International trade impact on food security among selected low-middle and low-income countries

by

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Abstract

Food security is a relevant indicator of development and, for years, a topic of discussion for organizations aiming to improve this in developing countries. International trade, on the other hand, has been a tool to facilitate access to foods that a country's domestic production cannot cover; however, through the literature review about these topics, there has been a debate on whether international trade might, in fact, harm countries' state of food security. Low-middle and low-income countries have a state of food security that comes from a good to a weak level, according to the Global Food Security Index (GFSI). This thesis aimed to determine whether international trade affects food security and in which direction this impact moves in a set of low-middle and low-income countries. For these, two significant indicators of food security were analyzed: food availability and food affordability. Data from diverse sources was collected to construct variables that were related to countries food supply measured by kilograms and kilocalories and food diet costs ratio to per capita income to measure food affordability. These main measures were analyzed using inferential methods and an econometric model regarding general trade, food, and other trade-related variables. In the case of food availability, the models used were OLS and an Instrumental Variable model obtained from the gravity model of international trade. The methods used for food affordability were a GLS-AR1 model and OLS and IV, models. By-country estimates and panel estimates were obtained for the two factors. For both indicators, it was found that international trade variables do affect both affordability and availability of foods in those countries; however, the direction of these effects was variable among the factors. For food availability, the total trade of merchandise as a percentage of GDP, in most cases, caused a negative impact on food availability, except when analyzing the panel estimates;

the effect of food imports and exports was more diverse depending on the country, and more conclusive for food exports in the panel estimates. The negative or positive effect of trade was more pronounced when analyzing the availability through kilocalories, and the created IV proved to have larger estimates. In the case of food affordability, the results were more constant; most trade-related variables were found to cause a diminution in the ratio between diet cost and income, thus, making food affordable. The agricultural tariff was the only variable that negatively affected affordability, but this is expected as tariffs represent a trade barrier. The present research adds to the literature a supporting investigation that, given the data, model, and assumptions made, indicates that the food trade is favorable for those countries in which food security state is critical, principally in affordability factor.

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Chapter 1 - Introduction and Research Objectives

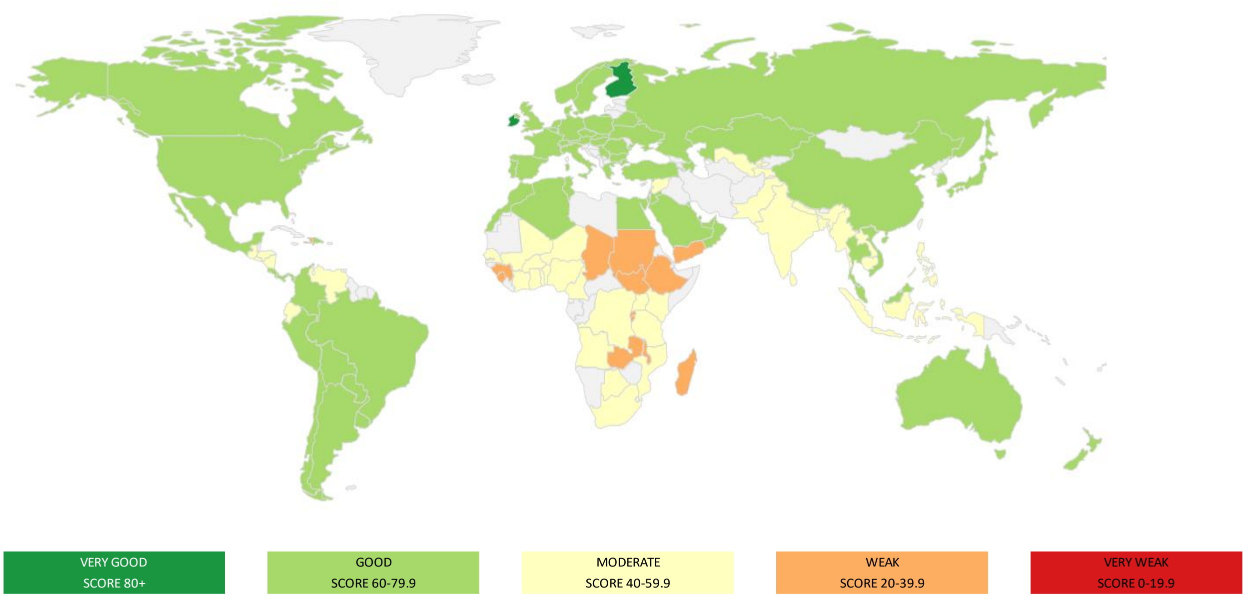
According to the United Nations World Food Summit in 1996: "*Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*." On the other hand, USAID adjusted it to have its own definition: "*Food security means having, at all times, both physical and economic access to sufficient food to meet dietary needs for a productive and healthy life*" (USAID, 2022).

International trade has been a tool to provide countries with access to foods that their domestic production cannot meet, and at the same time, it is said that it has had a role in reducing the volatility in price for staple foods (Smith and Glauber, 2020). However, there has been a continuous debate on whether international trade positively contributes to enhancing food security in specific countries or sets of countries **(**Dorosh, Rashid, and Asselt, 2016; Agcaoili and Rosegrant, 1995; Ly et al., 2020).

In its last report, the United Nations classified 46 countries as lower-middle-income, having a per capita gross national income (GNI) between $1,026 to $3,995, and ranked 32 as low-income countries, with a GNI of less than $1,025 (UN, 2020). Most of these lower-middle and low-income countries are in Africa, Asia, and Latin America.

The GFSI (Global Food Security Index) has made a per country analysis of 48 of these 78 low and low-middle countries; the analysis involves the principal issues evolving food security, having an overall food security environment ranking. Among these 48 low and low-middle countries, five are reported to have a good food security environment, 31 a moderate level, and 12 a weak level, not reporting countries within the category of very weak food security environment. Figure 1.1 contains the categorization of all 113 countries ranked by the GFSI, where the darker green represents very good food security, lighter green countries fall into the good category, yellow in the moderate, and orange in the weak. The figure was taken out of the GFSI reported for all countries in 2020. (The Economist, 2022).

Figure 1.1[1]. World Food Security Environment, GFSI – 2020



The contents of this GFSI analysis were one of the primary motivations of the present thesis. Among the different factors analyzed within the overall food security score that this index provides there are four category rankings detailing the factors around food security: affordability, availability, quality and safety, natural resources, and resilience.

The GFSI follows a quantitative and qualitative methodology creating a score index between zero and a hundred on each category analyzed and an overall score in food security in which affordability and availability represent the 64.8% of the weight in the final score. An example of how the scoring works can be taken from the indicators in the affordability factor; some of the qualitative indicators include funding for food safety net programs, coverage of these

[1] Figure from The Economist, 2022 – GFSI annual analysis, 2020.

programmes, access to finance and financial products for farmers, among others. In the quantitative side for affordability some indicators are change in average food costs, inequality-adjusted income index and proportion of population under global poverty line (*The Economist*, 2022).

In the affordability and availability categories, some international trade indicators add up to the final score, such as agricultural import tariffs and sufficiency of supply, including the overall food supply in each country measured by domestic production, import, and exports.

Although all these countries are classified in comparable levels of per capita income, there is a large difference in their levels of total trade. From these 48 countries, in 2018, their total trade, which is just the sum of imports and exports in millions of US Dollars, ranged between 870.01 and 839,242.42, which indicates a difference of 96,363.54% between the bottom and top trading countries (WTO, 2018). Looking at the map and the color classification, their levels of food security do not show a clear difference either; when transferring this visual to actual data, for example, the per capita food supply, this range is considerably narrower than the one seemed on trade levels. The difference between the country with the largest food supply in Kg (Uzbekistan) and the one with the lowest level (Yemen) is 185.37% (FAO, 2018-1), this considering the same year the trade difference was calculated.

This thesis aims to evaluate whether international trade has an effect on food security among selected low and low-middle income countries; this selection is taken from the GFSI analysis and data availability. This main objective is divided into two specifics; those specifics measure two of the four categories of food security declared by the GFSI but relate them to aspects of trade as the primary source of measurement:

- Analyze international trade effect on the availability of food in these countries.

- Analyze international trade-related variables' impact on the affordability of the diets in these countries.

The availability factor is analyzed to determine, first whether higher levels of trade are related with higher levels on the country's population's disposable food. The second approach is to determine whether the overall trade contribution of these countries and specifically their food trade is associated in any direction with its per capita food supply or their per capita caloric intake, both being principal measures of food availability.

On the other hand, affordability is studied to establish an effect on the cost of a basic diet in the country related to economic trade determinants or variables such as tariffs, terms of trade, and general and food trade balance.

This thesis fills gaps related to the study of food security and its connection with international trade within the countries analyzed, intending to advise policymakers, specifically those related to the decision making in trade policy, on whether the analyzed countries are, under the limitations and assumptions made on the thesis methods, better or worse off in their food security because of trade. This thesis will advise on relaxing or strengthening trade barriers, specifically those related to the food trade.

Chapter 2 - Literature Review

The following section will provide food security research and its relationship with international trade; this section is divided into three subsections, the first two according to the indicators that the thesis objective is trying to achieve, food availability, and food affordability. The third section is other food security-economic research that could be indirectly related to both main parameters; this subsection includes price shocks and price transmission research; price transmission is also related to international trade directly. This chapter aims to compile the most important information regarding these topics and whether the present thesis adds or fills the gaps to the reviewed literature performed regarding food security and international trade in developing countries.

2.1 International Trade and Food Security

There has been a considerable amount of previous literature analyzing the effects of trade liberalization on food security. Some examined the impact of policies or trade agreements at the country level (Dorosh, Rashid, and Asselt, 2016; Baylis, Fan, and Noguera, 2019; Antamoshkina and Rogachev, 2021; Dash et al., 2020). Other research analyzed the effects over groups of countries (Bezuneh and Yiheyis, 2014; Kang, 2015**)**, while there has been research related to international trade and food security focusing on a specific product that contributes to the most valuable nutritional value in the diet of the analyzed country, finding a positive effect (Asche et al., 2015).

Different factors of food security have been analyzed over time, some of them directly related to food security categories such as food affordability and availability and others straight related to price changes on staple foods. According to the FAO, Staple foods are "*one that is eaten* *regularly and, in such quantities, as to constitute the dominant part of the diet and supply a major proportion of energy and nutrient needs."*

2.1.1 Food Availability research

Chavas (2000) developed a microeconomic model to explain the relationships between food demand and nutrition. The research included food availability measures such as food produced, food and non-food inventory, individual monetary wealth, prices, and purchasing decisions. Many researchers have analyzed overall food availability by using the FAO (Food and Agriculture Organization) food balance sheets which accounts for the total domestic production plus imports, minus exports, non-food issues of the raw materials, wastage, and storage, per country (Warr, 2014; Burchi and De Muro, 2016, and Porkka, et al., 2013). Others analyzed the availability of specific products by using the same balance sheets, for example, cereals imports dependency (Capone et al., 2014).

Literature regarding the direction of the effect of international trade on food availability is divided, specifically those related to trade liberalization. Bezuneh and Yiheyis (2014) analyzed the impact of trade liberalization on food availability, measured in dietary energy supply as the dependent variable, in 37 developing countries in the period before and after a series of trade liberalization policies were approved using a dummy variable to represent the change, finding a negative effect of this liberalization over the dietary energy supply.

Others like Ly et al. (2020), which analyzed data for 10 Southeast Asian countries using panel regressions, explicitly focusing on factors such as availability, stability, and accessibility, at the end of their research, recommended a reduction in trade barriers. Others like Herath, Liang and Yonbing (2014) found inconclusive results regarding the importance of trade agreements on food availability. A food import price variable negatively affects the dietary energy supply of the signing countries of the Association of Southeast Asian Nations (ASEAN) trade agreement.

