.7548***	0.1159
	(0.0412)	(0.7076)	(0.0412)	(0.0409)	(0.1829)
Proteins	1.4070***	6.7151***	1.3495***	4.4057***	1.7680***
	(0.0396)	(1.0975)	(0.0604)	(0.6814)	(0.1148)
Fixed effects:					
exporter × product	✓	✓	✓	✓	✓
country-pair	✓	✓	✓	✓	✓
year	✓	✓	✓	✓	✓
Observations	3,959,084	886,061	3,070,686	2,111,264	1,845,125
R-squared	0.7118	0.7176	0.7774	0.5222	0.8725

Notes: the explanatory variables ‘carbohydrates’, ‘lipids’ and ‘proteins’ are measured in metric tons; column (1) reports the results of the model estimated on the full sample, columns (2) and (3) the results of estimation performed on the two complementary subsamples of animal and vegetal food while columns (4) and (5) of those on the subsamples of processed and unprocessed food; clustered standard errors (country-pairs and year) are reported in parenthesis; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 1: The evolution of macronutrients' export prices (1996-2014)



Notes: the figure reports the point estimates and 95% confidence intervals (dashed lines) for the export price of macronutrients over the period 1996-2004; exporter×product and country-pair fixed effects included; standard errors are clustered at the country-pair level.

Table 6: North-South trade in macrountrients (from LICs' perspective)

Year	Sample	Carbohydrates			Lipids			Proteins		
		Export	Import	T.B.	Export	Import	T.B.	Export	Import	T.B.
					A) Total trade					
1996	Full	1,952	11,408	-9,457	412	1,959	-1,547	516	1,876	-1,360
2005	Full	4,182	32,880	-28,698	1,650	5,309	-3,659	1,012	5,123	-4,111
2014	Full	8,313	56,636	-48,324	4,743	12,915	-8,172	2,133	10,053	-7,920
					B) By biological origin					
1996	Vegetal	1,922	11,283	-9,361	345	1,771	-1,426	290	1,529	-1,239
	Animal	30	126	-96	67	187	-120	226	347	-121
2005	Vegetal	4,139	32,591	-28,452	1,560	4,997	-3,437	662	4,539	-3,877
	Animal	42	289	-247	90	312	-222	350	584	-234
2014	Vegetal	8,079	56,026	-47,947	4,448	12,134	-7,686	1,486	8,372	-6,886
	Animal	234	610	-377	295	781	-486	646	1,680	-1,034
					C) By processing stage					
1996	Unprocessed	1,136	8,513	-7,377	178	351	-173	371	1,688	-1,317
	Processed	816	2,896	-2,080	234	1,607	-1,374	144	188	-44
2005	Unprocessed	2,219	25,019	-22,799	502	972	-470	703	4,544	-3,841
	Processed	1,962	7,861	-5,899	1,148	4,338	-3,189	309	579	-271
2014	Unprocessed	4,994	43,491	-38,497	1,453	2,422	-969	1,515	8,796	-7,282
	Processed	3,319	13,145	-9,826	3,290	10,492	-7,202	618	1,257	-638

Notes: the table reports the LICs' total import, total export and trade balance for each of the three macronutrients with respect to the RoW; values are expressed in thousands of metric tons.

Table 7: North-South trade in micrountrients (from LICs' perspective)

	1996	2005	2014
	Vitamins		
Vitamin A	-5,236	-36,022	-96,911
Thiamin (Vitamin B1)	-43	-130	-228
Riboflavin (Vitamin B2)	-17	-56	-112
Niacin (Vitamin B3)	-641	-1,861	-3,325
Vitamin B6	-39,549	-137,300	-241,400
Folate (Vitamin B9)	-8,806,000	-30,770,000	-56,030,000
Vitamin B12	-25,992	-22,360	-127,000
Vitamin C	60	-1,218	-3,785
Vitamin D	-27,738	-2,578	-34,411
Vitamin E	-206	-526	-1,261
Vitamin K	-494,200	-782,700	-2,381,000
	Minerals		
Iron	-338	-1,079	-1,910
Zinc	-371	-1,114	-1,872
Calcium	-4,659	-15,755	-29,515
Phosphorus	-43,183	-123,300	-213,500
Potassium	-37,011	-133,700	-239,500
Sodium	-3,268	-12,298	-22,759
	Fatty acids		
Monounsaturated	-557	-1,151	-2,731
Polyunsaturated	-354	-783	-1,527

Notes: the table reports the LICs' trade balance with the RoW for selected nutrients and micronutrients; the values are vitamins and minerals are expressed kilograms, those of fatty acids in metric tons.