Bentley (2017) analyzed USDA and FAO but in a developed country like the U.S. to capture the behavior of food availability in this country by analyzing the components of the food balance sheets, while Dorosh, Rashid, and Asselt (2016) quantified household demand, which can be considered as a measure of food availability. Agcaoili and Rosegrant (1995) projected decreases in food supply due to trade liberalization under four scenarios; however, Baldos and Hertel (2015) concluded that segmented economies with more trade barriers are more negatively influenced by climate change on their food security, specifically their caloric consumption and malnutrition count.

As per the research cited above, regardless of the availability of research assessing the effects of international trade on food availability, the present thesis provides: (1) an quantitative, more in-depth analysis using econometric tools such as instrumental variables to account for causality issues between trade and food supply (Kg and Kcal) which has not been accounted on previous research, (2) an analysis of two food availability units of measure that behave differently, most of the previous research has focused only on one of them, and (3) the inclusion of trade-related variables that do not account for specific events on trade policy such as trade liberalization but for more quantitative measures such as general merchandise trade and food trade specifically which will provide more insight in at what extent those two trade categorizations affect food availability.

2.1.2 Food Affordability research

Affordability, on the other hand, has been analyzed in diverse approaches. For example, by studying diet costs and incomes or purchase power factors in this case, Colchero et al.

(2019) calculated the affordability of food in Mexico considering energy and nutritional requirements and analyzed this affordability factor over time by using survey collected data on diet sufficiency and monthly household income. Mason et al. (2011). analyzed the affordability of staple foods (maize and wheat) in Zambia and Kenya, determining how staple foods purchase power has changed over the course of 15 years and with the factor of food price crisis, the purchasing power analysis was made using variables of quantity of a given staple food affordable per average monthly, urban per capita income, per capita GDP, formal sector wage and services sector value-added per employee and the deflated retail price for staple foods.

Other researchers use the factors analyzed on the GFSI score. For example, Capone et al. (2014) measured affordability with variables such as cereal and food import dependency, consumer price index, food price level index, household food expenditure, and food affordability score (from the GFSI). Finally, some studied directly macroeconomic variables based on the coefficient of poverty, coefficient of food consumption, and Gini coefficient or income inequality (Antamoshkina and Rogachev, 2021).

In Chavas (2000) food affordability components are included, such as prices, individual purchasing decisions, and borrowing capacity. Warr (2014) also measured an affordability factor: consumer price data, advising policies to control higher prices coming from importing products. Other research somewhat related to the connection between food affordability and land expansion like Delzeit et al. (2017) as a secondary part of the research, included pricing effects of this expansion, concluding that it would cause reduced prices on soybeans and wheat, being the last one relevant part of the analyzed country, India.

The literature mentioned above achieves to analyze food affordability at the extent of data they found available and mostly related to macroeconomic factors, however, there has been little to none direct relationship analysis between food affordability and international trade, also the measures of food affordability are not clear and constant through the research found. This thesis aims to provide a series of additions to literature, the main ones include: (1) a new unit of measure to analyze food affordability that provides an intersection between food retail prices collected on each country, per capita income, and food groups consumption, and (2) analyze the direct impact of total trade and food trade on food affordability by using the measure mentioned above, as well as using econometric instruments to account for possible causality issues, but at as a complementary addition to the research.

2.1.3 Other research related: Price transmission

The research related to prices also has been conducted under different approaches: Hatzenbuehler, Abbott, and Abdoulaye (2017) analyzed price transmission of maize, millet, sorghum, rice, cassava, yams, and cowpeas, by applying linear regression over the price levels adjusted to exchange rate and ad valorem tariffs and then using the residuals in an error correction model to measure price dynamics. Ivanic and Martin (2014) analyzed trade protection policies affecting price insulation and thus price volatility by estimating through an econometric approach the price insulation parameters using a global general equilibrium model; the results indicated a direct increment in price volatility because of those policies.

Other research not directly related to price transmission but related to food security include the one made by Gutierrez and Piras (2014) who measured price shocks in wheat prices as a consequence of other international dynamics not merely related to trade, such as food consumer prices, cost of inputs, US dollar currency changes, among others. Summarizing the research in this subsection, price transmission or price shocks are strictly related to food security, especially food affordability, particularly when they affect staple foods such as cereals (all included) or specific products (wheat).

After analyzing a wide range of literature found and connecting it with the background presented in the introduction part of the research objectives, it could be concluded that the present thesis has a place in the gaps of literature relevant to international trade in food security. This thesis includes an analysis of the two principal food security indicators and measuring them through more developed models that will be discussed in the methodology chapter.

Chapter 3 - Data Description

To test the stated objectives, it is necessary to collect data to measure the relationship between international trade and food security, specifically data related to the specific factors to analyze, availability and affordability. This chapter describes the available data, directly and indirectly, related to food security indicators and trade indicators; the data defined will only fall within the scope of low-income and low-middle income countries. The chapter will contain three sections: First, general and food specific trade data, then data related to food availability and the third section consists in data linked to food affordability including food prices and income of the set of countries analyzed. This chapter explores the data available regarding some of the dependent and independent variables used to construct the models explained in the methodology chapter visually and descriptively. As the data analyzed is extensive and considering the large amount of countries included in the research, some of the visual and descriptive representations of the data are made using some of the selected countries and other data analysis is made using the income group classification.

3.1 International Trade

This section will present a descriptive and visual analysis of data related to trade, specifically total merchandise trade, food trade, and other types of trade-related variables used in the methodology section to construct the final models. The data sources for these variables are primarily from the WTO and the FAO. One specific data point comes from the World Bank, the trade percentage of GDP. The period analyzed of these variables changes depending on the factor analyzed; these periods are described more in detail in the methodology section (WTO, 2018; WTO, 2021-1; WTO, 2021-2; FAO, 2018-2; FAO, 2021; The World Bank, 2018).

As mentioned before, the present thesis provides an analysis by country; presenting a summary per country would be difficult to assess, so the summary statistics for trade-related variables are given by income group; this can be found in table 3.1. The countries belonging to the low-income classification are Benin, Burkina Faso, Ethiopia, Guinea, Madagascar, Mali, Mozambique, Malawi, Niger, Nepal, Rwanda, Chad, Uganda, and Togo. On the other hand, the countries in the low-middle income classification are Bangladesh, Bolivia, Cote d'Ivoire, Cameroon, Egypt, Ghana, Guatemala, Honduras, India, Indonesia, India, Kenya, Cambodia, Laos, Morocco, Nigeria, Nicaragua, Pakistan, Philippines, Senegal, El Salvador, Tajikistan, Ukraine, Yemen, and Zambia. These countries constitute the total of countries analyzed, but not all of them were studied in the models of both factors of food security.

In table 3.1, it is noticeable a growing trend in food trade and total merchandise trade; another clear point is that low-middle-income countries have a more considerable general trade and food trade; however, this could be biased by the presence of high trading countries such as India, Viet Nam, Indonesia, Philippines, Ukraine, and Egypt. The proportion of food trade over total merchandise trade seems constant through the years explored, being more prominent in low-income countries by around 16%.

Another important point to analyze is how these trade data relate to the state of food security in the analyzed countries. Figure 3.1 shows the top 20 trading countries analyzed in this research; the size of the point indicates their trade measured in billion dollars. A label with the country code and the food security score provided by the GFSI was included. Some relevant points in this figure are that some high trade countries like India (IN) have the same food security score as lower trading countries like Guatemala (GT), and the countries with the highest food security score, Ukraine (UA) and Morocco (MA), don’t seem to have highest levels of trade, for example, Philippines (PH) or Indonesia (ID).

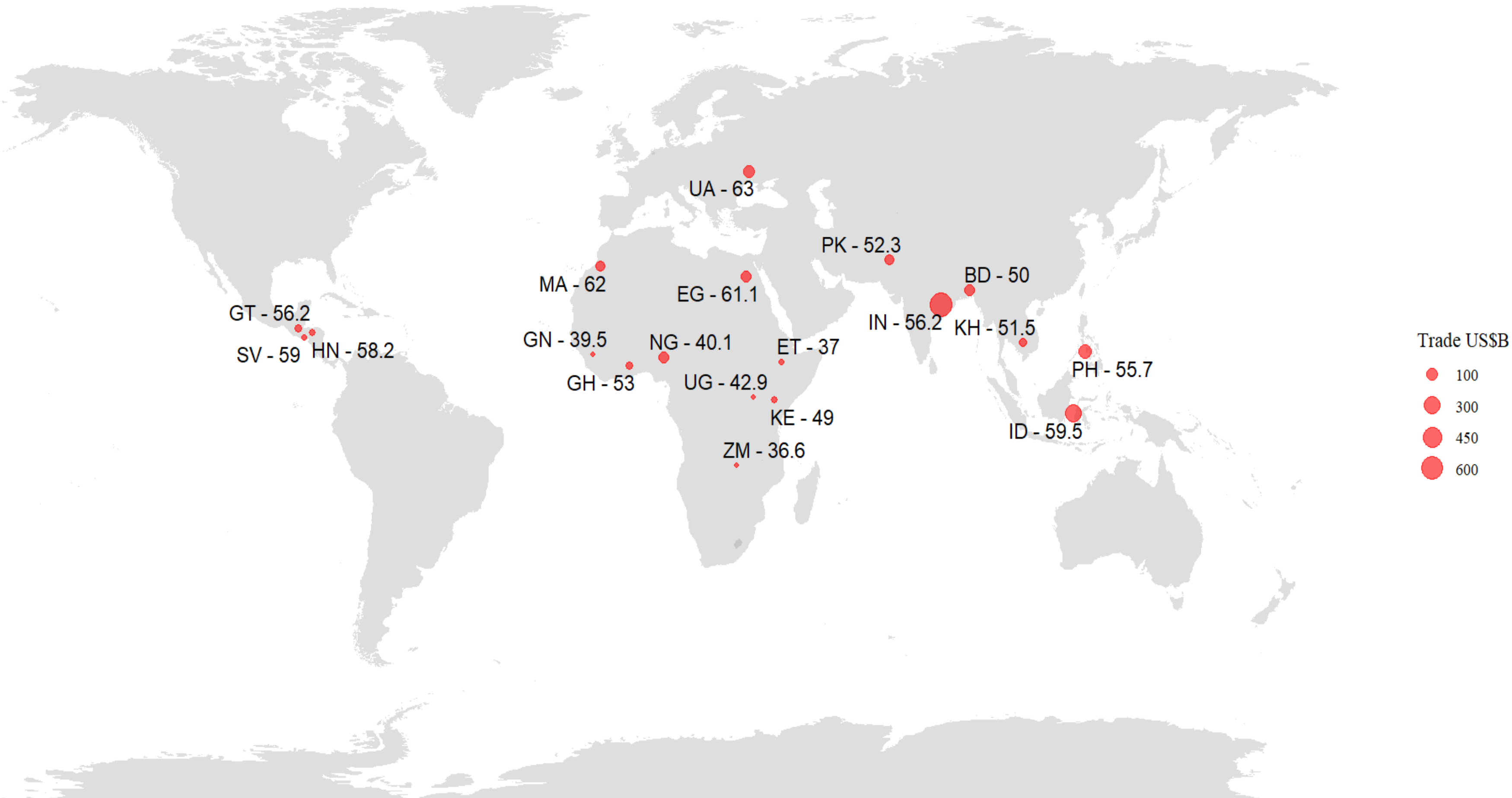
The countries included in the calculation for the table below include for low-income countries: Benin, Burkina Faso, Ethiopia, Guinea, Madagascar, Mali, Mozambique, Malawi, Niger, Nepal, Rwanda, Chad, and Togo. For low-Middle income countries: Bangladesh, Bolivia, Cote d’ Ivoire, Cameroon, Egypt, Ghana, Honduras, India, Indonesia, Kenya, Cambodia, Lao, Morocco, Nigeria, Nicaragua, Pakistan, Philippines, Senegal, El Salvador, Tajikistan, Ukraine, Viet Nam, Yemen, and Zambia.

Table 3.1[2]**.** Summary Statistics - Trade data, by income group

Values	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Low-Income countries											
- Average Total Merchandise Trade (US$ Billions)	4.79	5.68	6.34	6.67	7.21	6.45	6.50	7.16	7.89	7.93	7.90
- Average Food Imports (US$ Billions)	1.39	1.84	1.79	2.27	2.39	2.23	2.37	2.81	2.94	2.57	2.60
- Average Food Exports (US$ Billions)	1.41	1.75	1.69	2.17	2.26	2.12	1.76	2.09	2.13	2.08	1.90
- Food trade over Total Trade (%)	58.42%	63.09%	54.89%	66.51%	64.43%	67.42%	63.53%	68.47%	64.24%	58.56%	56.95%
Low-Middle income countries											
- Average Total Merchandise Trade (US$ Billions)	72.31	92.46	95.39	95.40	96.51	84.43	82.47	96.61	108.47	108.29	96.76
- Average Food Imports (US$ Billions)	10.76	14.59	15.08	15.05	16.11	15.21	15.37	18.09	18.15	18.14	18.72
- Average Food Exports (US$ Billions)	12.94	18.15	19.06	18.43	19.26	17.13	16.89	19.75	19.64	19.25	20.31
- Food trade over Total Trade (%)	32.78%	35.41%	35.79%	35.10%	36.65%	38.30%	39.12%	39.17%	34.84%	34.53%	40.33%

[2] Constructed with data from the FAO and the WTO

Figure 3.1[3]**.** Map of top trading countries and their food security score, 2020



[3] Constructed with data from the WTO and the GFSI

3.2 Food Availability

Regarding food availability, there are some data available that seek to measure this parameter; this thesis will use two specific units' measures of food availability which are food supply in kg and food kilocalories supply; these data is available in the food balance dataset from the FAO (FAO, 2018-1). The food supply in kilograms is the aggregation of all food groups in kilograms and is calculated based on parameters like production, imports, exports, waste, and industry use.

Table 3.2[4]. Food Availability in selected countries, 2018

Country	Supply (Kg)	Kilocalories	Country	Supply (Kg)	Kilocalories
Ghana	882.47	3,071	Tajikistan	555.47	2,463
Ukraine	875.68	3,021	India	554.80	2,560
Lao	847.31	2,778	Philippines	546.99	2,723
Egypt	737.22	3,298	Burkina Faso	519.52	2,748
Viet Nam	722.59	2,916	Niger	513.58	2,661
Benin	705.71	2,755	Mozambique	504.75	2,158
Cameroon	698.65	2,750	Kenya	491.31	2,174
Nepal	674.40	2,867	Cambodia	481.75	2,708
Morocco	672.37	3,409	Nicaragua	478.44	2,625
Mali	658.01	2,881	Bangladesh	478.16	2,611
Cote d'Ivoire	651.32	2,873	Pakistan	463.95	2,466
Malawi	642.00	2,618	Togo	458.27	2,396
Rwanda	632.06	2,224	Honduras	452.46	2,683
Nigeria	621.48	2,578	Senegal	433.97	2,596
Guinea	576.41	2,806	Madagascar	421.07	1,890
El Salvador	574.86	2,683	Ethiopia	359.66	2,452
Bolivia	571.39	2,476	Zambia	357.40	2,254
Indonesia	566.01	2,945	Chad	318.07	2,292
			Yemen	316.28	2,009
Average Supply (Kg)				568.00	
Coefficient of Variation - Supply (Kg)				24.88%	
Average Kilocalories				2,632.92	
Coefficient of Variation - Kilocalories				12.23%	

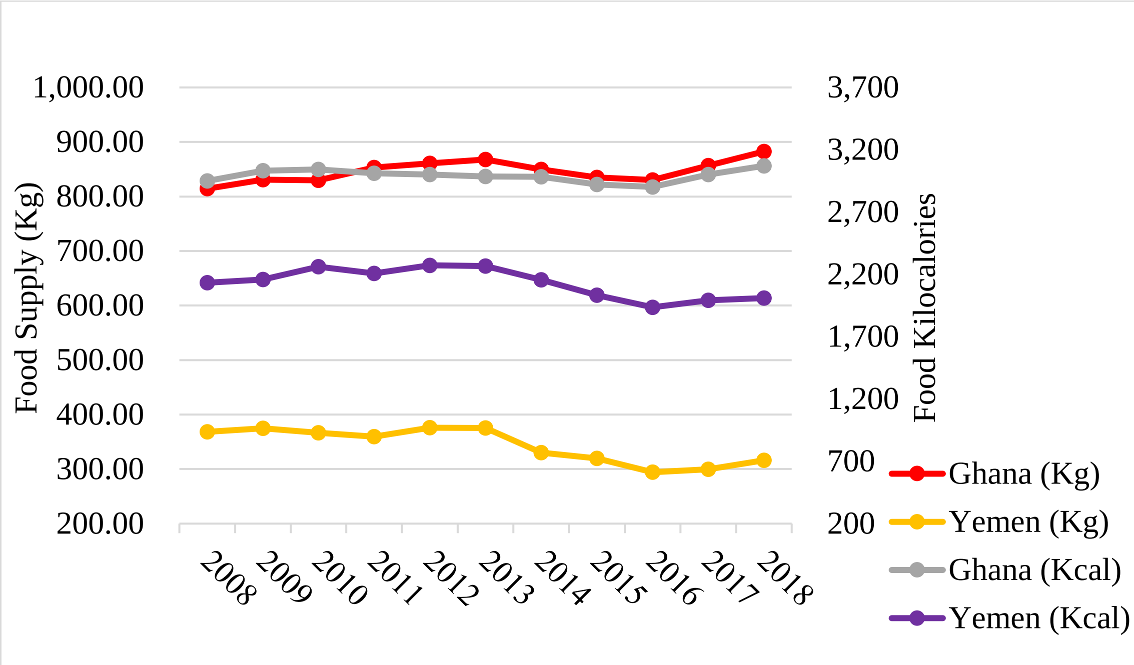
[4] Constructed using FAO-Food Balance data

Table 3.2 presents the availability data of 37 countries analyzed in this research for 2018. The data is presented in both units of measure and provides a summary of statistics at the bottom of the table. A critical outcome of this descriptive analysis is how these availability measures are related to each other; although they are not comparable in terms of average, their coefficient of variation is different; it is observed that the supply in kilograms is more variable between the analyzed countries than the kilocalories supply.

Another relevant point of discussion that can be taken out of this descriptive analysis is how the kilocalories availability differs from the daily recommendations and therefore affecting the food security state of those countries. The National Research Council in the US estimated by using formulas created by the WHO (World Health Organization) that the required allowance should range between 2,200 kcal per day (women) and 2,900 kcal per day (men), considering a light to moderate daily activity (National Research Council, 1989). By table 3.2 it can be noticed that most countries fall within this range however, there are four cases in which the average availability falls below the recommendations, these are: Mozambique, Kenya, Madagascar, and Yemen, therefore the relevance of analyzing the effect of trade in maybe positively affect the allowance of those countries, especially in the case of Yemen which has a critical score in the GFSI food availability factor score.

Food availability has slightly changed through time; the trending graph below (Figure 3.2) represents the trends in both measures of food availability for the two countries that have the highest (Ghana) and lowest (Yemen) available food. There is a flat growth in the first years, followed by a decline in food availability for both countries in the time frame from 2012 to 2016, and finally for the last two years graphed the availability starts to increase, however overall, the change has not been relevant as per seen on the graph.

Figure 3.2[5]**.** Food Availability in Ghana and Yemen (2008-2018)



3.3 Food Affordability

In comparison with food availability, there is not much data to measure food affordability; however, valuable data can be converted into parameters to analyze this relevant food security factor. For example, for this research purposes, two main data sets were used to analyze this factor; the global dietary database contains consumption patterns of a set of food groups for all countries and is updated every 3 to 5 years (GDD, 2021). The other primary data set used was the World Food Programme, global food prices, which contains actual retail prices of different foods in each important market in each country (WFP, 2021). Although relevant, this dataset is very constrained in the types of food reported historically; this was why the number of countries in which affordability was analyzed was reduced.

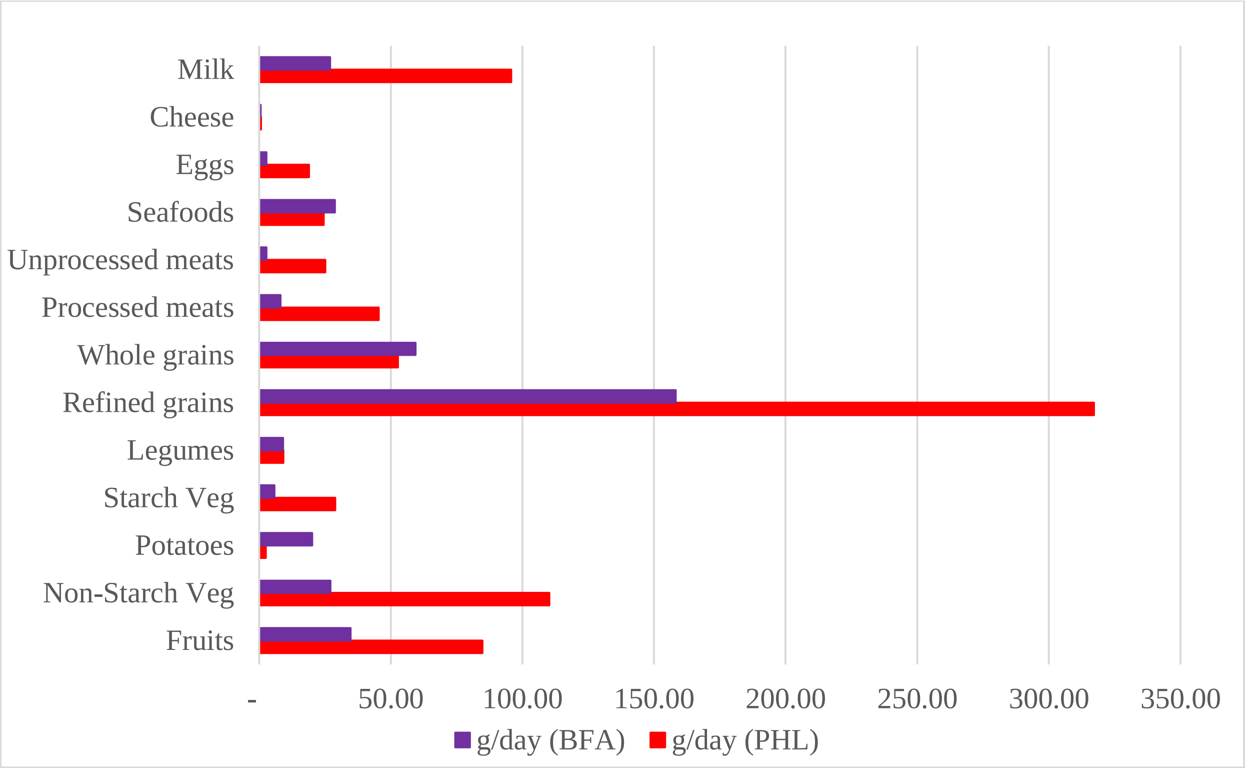
[5] Constructed with data from FAO, 2018-1

The global dietary database has diverse consumption groups focused on four main categories: foods, beverages, macronutrients, and micronutrients; however, for this research, the only ones considered are foods and some items in beverages. Data is cataloged by age, gender, and education groups; however, the one taken was the overall consumption for this thesis. The consumption patterns are important data to measure affordability as it provides insights of how's the consumption behavior in those countries, however this consumption becomes relevant when unifying it with price and income data, this is briefly explained at the end of this section.

The consumption patterns for two countries from different regions and income groups are represented in figure 3.3. It can be noticed that in most food groups Philippines (PHL, red) has a more significant consumption than Burkina Faso (BFA, purple); these consumption patterns can relate, first, to their average per capita income, for example, in the year graphed (2018) the per capita annual income in Burkina Faso was US$672.84, and in the Philippines, it was around US$3,279.59.