Table 8: Implicit prices of macronutrients: LICs *vs.* RoW and North-South trade

	Dep. variable: Trade Value (thousands of const. 2010 $)			
	(1) LICs	(2) RoW	(3) LICs to RoW	(4) RoW to LICs
Carbohydrates	0.7652***	0.0634***	1.0682***	0.2426***
	(0.2048)	(0.0237)	(0.3015)	(0.0598)
Lipids	0.9638***	0.7515***	0.9413***	0.7809***
	(0.1149)	(0.0412)	(0.1103)	(0.0414)
Proteins	1.2866	1.4075***	1.3508***	0.8123***
	(0.7433)	(0.0395)	(0.7493)	(0.3896)
Fixed effects:				
exporter × product	✓	✓	✓	✓
country-pair	✓	✓	✓	✓
year	✓	✓	✓	✓
Observations	149,211	3,809,873	104,271	464,276
R-squared	0.4045	0.7137	0.4233	0.8060

Notes: the explanatory variables 'carbohydrates', 'lipids' and 'proteins' are measured in metric tons; column (1) reports the results of the model estimated on the LICs' export only and column (2) on RoW's export only; columns (3) and (4) report the estimates on the LICs' export towards RoW and vice versa; clustered standard errors (country-pairs and year) are reported in parenthesis; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Implicit prices of macronutrients in animal and vegetal food: North-South trade

	Dep. variable: Trade Value (thousands of const. 2010 $)			
	Animal food		Vegetal food	
	(1) LICs to RoW	(2) RoW to LICs	(3) LICs to RoW	(4) RoW to LICs
Carbohydrates	7.5401***	2.3257***	1.1234***	0.2739***
	(1.4717)	(0.4120)	(0.3047)	(0.0575)
Lipids	-2.7899	2.8912***	0.9839***	0.7802***
	(3.3311)	(0.2891)	(0.1282)	(0.0419)
Proteins	14.9870***	3.6225***	0.7940	0.5910
	(5.4449)	(0.2479)	(0.7040)	(0.3806)
Fixed effects:				
exporter × product	✓	✓	✓	✓
country-pair	✓	✓	✓	✓
year	✓	✓	✓	✓
Observations	18,357	114,766	85,501	348,913
R-squared	0.5564	0.7998	0.4418	0.8311

Notes: the explanatory variables 'carbohydrates', 'lipids' and 'proteins' are measured in metric tons; column (1) reports the results of the model estimated on LICs' export of processed food towards RoW and column (2) on RoW's export of animal food towards LICs; columns (3) and (4) are analogous to the first two except for that they refer to vegetal food; clustered standard errors (country-pairs and year) reported in parenthesis; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 10: Implicit prices of macronutrients in processed and unprocessed food: North-South trade

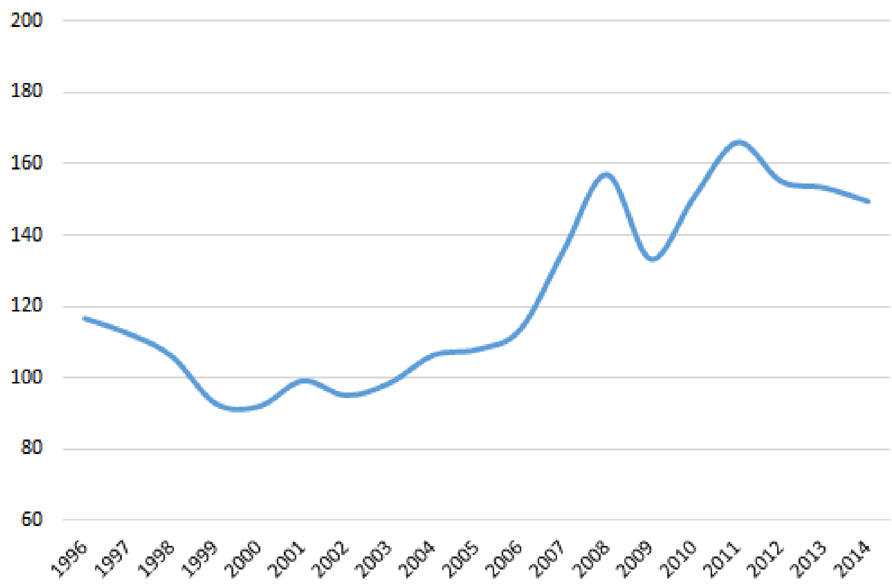
	Dep. variable: Trade Value (thousands of const. 2010 $)			
	Processed food		Unprocessed food	
	(1) LICs to RoW	(2) RoW to LICs	(3) LICs to RoW	(4) RoW to LICs
Carbohydrates	0.5170***	0.3728***	2.4639***	0.1197
	(0.0715)	(0.0232)	(0.8832)	(0.0935)
Lipids	1.0260***	0.7765***	2.9514***	-0.3216
	(0.1702)	(0.0404)	(0.8918)	(0.6803)
Proteins	2.7770***	3.4729***	-5.3982	1.5484***
	(0.4935)	(0.1930)	(3.2426)	(0.5613)
Fixed effects:				
exporter × product	✓	✓	✓	✓
country-pair	✓	✓	✓	✓
year	✓	✓	✓	✓
Observations	39,436	283,407	64,258	180,226
R-squared	0.6317	0.8828	0.4776	0.8412