The three data points explained for food affordability in this section are the main databases used to create the unit of measure of this factor to later be compared with the international trade data described on the first subsection. The measure for food affordability used for this research is made by matching the consumption patterns of food groups with the available food retail price data to obtain a measure of the cost of a basic diet on each country, then this cost is associated to the average per capita income to obtain a ratio of food cost that will be analyzed against trade variables. How this measure is created is explained in detail on the methodology section.

Figure 3.3[6]**.** Consumption Patterns for Philippines and Burkina Faso, 2018



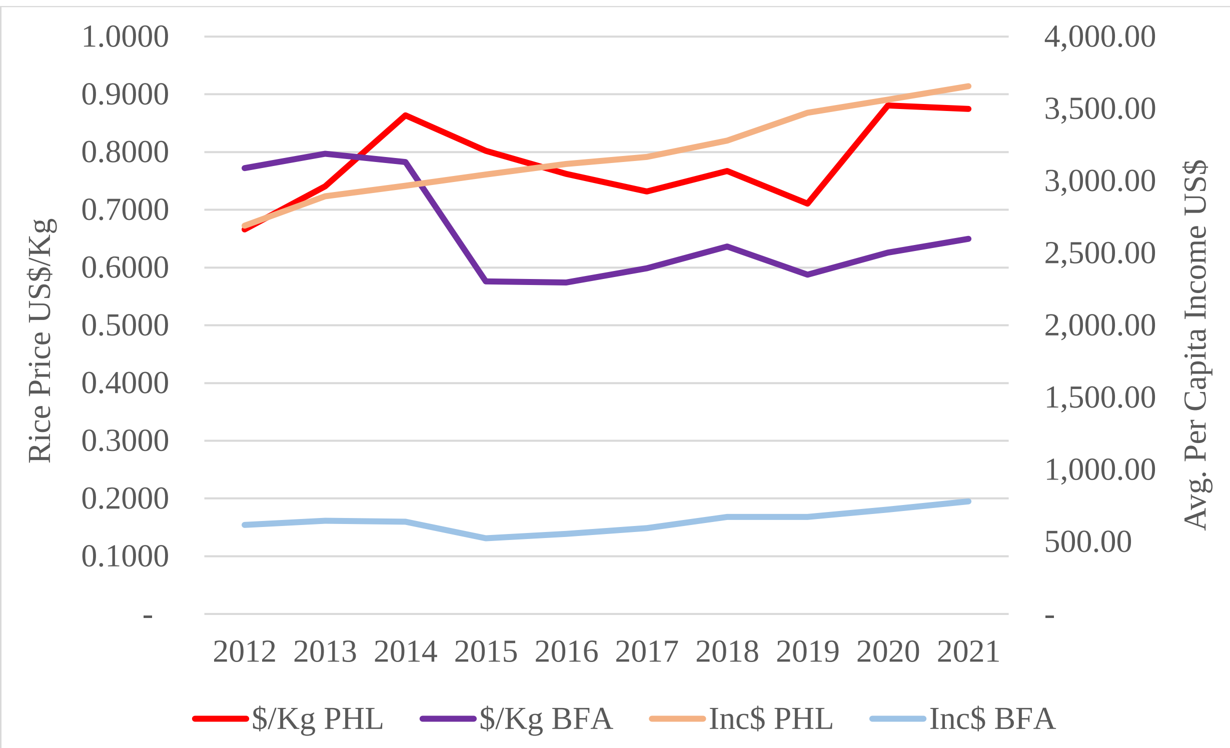
This difference in consumption is also related to the other relevant data to measure affordability: retail prices. Figure 3.4 represents a trend line per kilogram price of rice from 2012 to 2021 in both countries; the graph data is the average price of rice in all the markets reported in the WFP data set; rice belongs to group number seven of the Global Dietary database which in the graph above was represented by the label of "Refined Grains" which as seen in the chart above is the highest group of consumption.

Lines red and purple represent the trend line for rice price (Kg) for the Philippines and Burkina Faso, respectively. It is noticeable that the prices are not very separate between the countries, being slightly higher in the Philippines; however, the trend of change through time is different, with more clear decreases in the case of Burkina Faso. An income trend line was also

[6] Constructed with GDD data, 2018.

included in the graph; in this case, the income gap is clearly prominent, being the Philippines the pale orange line and Burkina Faso the pale blue line. A critical outcome of this graph is that although prices of the same staple good are very close, the income is significantly different between the countries, making the Philippines, in theory, more food secure than Burkina Faso. Transferring this theory to already estimated measures made by the GFSI, the Philippines has a food security score of 55.70, whereas Burkina Faso's score is 47.40; this is just the overall score, but if the affordability factor score alone is compared, the gap is more extensive. Philippine's affordability score is 66.5, and Burkina Faso's is 45.40; this gap is well represented by the prices and income behavior shown in the graph.

Figure 3.4[7]. Prices (Rice) and Income trend lines for Philippines and Burkina Faso (2012-2021)



[7] Data from WFP, 2021 and The World Bank, 2021 – All data is in real terms.

Chapter 4 - Methodology

To achieve the previously discussed research objectives and given the data described in the previous section, it is essential to analyze the most feasible models to measure both parameters of relevance. The present chapter will explain statistical models to explore food availability and affordability in detail; therefore, the chapter is divided into two main sections per the parameters to analyze. The composition of this chapter will allow readers to understand first a brief portion of the background on why the proposed models are promising in finding significant results and how they differ or are similar to small pieces of literature. Then the subsequent explanation of the argument behind those models will be provided, including equations, variables generations, transformations to the model, and any other specific and relevant detail on which the models were based.

4.1 Food Availability

As previously discussed in the literature review section, simple calculations using FAO data and with a basic descriptive statistical analysis have been developed by other authors. Burchi and De Muro, 2016; Porkka, et al., 2013, and Bentley, 2017. This last author only analyzed USDA and FAO data calculations, including domestic production, imports, exports, and uses of the food produced (industry, feed, etc.), and used the food supply data obtained or downloaded to capture the essence of food availability in the United States.

Given the lack of significant models found in the literature to analyze food availability and its relationship with other economic occurrences such as trade, this thesis aims to provide two different approaches to capture the association between food availability and trade. The first one is a simple statistical analysis between trading groups ranked by their level of trade which will only serve as an introductory part of what would be expected from the second model approach.

The second model consists of a more in-depth analysis using empirical methods of research to attempt to explain the relationship between international trade and food supply on a country-by-country basis and in a panel data analysis. This second model is the principal focus of the study of food availability parameters.

4.1.1 T-test approach

There has been some research using this type of methodology: Bezuneh and Yiheyis (2014) used a t-test to differentiate the effect of trade liberalization on food availability. Even though it was not the primary model of the research by Bezuneh and Yiheyis (2014), it served as a set-up to introduce the rest of the analysis that included other variables. On the other hand, Dash et al. (2020) employed the same model to analyze international trade agreements effects, using time series analysis for before and aftereffects. Thus, in this thesis, for this first approach, a paired t-test will be applied to the two trade groups.

The t-test approach aims to determine by the simple statistical method of group division whether the food supply of countries with a high level of trade and countries with a lower level of trade present a significant statistical difference in their total per capita food supply. This food supply is the aggregation of all food groups in the FAO's food balance database.

The countries were divided into three groups; the division was made based on their WTO (World Trade Organization) import and exports ranking. This ranking is made considering the overall country's contribution to global trade; in terms of this research, the ranking only includes the countries of scope (WTO, 2020). For a paired t-test, it is required to have two groups with the same number of countries. For doing this division, it was necessary to make some assumptions to consider the optimal breakdown points of high trading countries and low trading countries. Two approaches were contemplated for the analysis, the first one considering the initial total of scope countries (44). By splitting the countries into two groups, the division points conceptualize the low trading countries as those whose trade falls below US$15,000 million or those whose total trade represents less than 0.5% of the total trade of the complete set of countries.

The second country division was considered for testing if the same results were obtained. The group was created out of a random parameter to split the countries, and the random parameter was to divide the countries with a splitting point of US$10,000 Million in trade; therefore, those countries in the high trade group were the ones with trade higher than this parameter and vice versa for the low trade group, by making this assumption and to have paired groups to run the test, only 32 countries were considered, and because one of the main scopes of doing this research is deep in the knowledge on the importance of trade to food security the countries left out of this second group were the ones with the highest food security score according to the GFSI.

The final division of countries was constructed to provide a sensitivity analysis of the food supply among the top 10 trading countries and the bottom 10 trading countries among the complete initial set of 44 countries. By adding this third control group the results will explain more about the separation in food supply between high trade countries and low trade countries by going to the extremes in the set of countries.

To have a horizon before stepping into a more in-depth analysis that the second model of this parameter will give, it was necessary to state a hypothesis to conclude on this approach. Based on the previous literature and economic intuition, the hypothesis was that countries with larger general trade flow (import and exports) would have a statistically significant difference in food supply (higher) to those countries with lower trade flow.

4.1.2 Empirical regression approach

The second approach to analyzing food availability consists of a regression model to capture the relationship between food availability and a set of trade variables. This model will provide further evidence in favor or against the results obtained through simple statistical analysis such as the one made by the t-test. A t-test approach used by other authors does not consider influential parameters, for example, whether a country is self-sufficient to have a safe food supply and other deficiencies that could be solved by deeper econometrical models using a set of variables that could capture variation that's not visible by only considering trade and food security levels.

Food availability as a response variable can be represented in more than one type of data; for example, Dorosh, Rashid, and Asselt (2016) used different quantity measures to capture food availability in the form of food household demand. Burchi and De Muro (2016) used the food balance in quantity terms for their food security analysis. However, other researchers like Porkka et al., 2013 and Bentley, 2017 analyzed food availability in caloric intake. Both data types are available on the food balance sheet from the FAO. Two regressions were estimated to capture the variability of how the trade variables are affecting both measures of food availability. The first one uses the per capita food supply in kilograms as the aggregation of all food groups (same data used for the t-test) as a food demand measure, and for the second model contains as a response variable the per capital food kilocalories availability as a nutritional measure for food security.

To avoid the possible correlation problems between the independent variables of food supply and the food imports and exports data which are considered in the calculation of this food supply, the best approach was the use of ratios instead of the primary nominal data; the proposed ratios are General trade as a percentage of country GDP, food imports as a percentage of total trade and food exports as a percentage of total trade. To keep consistency in the two independent variables studied, the use of ratios will apply to the food kilocalories regression as well.

However, as mentioned before, by only using trade variables in the analysis, the model would not be able to capture the possible food self-sufficiency of a country. A set of agricultural variables were introduced in the model to control for this: agricultural production value as a proportion of the GDP, the agricultural trade as a percentage of agricultural production, and the per capita cropland; this last variable has been used in research made about the implications of international trade and/or free trade agreements over food security in-country groups **(**Ly et al., 2020; Herath, Liang, and Yonbing, 2014; Dithmer and Abdulai, 2017**).** Herath, Liang, and Yonbing, 2014 defined land as irrigated land as a percentage of the cropland. Meanwhile, Ly et al., 2020 used land in their model as the share of agricultural land over the total land area of a country. Lastly, Dithmer and Abdulai (2017) estimated their results by using arable land (hectares per person).

As per the literature found, most of the research has been conducted on a country-by-country basis; the present research aims to study these effects. Each regression model will be applied to all countries using separate data. After defining this methodology and identifying which variables are feasible in analyzing the impact of trade on food availability, with two variables as a principal measure, two main equations were defined:

$$FS_{it} = \beta_0 + \beta_1 PTG_{it} + \beta_2 PFE_{it} + \beta_3 PFI_{it} + \beta_4 PAG_{it} + \beta_5 PATP_{it} + \beta_6 PCC_{it} + \varepsilon_{it} \quad (1)$$

$$FKcal_{it} = \beta_0 + \beta_1 PTG_{it} + \beta_2 PFE_{it} + \beta_3 PFI_{it} + \beta_4 PAG_{it} + \beta_5 PATP_{it} + \beta_6 PCC_{it} + \varepsilon_{it} \quad (2)$$

The two equations have the same set of independent variables to explain, in equation one, the total per capita food supply, and in equation two, the per capita kilocalories intake in each country. As this is a country-by-country analysis, the subscript *i* indicates a determined country analyzed, and the subscript *t* represents the years in which the regression was run. The proposed variables coding is explained on the following table:

Table 4.1. Description of Variables– Food Availability Models

Variable code	**Variable name**	**UOM**	**Equation**
FS	Per capita food supply	Kg	Equation 1
$FKcal$	Per capita food intake	Kilocalories	Equation 2
PTG	Proportion of Trade over GDP	%	Both equations
PFE	Proportion of food exports over total trade	%	Both equations
PFI	Proportion of food imports over total trade	%	Both equations
PAG	Proportion of agricultural production over GDP	%	Both equations
$PATP$	Ratio of agricultural trade over agricultural production	%	Both equations
PCC	Per capita cropland	1000 ha	Both equations

The model described above aims to compare country specifics parameters of food security with trade in general terms and with food trade specifically. This comparison is expected to relate to the hypothesis previously described in the t-test methodology description that trade has a direct positive relationship with food security parameters, especially with food availability in those countries. However, determining whether trade generates an increase or decrease in that country's food availability can be considered risky because, regardless of the apparent relationship these variables have, it is complicated to be entirely sure about the causality of these two events. As per main economic reasoning, an increase in trade for a country can result in more food available for their consumers; however, more food supply in a determined country would reduce the demand, demand that could potentially lead to decreases in trade, imports specifically. Therefore, it is necessary to apply a more complete method to deal with the causality issues. For this, a new version of the present model introduces an instrumental variable (IV); the following section will explain in detail this methodology.

4.1.2.1 Empirical regression approach – IV Introduction

Previous research has been conducted to determine whether trade benefits the world in more than one aspect. In specific terms, Frankel and Romer (1999) analyzed whether trade causes growth by measuring income as the primary source of growth; however, similarly to this current research, causality issues arise, primarily related to how trade influences income. To avoid possible correlations in the primary model with the error term or omitted variable bias, they introduced an instrumental variable to account for the natural factors that determine trade patterns; the instrumental variable consisted of the fitted values of a gravity model.

The gravity model of international trade was introduced theoretically for the first time by Tinbergen (1962), accounting for the movements of international trade flow in terms of population, incomes of trading countries, and distance. This model has been widely used by authors such as Sun and Reed (2010), Jayasinghe and Sarker (2008), and Grant and Lambert (2008) for analyzing the overall effects of trade agreements which is different at some point from the research made by He (2022) which did not use the gravity model as the primary approach for analyzing trade agreements, instead used a similar approach as the one applied by Frankel and Romer (1999), with an innovation of including the sea distance and air distance variables and using a weighted distance that was not time-invariant.

Therefore, the present IV model aims to combine Frankel and Romer (1999) and He (2022) to account for causality issues between international trade and food security (availability). Two gravity equations were formulated in trading groups[8], in one the countries of interest were the exporters and in the second equation they were exporters to be able to obtain

[8] Data for the gravity equations was obtained from the Centre d'Etudes Prospectives et d'Informations Internationales Economics, CEPII, 2018.

country-by-country estimates by year by trading direction, also with the difference of Frankel and Romer (1999), fixed effects were applied in terms of exporter and importer countries as in He (2022), however their weighted distance approach was not taken into account. The combination of both literature models is the most feasible approach to transfer the predicted values to equations one and two. The central gravity equation is described below:

$$lnPTG_{it} = \alpha_0 + \alpha_1 lnD_{ij} + \alpha_2 contig_{ij} + \alpha_3 comlang_{off_{ij}} + \alpha_4 RTA_{ij} + fe_j + fe_i + \mu_{ijt} \text{ (3)}$$

Where a logarithm transformation was made to the dependent variable and one of the independent variables. The main variable of analysis in this model is the percentage of trade over GDP of the country *i* on year *t*, which is a function of the distance (main cities) of country *i* to countries *j*, a dummy variable representing the contiguity or shared border of country *i* to countries *j*, and two other dummies representing whether the countries share language and whether those countries have a Regional Trade Agreement (RTA) between each other. As previously mentioned, two gravity equations were estimated considering the countries as exporters first and then as importers. These regressions run in a panel data set-up where the trade of each of the countries under the scope of this research are analyzed against their trade characteristics with countries in the world with which they trade. Also, it is essential to point out that fixed effects were applied to the gravity model for that reason, other unilateral variables such as population and GDP were disregarded of the final model. After this process, fitted values from these 11 equations were generated by country under the following equation:

$$\widehat{PTG_{it}} = \sum_{it} \exp\left(\alpha_1 + \alpha_2 + \ldots + \alpha_6\right) \text{ (4)}$$

The above equation reproduces the predicted values from the gravity equation (3), precisely, the proportion of trade over GDP fitted values, by adding the coefficients of the variables that determine natural trade patterns in that specific country. Estimates of these predicted values were obtained for each country, again in terms of imports and exports, then these values were added and then included in the dataset of each country; those predicted values represent the instrumental variable to be used on equations one and two; thus, these equations will take the following structure:

$$FS_{it} = \beta_0 + \beta_1 \widehat{PTG_{it}} + \beta_2 PFE_{it} + \beta_3 PFI_{it} + \beta_4 PAG_{it} + \beta_5 PATP_{it} + \beta_6 PCC_{it} + \varepsilon_{it} \quad (5)$$

$$FKcal_{it} = \beta_0 + \beta_1 \widehat{PTG_{it}} + \beta_2 PFE_{it} + \beta_3 PFI_{it} + \beta_4 PAG_{it} + \beta_5 PATP_{it} + \beta_6 PCC_{it} + \varepsilon_{it} (6)$$

The equations above are the instrumental variables equations; as mentioned before, the only difference is using the predicted values of equation four as an IV for the percentage of trade over the GDP variable. While this instrumental variable set-up is efficient in dealing with causality issues, more evidence must be provided to determine whether it provides the most efficient estimators. A Wu-Hausman test was applied to compare the OLS estimators from equations one and two and the 2SLS estimators obtained from equations five and six. The efficient estimators are the ones presented in the results chapter.

The purpose of the above-explained methodology is to obtain country-by-country estimates; however, this methodology can be applied to panel models as well. To observe the overall effect of the set of countries analyzed, equations one through six will be run to get OLS and then 2SLS estimators for the complete set of countries by applying panel regressions, in this panel regressions fixed effects for year and country were applied to account for the specific characteristics of these countries and years that influence the relationship between international trade and food availability.

To summarize the first section of this chapter, after running the appropriate regressions following equations from one to six, the estimates obtained were

1. Country-by-country OLS estimates for food supply (Kg) model

2. Country-by-country OLS estimates for food calories (Kcal) model
3. Country-by-country 2SLS estimates for food supply (Kg) model
4. Country-by-country 2SLS estimates for food calories (Kcal) model
5. Panel (all countries) estimates for food supply (Kg) model
6. Panel (all countries) estimates for food calories (Kcal) model
7. Panel (all countries) IV estimates for food supply (Kg) model
8. Panel (all countries) IV estimates for food calories (Kcal) model

Although all these estimates are generated, only the most relevant estimates and those that resulted as more efficient after the appropriate testing are discussed in the results chapter. Finally, it is essential to clarify that, after the construction of these models and analyzing the available data, the number of countries in this analysis was reduced from 44 to 37, cutting the original set of low and low-middle-income countries in the GFSI model, given data availability.

4.2 Food Affordability

According to some literature review (Applanaidu, Bakar, and Baharudin, 2014; Jeder**,** Hattab, and Frija, 2020), two types of models are frequently used to analyze the food security and at some level the food affordability indicator, these are the VECM (Vector Error Correction Model) and VAR (Vector Autoregressive). Given that these models have some relationship, some authors applied tests to decide which one was more efficient, Jeder, Hattab, and Frija, 2020**.** Applanaidu, Bakar, and Baharudin, 2014 could be considered the most proximate to what this research wants to reproduce due to the "relationship-type approach." The authors measured the food security relationship against macroeconomic variables that also affect food affordability; the current study aims to measure the relationship against trade variables.

As per the research of Devesh and Affendi (2020), Kang (2017), and Wang et al. (2020) used the VAR model, other variations (i.e., VARX) and other models to measure food security in different countries and changing the variables to analyze, including macro-economic variables and agricultural variables, most of them with the approach of food availability. Gutierrez and Piras (2014) used the same model to measure wheat price shock's effects on global wheat prices, which can be transferred to food security as wheat is considered a staple food important for dietary changes.

Although there is a large availability of literature applying the VAR or VECM models, the present research is not able to replicate this methodology due to the small availability of time-series observations, and as these models work in a matrix system, the number of years, which are ten and number of variables that are pretended to be used in a country-by-country analysis, conflict with each other to reproduce these models also because both of them use lags and the model would not have enough freedom to choose the optimal lag.

An approach to preserve some of the modeling used in literature for a shorter time series is using a variant of the VAR without including the vector component but by using the autoregressive element; the chosen method applied is the AR1 or the autoregressive model of order one. The first AR1 model was introduced by McKenzie (1985) and was conceived to be used for time-series analysis. Autoregressive models have been used in a wide variety of research Amwata, Nyariki, and Musimba, 2016 used GLS (Generalized Least Squares) and AR (Autoregressive) models to determine links between climate factors and food security in a specific zone of Kenya. AR1 model was also used for international trade-related research with country-by-country estimates of how the terms of trade of countries have been affected through time (Ram, 2004).

Kim and Beladi (2005) used the AR1 model combined with GLS to determine whether the openness to trade influences inflation. Additionally, they added some control variables to their model and used this model to analyze a set of 62 countries. A similar methodology was applied by Sachsida et al., 2003 whose research had the same objective as the one cited above. Finally, an utterly different study used the same GLS-AR1 methods, this time in a gravity model, to analyze the expansion of the European Union and its gains of trade, Papazoglou et al., 2006.

Given this diverse literature found and the feasibility of applying AR1 and GLS, this was the chosen method to apply to the model. After deciding on a specific methodology, the following step was to set up feasible variables to analyze the relationship between trade and food affordability. As mentioned at the beginning of this section, most of the research found regarding food affordability relates to the analysis of macroeconomic variables. Most of this past research has lacked an efficient measure of food affordability as their principal measure of food security has been focused on food production indexes (Applanaidu, Bakar, and Baharudin, 2014; Jeder, Hattab, and Frija, 2020). To better approach this issue and use the data described in the previous chapter, the present research aims to construct a measure of food affordability.

4.2.1 Dependent Variable Construction

The retail price data and the global dietary database were used to construct the analysis variable to measure affordability. Some challenges were found that led to reducing the number of countries of analysis to 16 and defining the time-series analyzed to the 2012-2021 period regardless of these two databases having data from 1990. Given the constraints found in the moment of combining these two databases, some assumptions had to be made. The definition of the food groups provided by Global Dietary Database, GDD (Appendix A, Table 6.1) served to pair the consumption data with the retail price database. However, as these are food groups, they contain more than one food; therefore, an average price of the retail price data of these foods belonging to a GDD food group was used to calculate the diet cost for that group. A mathematical description of this procedure is found below:

$$DC_{vi} = \frac{1}{n} * \sum P1_{vi} + P2_{vi} + \ldots + Pn_{vi} \text{ (7)}$$

Where *DC* represents the diet cost of food group *v* on country *i*, and *n* represents the number of food types in the food group *v*. For example, in the meat food group, the calculation of the diet cost of this food group was calculated using the average price of bovine meat, chicken meat, and pork meat. It is important to mention that the data suffered a considerable number of transformations to make it feasible for analysis.