Notes: the explanatory variables 'carbohydrates', 'lipids' and 'proteins' are measured in metric tons; column (1) reports the results of the model estimated on LICs' export of processed food towards RoW and column (2) on RoW's export of processed food towards LICs; columns (3) and (4) are analogous to the first two except for that they refer to unprocessed food; clustered standard (country-pairs and year) errors are reported in parenthesis; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix

List of LICs: Afghanistan, Bangladesh, Benin, Bhutan, Bolivia, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo, Djibouti, Dominica, Eritrea, Ethiopia, Gambia, Ghana, Grenada, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Ivory Coast, Kenya, Kiribati, Kyrgyzstan, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Marshall Islands, Mauritania, Micronesia, Mongolia, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Papua New Guinea, Moldova, Rwanda, Saint Lucia, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, Sudan, Tajikistan, Timor-Leste, Togo, Tonga, Tuvalu, Uganda, Tanzania, Uzbekistan, Vanuatu, Viet Nam, Yemen, Zambia, Zimbabwe.

Figure A1: FAO Food Price Index (1996-2014)



Note: the figure reports evolution of the deflated Food Price Index between 1996 and 2014. Source: FAO.

Table A1: Implicit price of macronutrients estimated using alternative sets of fixed effects

	Dep. variable: Trade Value (thousands of const. 2010 $)			
	(1)	(2)	(3)	(4)
Tons of carbohydrates	0.0671***	0.0720***	0.0671***	0.0673***
	(0.0234)	(0.0250)	(0.0234)	(0.0242)
Tons of fat	0.7507***	0.7560***	0.7499***	0.7521***
	(0.0412)	(0.0417)	(0.0412)	(0.0413)
Tons of protein	1.3926***	1.3899***	1.3929***	1.3941***
	(0.0416)	(0.0413)	(0.0416)	(0.0406)
Fixed effects:				
country-pair	✓		✓	
country-pair × year				✓
exporter		✓	✓	
exporter × year	✓			
importer		✓	✓	
importer × year	✓			
product		✓		✓
year		✓	✓	
Observations	3,964,296	3,967,157	3,964,316	3,923,712
R-squared	0.6889	0.6755	0.6853	0.6975

Notes: the explanatory variables carbohydrates, lipids and proteins are measured in metric tons; clustered standard errors (country-pairs and year) in parenthesis; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2: North-South trade in macrountrients (LICs' perspective) - Human nutrition only

Year	Sample	Carbohydrates			Lipids			Proteins		
		Export	Import	T.B.	Export	Import	T.B.	Export	Import	T.B.
					A) Total trade					
1996	Full	920	10791	-9872	196	1891	-1695	241	1772	-1530
2005	Full	2120	31300	-29179	809	5066	-4257	497	4875	-4378
2014	Full	4378	54600	-50222	2151	12595	-10444	1089	9705	-8616
					B) By biological origin					
1996	Vegetal	904	10671	-9767	160	1727	-1567	128	1453	-1324
	Animal	16	120	-105	36	164	-128	113	319	-206
2005	Vegetal	2100	31022	-28923	764	4781	-4017	339	4338	-3998
	Animal	21	277	-257	45	285	-240	158	537	-379
2014	Vegetal	4267	54013	-49746	2025	11868	-9843	797	8147	-7350
	Animal	111	587	-476	126	727	-600	292	1559	-1267
					C) By processing stage					
1996	Unprocessed	498	8060	-7562	84	334	-250	170	1605	-1434
	Processed	421	2731	-2310	112	1557	-1445	71	167	-96
2005	Unprocessed	1111	23937	-22827	270	927	-657	346	4331	-3986
	Processed	1010	7362	-6353	539	4139	-3600	152	543	-392
2014	Unprocessed	2681	42268	-39587	805	2368	-1562	790	8513	-7723
	Processed	1697	12332	-10635	1346	10227	-8881	299	1192	-893

Notes: the table reports the LICs' total import, total export and trade balance for each of the three macronutrients with respect to the RoW (*the table refers only to the macronutrients that are embedded in products that will be directly used for human nutrition*); values are expressed in thousands of metric tons.