The retail price data was available in local currency, so all those data points were transformed into US dollars using the data from the US Treasury reporting system, the quarterly foreign exchange rate was the best approach possible given that these local prices are collected every 15 days (Fiscal Data Treasury, 2021). Also, the price data used most of the time kilograms as unit of measure (UOM), however, some data was available in other UOM, so transformation into Kilograms was made to standardize the dataset.

Most countries analyzed paired measures on diet consumption and price retail data for the food groups where staple foods were found, i.e., rice, wheat flour, beans, legumes, etc. This measure might be considered arbitrary given the assumptions made and overall imperfect. Still, as previous literature has proven, there hasn't been a perfect measure of affordability or data available to construct a feasible parameter.

The diet cost measure explained above is not the primary independent variable in this model but the foremost step to construct it. As the present study tries to measure how affordable for a given country this diet cost is, the final variable is the ratio between the diet cost and the average per capita income of each country, defined by the equation below:

$$RFEI_{it} = \frac{\frac{\sum DC_{vit}}{IN_{it}} * 100}{\%ExpFactor} \quad (8)$$

The first part of the equation represents the aggregation of the diet cost of all food groups (*v*) in a country (*i*) each year (*t*) multiplied by a hundred, the reason will be explained later. The result of this operation then was divided by the income (*IN*) of that country *i* in that same year. As mentioned before, some constraints in the data didn't allow to include all countries. Most of these constraints are related to the difficulties associated with matching consumption and price data, i.e., a country with high consumption of the food group containing rice did not have rice price data available for the set time-series period. Meaning that the matching percentage of the country's consumption related to the retail price availability was low. The countries in which the matching percentage was greater than 50% were the ones included in the analysis.

To account for the remaining percentage that was not considered, a factorizing process to get to a 100% was the method used; that was the reason why the numerator was multiplied by a hundred. The *%ExpFactor* is just the sum of the food groups' consumption proportion considered in the matching process. To illustrate better this process, see the table below for the case of India:

Table 4.2. Data comparison WFP and GDD, consumption percentages – India

Country	Food Product (WFP data)	UM	Dietary Code (GDD)	% Consumption
India	[9]Rice	Kg	v07	36.18%
	Wheat	Kg	v08	14.58%
	Potatoes	Kg	v03	5.34%
	Onions	Kg	v02	20.08%
	Milk	L	v57	10.93%

[9] Both food products belong to the same consumption group (v07); therefore, their consumption factor is the same, and only one of the values is considered for the sum.

[9]Wheat Flour	Kg	v07	36.18%
		%ExpFactor	**87.11%**

The table 4.2 illustrates the patterns of consumption of the most relevant food groups in India. The highest consumption group is v07, with 36.18% of the total diet. The WFP database contained retail price data of some food types that fall into the v07 group definition; therefore, this represents a match in data. The other four food groups were able to match consumption and retail price data, allowing the analysis to account for retail price data of the foods that represent 87.11% of the food consumption in India. The illustrated in equation eight for India is just the diet cost of these five food groups (from equation seven) multiplied by a hundred and divided by the factor of 87.11%; of course, this factor changes by country, but as mentioned, to be considered in the analysis, this must be greater than 50%.

4.2.2 Food Affordability GLS Model and IV Model

After obtaining the variable of analysis from equation eight, the subsequent step in the model setup is to define the most important variables to measure the relationship between food affordability and trade. As no precedent of this type of study was found, the present research tried to define some relevant variables on international trade that could relate to how affordable food is. Regardless of measuring this relationship, it was essential to control for factors that might affect food affordability and do not relate to international trade. The data of these trade-related variables were converted from nominal to real terms using the consumer price index (CPI). The ultimate model is described below:

$$RFEI_{it} = \gamma_0 + \gamma_1 TR_{it} + \gamma_2 FT_{it} + \gamma_3 AgT_{it} + \gamma_4 TOTC_{it} + \gamma_5 TT_{it} + \varepsilon_{it} \quad (9)$$

Where the independent variable comes from the calculation made on equation eight. The explanatory variables are the total trade of a country *i* on a year *t* (TR), the total food trade (FT), agricultural tariffs (AgT), the terms of trade of cereals food group (TOTC), and a time trend (TT).

As opposed to the availability model explained in the first section, the independent variable and the explanatory variables don't directly relate to how those variables are obtained; that's why ratios were unnecessary for this model. Another essential variable to discuss is the inclusion of the terms of trade of cereal food groups. As previously mentioned, the country's highest consumption is mainly concentrated on staple foods, most of them cereal; this and the data availability were the primary reasons to include this variable. It is important to remember that the terms of trade are the ratio between the export price and import price, in this case only including cereals.

One challenge of the present model that arose was the same found in the availability model, referring to the possibility of causality issues between food affordability and trade. However, it wasn't easy to set up the same instrumental variable model used for the first parameter in this case, primarily because of data availability. The gravity database contained data up to 2019, and the affordability model has more recent years, so being able to update this database for all countries of the world is out of the scope of what this research can achieve. Therefore, country-by-country estimates were challenging to accomplish, and the instrumental variable was not used in this case.

However, a panel data omitting out the recent years (2020-2021) was a viable method to follow the instrumental variable methodology, joining the data of the 16 countries in a single panel regression model applying equation nine, this time covering the period of 2012-2018. The definition of the gravity equation to get the predicted values is somewhat different from the one applied in the availability model (equations three and four), as the percentage of trade over GDP is not a variable in the affordability model. Therefore, the correct gravity equation for the IV is explained below:

$$lnTR_{it} = \alpha_0 + \alpha_1 lnD_{ij} + \alpha_2 contig_{ij} + \alpha_3 comlang_{off_{ij}} + \alpha_4 RTA_{ij} + fe_i + fe_j + \mu_{ijt} \quad (10)$$

The only difference between equation three and equation ten (above) is the dependent variable of analysis in the gravity model. In this case, the variable of interest is the total trade of country *i* to the world on each year *t*. The process of doing two gravity equations accounting these countries as exporters and then as importers remains the same as above mentioned. After applying this equation two times, as in the availability model, the next step is to get the predicted values and transfer those to equation nine. The following two equations represent this process:

$$\widehat{TR_{it}} = \sum_{it} \exp\left(\alpha_1 + \alpha_2 + \ldots + \alpha_6\right) \ (11)$$

$$RFEI_{it} = \gamma_0 + \gamma_1\widehat{TR_{it}} + \gamma_2 FT_{it} + \gamma_3 AgT_{it} + \gamma_4 TOTC_{it} + \gamma_5 TT_{it} + \varepsilon_{it} \ (12)$$

An additional detail to point out is that as in the panel model for food availability, fixed effects for year and country were applied. To summarize this section, after running the described regression in equation nine for both panel and country data, the obtained estimates were:

1. Country-by-country GLS-AR1 estimates for food affordability
2. Panel (all countries) estimates for food affordability
3. Panell (all countries) IV estimates for food affordability

Chapter 5 - Results and Discussion

The present chapter presents the proposed model results and discusses them in line with the stated objectives presented at the beginning of the thesis. Although various models were estimated, only the most relevant to the appropriate methodology and objectives are reported and discussed in the chapter and all other results are available upon request. The chapter is divided into two main sections around the food security parameters this research was constructed, additionally a final section is included to provide details regarding research limitations and future potential research coming from the present results. Each of the two main sections are divided into subsections depending on the specific methodology in which they are developed. The purpose of this chapter is to construct a basis for the conclusions of this thesis, give guidance on whether the objectives were achieved, and discuss which of the proposed methodologies was more feasible to accomplish those objectives.

5.1 Food Availability

As mentioned in the methodology chapter, this thesis measured the relationship between food availability and international trade through three different methodologies. The first one was an inferential statistical analysis by applying a paired t-test using food supply and trade data. The second, by applying an OLS regression model in which the food availability measured by two different parameters is a function of trade-related variables and agricultural production control variables. Finally, the third approach is the estimation of an IV regression using measures of trade that are exogenous to food security measures. These three approaches represent the three subsections in which the food availability measure section is divided. It is important to remember that both OLS and IV models were run on a country-by-country basis and by using panel regressions with all countries included in this model.

5.1.1 T-test results

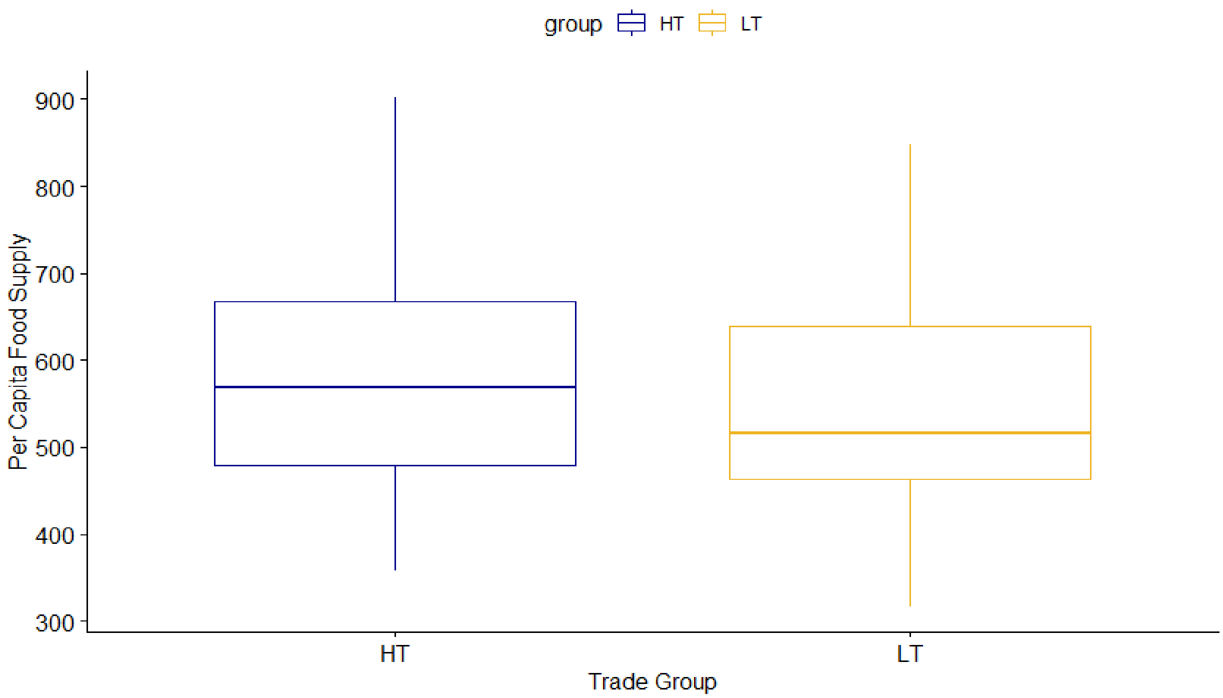
As stated in the methodology chapter, this thesis proposed running three different paired t-tests, using trade levels data to separate high trade level countries from low-level trade countries and comparing their food supply levels to state whether there was a statistically significant difference in the food supply of both groups, and finally doing a sensitivity analysis using the same t-test approach but only considering the extremes of the high trade and low trade groups of countries, the top and bottom 10 trading counties.

There were three different paired t-tests in which the only difference was regarding how the trade level groups were split. However, the reasoning and hypothesis for both are the same: countries with higher levels of trade are expected to have a statistically significant different food supply from those with lower levels of trade, specifically higher per capita food supply at high levels of trade.

After performing the division of the groups, two paired t-tests were estimated for each of the paired groups, having a total output of six results. In the first paired t-tests, there was no established condition in the analysis. However, on the second paired t-test, an alternative of "greater" was established; the purpose of this second estimation was to communicate to the software the expected hypothesis, which is that one of the groups will have a greater level of food supply, to compare if there was a difference between the results.

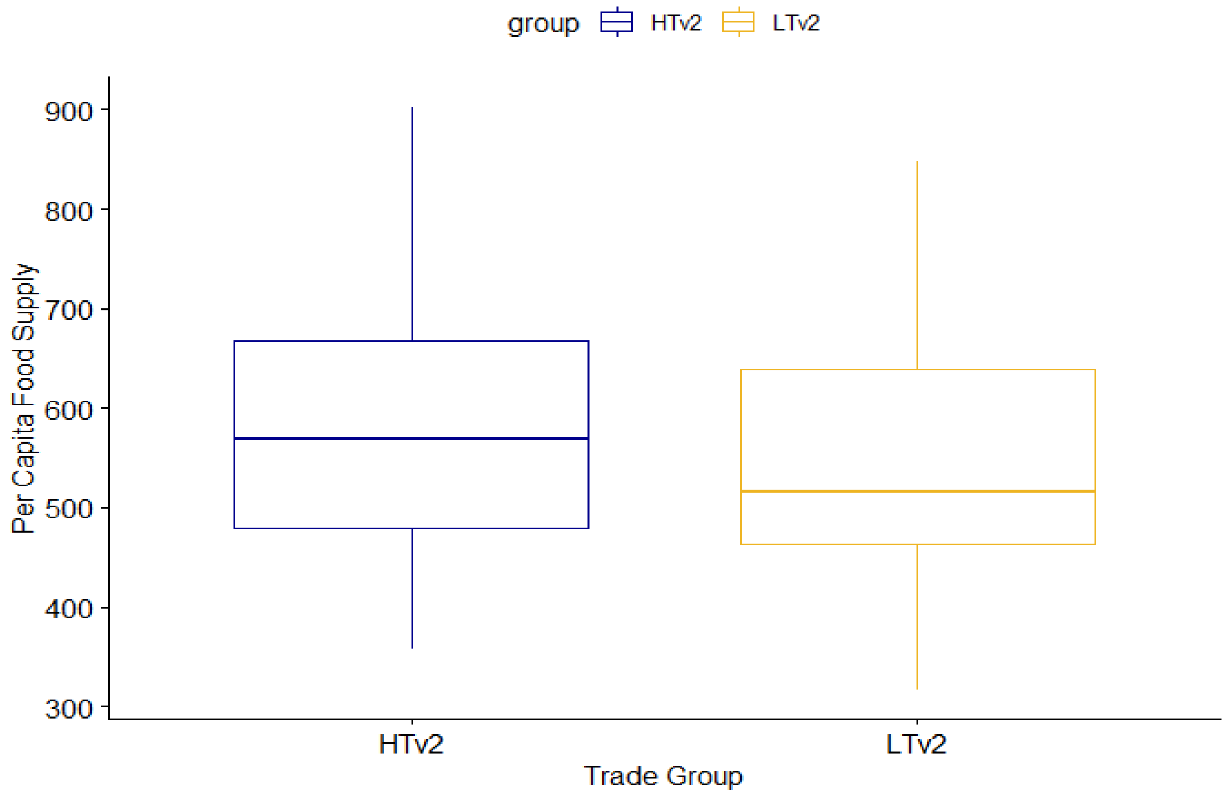
The first set of paired t-tests had a total of 44 countries divided into two groups, split by a trade amount of US$15,000 million or 0.5% of total trade, both the general t-test and the conditional t-tests with the greater alternative obtained p-values above 0.05. This value indicates no statistically significant difference in the per capita food supply (kg) between the two groups. Figure 5.1 represents a boxplot of the per capita food supply of the high trade level group (blue) and low trade level group (yellow). It can be noticed that there is not a statistically significant difference between the food supply of the groups of nations.

Figure 5.1. Boxplot of Food Supply for High trade and low trade groups (2018)



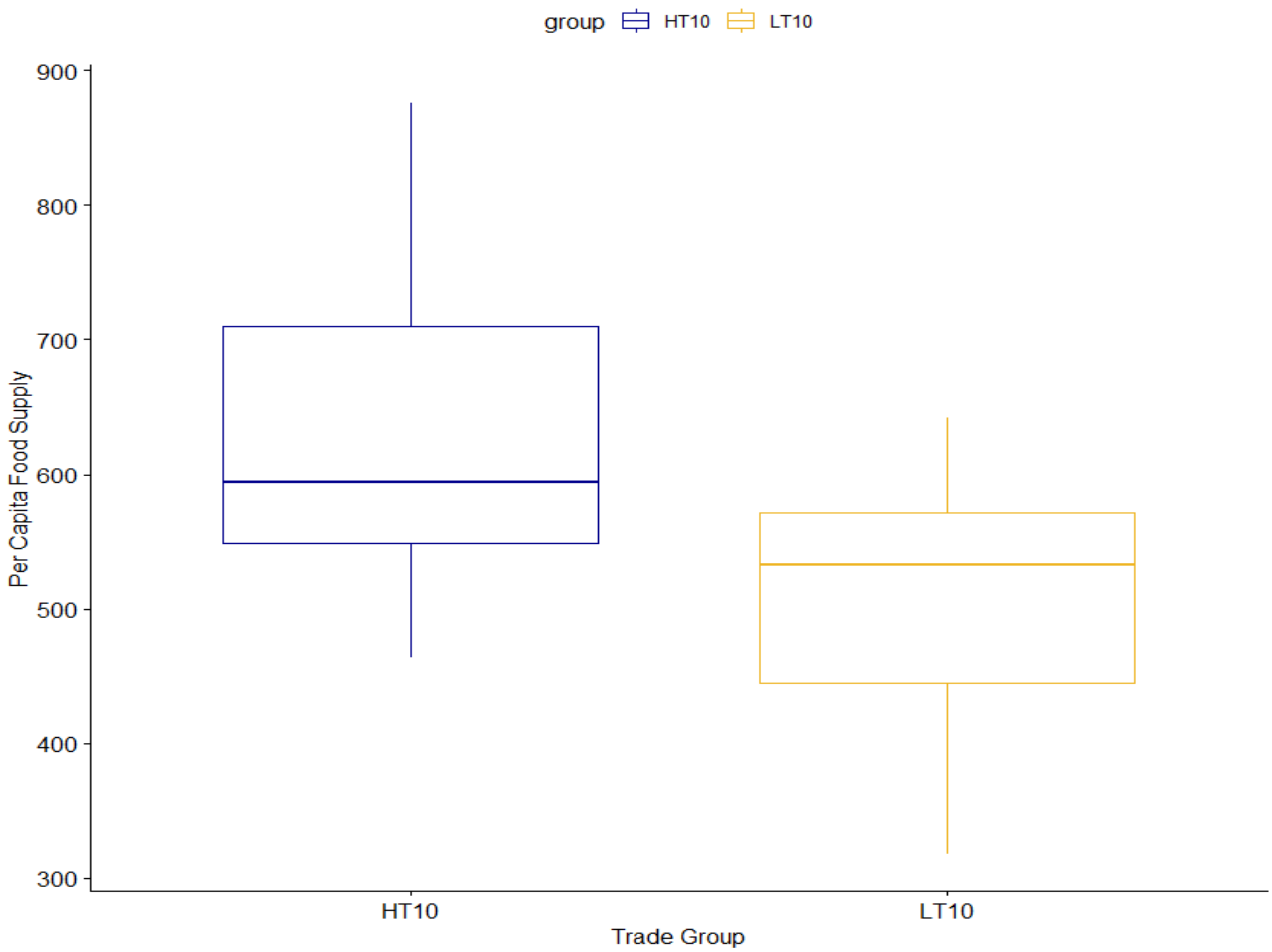
Similar behavior was found when estimating the two paired t-tests for the second set of high trade level and low trade level groups. These groups were cut by US$10,000 Million in trade value, leaving two groups of 16 countries each. The general and conditional t-tests run got a p-value of less than 0.05, meaning that the null hypothesis fails to be rejected. Therefore, there is no evidence that the two groups' true difference in means is not equal to zero, meaning that both groups' food supply is seemingly similar. Figure 5.2 represents the food balance levels of these two groups; there is no noticeable difference visually in the means of both groups' food supply.

Figure 5.2. Boxplot of Food Supply for High trade and low trade groups – 2nd Division (2018)



Finally, in the third group which represents the sensitivity analysis between the top 10 trading and bottom 10 trading countries, the results changed compared to the previous two groups analyzed. In this case the p-value obtained was lower than 0.05 for the conditional and general paired t-tests, indicating that there is statistically significant difference in the food supply in kilograms between the top 10 trading countries and the bottom 10. Figure 5.3 is a boxplot representing the per capita food supply in kilograms for this division, it is evident the more marked difference among the top and bottom trading countries when compared to figures 5.1, and 5.2.

Figure 5.3. Boxplot of Food Supply for Top 10 and Bottom 10 trading countries (2018)



As previously mentioned, some research has been applying a similar methodology to analyze food availability in terms of international trade. Bezuneh and Yiheyis (2014) made a t-test, but in this case, they made a before and after liberalization approach; as in two of the results in the present thesis, they didn't find a statistically significant difference in the food supply (measured by dietary energy supply) before and after trade liberalization of 37 developing countries.

Two of the three findings made in this thesis and the evidence found in previous literature point out that trade, in general terms, might not influence the food supply of a country as much, however when considering extreme levels of trade, the results change. The following subsection will prove which of the inferential analysis results shown in this subsection is transferred to econometric analysis, using by-country estimates and panel estimates as evidence.

5.1.2 Empirical regression country-by-country results

The following subsection presents the results of four regressions, estimated using country data of a set of trade-related variables and agricultural control variables. The four regressions are: first, the OLS and IV regression estimates that seek the connection between international trade and food availability measured by per capita caloric intake (kilocalories), and the OLS and IV regression estimates of the relationship between international trade and food availability, this time measured by the per capita food supply (kg). Essentially, this subsection covers the results of equations 1, 2, 5, and 6 described in the methodology section. The results are presented by country; although all four regressions were estimated for the total of countries (37), only the most representative and relevant results are discussed; some other results can be found in Appendix C. Also, it is essential to point out that the results for the gravity model made to obtain the instrumental variable for the proportion of trade over GDP used in the estimation of equations 5 and 6 are not presented because they are not relevant for this research; however, they can be found in Appendix B, Table 6.2.

Nine out of thirty-seven sets of regression estimates will be presented for discussion. The results will be presented in two blocks made by regionality, meaning the continent those countries belong to; however, the discussion will also include some debate regarding characteristics that these countries present in terms of income group, their GFSI score in terms of availability, and whether those countries are primarily main food exporters or importers. In some cases, the countries whose estimates were not reported will be mentioned as they share similarities in effect direction with some of the countries discussed in this section. There is an additional subsection attached to this subsection in which some particularities of country estimates will be briefly discussed.

Given that both OLS and IV were run for each parameter, both were tested through a Wu-Hausman test to evaluate which model was more feasible; a highlight chart included in the results tables marks the model that resulted in the more feasible. Also, a test of how strong the instrument was made to contribute to the relevance of the IV model.

Asian Countries

The first set of results presented is the nations belonging to the Asia region. The country's estimates are for Bangladesh, Cambodia, Indonesia, Nepal, Tajikistan, and Viet Nam. These results are presented in tables 5.1 through 5.6 and later discussed.

Table 5.1. Availability Model Results - Bangladesh

	Dependent variable:			
	FKcal		FS	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
Constant	2,683.512***	2,805.372***	686.067***	534.165**
PTG	-726.049**	-991.835**	-780.982***	-449.670*
PFE	1,870.646	1,213.946	10,346.490*	11,165.090**
PFI	-1,842.180**	-1,885.966**	-1,380.097**	-1,325.516***
PATP	697.384***	689.170***	386.645**	396.884**
Observations	11	11	11	11
R^2	0.877	0.848	0.881	0.828
Adjusted R^2	0.795	0.746	0.802	0.714
F Statistic (df = 4; 6)	10.677***		11.101***	
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 5.2. Availability Model Results – Cambodia

	Dependent variable:			
	FKcal		FS	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
Constant	6,157.000***	6,468.735***	2,071.013***	677.570
PTG	-285.854**	-339.821*	-75.624	165.609
PAG	292.680	240.932	-388.800*	-157.489
PFE	-1,648.920	-2,039.706**	360.848	2,107.647
PFI	-629.373	-758.210	-698.670*	-122.777
PCC	-12,464.410***	-13,229.060***	-4,976.278**	-1,558.341
Observations	11	11	11	11
R^2	0.913	0.909	0.938	0.646
Adjusted R^2	0.826	0.818	0.876	0.292
F Statistic (df = 5; 5)	10.518**		15.157***	
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 5.3. Availability Model Results – Indonesia

	Dependent variable:			
	FKcal		FS	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
Constant	4,014.527***	3,938.855***	757.348***	725.368***
PTG	-1,452.443***	-1,352.819***	-316.739*	-274.638
PAG	-4,497.998***	-4,548.894***	-1,781.816**	-1,803.325***
PFE	-375.120	-94.528	806.926	925.506*
Observations	11	11	11	11
R^2	0.902	0.901	0.839	0.837
Adjusted R^2	0.860	0.858	0.769	0.767
F Statistic (df = 3; 7)	21.450***		12.122***	
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 5.4. Availability Model Results - Tajikistan

	Dependent variable:			
	FKcal		FS	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
Constant	3,660.018***	3,702.896***	840.003***	825.415***
PTG	65.082	124.682	-86.661***	-106.939***
PFE	-2,150.713	-2,066.839	-199.656	-228.192
PCC	-14,554.280**	-15,531.300***	-2,371.454***	-2,039.048***
PAG	795.346*	860.751**	-61.449	-83.701**
Observations	11	11	11	11
R^2	0.930	0.928	0.983	0.980
Adjusted R^2	0.883	0.879	0.971	0.967
F Statistic (df = 4; 6)	19.777***		85.586***	
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 5.5. Availability Model Results – Nepal

	Dependent variable:			
	FKcal		FS	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
Constant	4,431.302***	2,713.657	772.671	189.628
PTG	544.782*	2,167.469	255.750*	806.560
PAG	-408.144	-278.903	30.026	73.896
PFE	-4,114.290**	-375.031	-1,939.497**	-670.231
PFI	1,146.214**	3,068.995	766.734**	1,419.409
PCC	-21,486.440	-16,272.850	-4,013.766	-2,244.049
Observations	11	11	11	11
R^2	0.967	0.595	0.948	0.713
Adjusted R^2	0.934	0.191	0.897	0.427
F Statistic (df = 5; 5)	29.528***		18.329***	
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 5.6. Availability Model Results - Viet Nam

	Dependent variable:			
	FKcal		FS	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
Constant	32.270	-697.382	-1,980.409**	-2,518.485**
PTG	468.739*	758.801**	383.747	597.650**
PFE	2,975.670	6,089.215**	3,463.406	5,759.464**
PFI	3,976.966*	4,687.139**	581.668	1,105.379
PCC	12,730.880**	12,153.440***	13,853.280***	13,427.450***
Observations	11	11	11	11
R^2	0.759	0.686	0.773	0.731
Adjusted R^2	0.598	0.477	0.622	0.552
F Statistic (df = 4; 6)	4.722**		5.118**	
Note:				*p<0.1; **p<0.05; ***p<0.01

In most of the results above, the variable of main interest and which estimation change through the two proposed models, which is the proportion of trade over GDP, was statistically significant at different levels. Likewise, some results were relevant for the variables of the proportion of food exports over total trade and the proportion of food imports over total trade. These three variables are the main indicators for the resolution of the objectives of this thesis.

There is certainly plenty of information that can be discussed from the results presented above, so a brief discussion of some modeling characteristics will be conducted; however, the main discussion will revolve around the trade-related variables and how these connect with the food availability of those countries and which characteristics could potentially make those countries to have this behavior.

From the modeling side, the results were ordered by how the models resulted feasible in each case. For example, Bangladesh and Cambodia, in the case of the measure of food kilocalories as the parameter of food availability, after running the Wu-Hausman test, both showed as more feasible model the OLS; however, in the case of food supply measured in kilograms, the most feasible was the use of the IV for measuring the general trade variable. The second set of countries got the OLS modeling as the most feasible, and the third pair of countries had a behavior opposite to the first pair of countries, opting for the IV model in the case of food caloric intake as a measure of availability and the OLS model for the case of food supply (kg). The strong instrument testing proves that the proposed IV is strong in most cases except for the data of Nepal and Cambodia.

Now looking at the specific estimates obtained, the first discussion will be on the proportion of trade over GDP (PTG). The first set of countries presented, Bangladesh, Cambodia, Indonesia, and Tajikistan, the four obtained negative estimates for the variable of PTG, although Cambodia (FS, IV Model) and Tajikistan (FKcal, OLS, and IV model) obtained positive estimates, the difference relies on that those estimates were not statistically significant. The general implication of these estimates is that when the total merchandise trade (import and exports) as the proportion of a country's GDP increases, the food supply, both in Kilograms and calories intake, decreases, meaning that total trade harms the food security of those countries on this food security factor. Other relevant observations that can be noticed in the tables is that in most cases, the effect of this variable increases by using the IV model in comparison with the general OLS model, implying that the OLS model could be underestimating the impact of PTG on food availability, this is true for most estimates except for Indonesia's estimates and the food supply (kg) estimates in Bangladesh. The same behavior is found in the literature, that although it has a different research focus, demonstrates that IV generated from gravity models tend to prove that OLS estimates underestimate the effect of the analyzed variables (He, 2022; Frankel and Romer, 1999).

Regarding the comparison of the effect of PTG on the two factors measuring food availability, there is an evident pattern determining that the PTG variable has a more significant impact on the caloric intake measure than the food supply measure; Indonesia's estimates are the most evident ones in which the difference of the effect on calories intake and food supply is more visible. However, it is hard to compare two different units of measure. The only exception to this behavior is found in the estimates of Tajikistan, although the difference is minimal.

Talking about the comparison between the country's characteristics and the magnitude and direction of these variables, most of these countries are in the income group of low-middle income countries except for Nepal; however, Nepal's estimates are positive and significant in the OLS model, meaning that PTG increases their food availability although the country is classified as low-income.

Regarding their GFSI availability score, Tajikistan has the lowest score among this group; there is not much to say about the estimates obtained for the caloric intake measure as they were not statistically significant. In the case of food supply, their estimate is negative but is the lowest among the ones which got the negative estimate, and this could indicate that although the country is not high scored, PTG does not negatively affect their food supply as other higher scored like Indonesia which is the highest score. However, their negative estimates in the case of caloric intake are the highest; also, Bangladesh, which has the second highest GFSI-Availability score, has the highest negative effect on food supply by PTG. Other factors like regionality don't seem to have a clear pattern regarding the direction and magnitude of the estimates obtained. Although all these countries belong to the same continent (Asia), they seem to get a diverse effect of this variable on their food availability.

The other two trade-related variables are directly related to food trade: the proportion of food imports over trade (PFI) and the proportion of food exports over trade (PFE). In terms of PFI[10], the results are divided; Bangladesh and Cambodia's estimates are negative, indicating that when the proportion of food imports over trade increases, their caloric intake, and the food supply in kilograms decrease. In Nepal and Viet Nam, a different pattern is observed, and PFI increases food availability in those countries. The expected result in this variable is to have a positive impact due that food imports would increase the national supply, at least in terms of the parameter measured in kilograms; however, in the case of kilocalories is not as straightforward due to that at least on the scope of this research it is impossible to verify the content of the foods that are being imported. As in the PTG case, the IV estimates are higher than the OLS estimates. As seen in the PTG case, PFI has a more significant effect on the caloric intake supply than the weight food supply of the countries.

In the case of country's characteristics, regionality nor income group seem to influence the patterns of the PFI estimates greatly. Their food availability score given by the GFSI does not seem to affect either; Bangladesh is the country with the highest score, and PFI harms their availability; however, Viet Nam is the second, and PFI has a positive effect on their availability. One interesting observation is that Bangladesh is a main food importer, meaning that their food imports are larger than their food exports; however, food imports negatively impact their food supply; however, Nepal is also a main food importer, and the effect of PFI is the opposite.

Moving on to PFE analysis, the behavior of results seems more diverse than in the other two trade-related variables. For example, one interesting finding is that in the case of Cambodia,

[10] Tajikistan and Indonesia PFI estimates are not reported because this variable was deleted from the model for multicollinearity issues.

Indonesia, and Viet Nam, the proportion of food exports over trade has a negative impact on caloric availability but has a positive effect on food supply in kilograms. One argument that can be discussed regarding this finding is that the food supply in kilograms is positively affected because the income coming from exports could be inferred this improve the country's ability to get more food. Regarding the caloric supply, it could also be assumed that these countries export more high caloric foods, reducing their supply; however, proving this theory is out of the scope of this research. In Tajikistan, the results were as expected; food exports would negatively affect the food supply of a country, reducing its reserves. Unlike PTG and PFI, there is no clear dominance of the IV model having higher effects (in absolute terms) than the OLS models; the results are mainly divided. Out of the main food exporters countries, only Viet Nam seems positively affected by an increase in food exports; the effects for Cambodia and Indonesia change depending on the factor analyzed. The country's regionality and income group don't create a clear pattern of similar results.

Other Asian countries like the Philippines, which were omitted from the main discussion, presented similarities in PFE with Tajikistan. Laos had similar results in PTG to Nepal and Viet Nam but, their estimates were not statistically significant. India, the most importer country out of the complete set, had negative estimates on the PFI variable, as seen in Bangladesh and Cambodia.

Finally, in terms of the agricultural control variables included in the models, in countries like Tajikistan, where the PFE effect is negative, their per capita cropland (PCC) effect is also negative. An argument for this is that this land is dedicated to food production that is being exported, reducing food availability, the same pattern is seen in Nepal, and the opposite behavior is found in Viet Nam estimates in which both PFE and PCC positively affect food availability.

African countries

The next set is Egypt, Malawi, and Rwanda. The discussion of these results will be less extensive than the ones above and contain highlights regarding the country's characteristics.

Table 5.7. Availability Model Results - Egypt

	Dependent variable:			
	FKcal		FS	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
Constant	2,315. 075***	2,302.697***	-37.405	-39.067
PTG	-158.963	-229.579	-136.706**	-146.191
PFE	-1,495.222***	-1,583.803***	-638.287***	-650.185**
PFI	503.479**	515.013***	382.486***	384.035***
PCC	27,216.560***	28,197.520***	19,865.360***	19,997.120***
Observations	11	11	11	11
R^2	0.969	0.967	0.975	0.975
Adjusted R^2	0.949	0.945	0.958	0.958
F Statistic (df = 4; 6)	47.283***		58.183***	
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 5.8. Availability Model Results – Malawi

	Dependent variable:			
	FKcal		FS	
	OLS (1)	*instrumental variable* (2)	*OLS* (3)	*instrumental variable* (4)
Constant	3,547.334***	3,556.065***	1,374.827***	1,378.483***
PTG	405.748	524.902*	225.923	275.820*
PAG	-171.019	-218.076	-78.433	-98.139
PFE	2,486.787**	2,595.714**	-32.487	13.128
PFI	343.534	391.283	-203.556	-183.560
PCC	-5,794.253***	-5,937.541**	-3,351.423**	-3,411.428**
Observations	11	11	11	11
R^2	0.818	0.813	0.802	0.799
Adjusted R^2	0.635	0.627	0.603	0.599
F Statistic (df = 5; 5)	4.481*		4.038*	
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 5.9. Availability Model Results – Rwanda

	Dependent variable:			
	FKcal		FS	
	OLS (1)	*instrumental variable* (2)	*OLS* (3)	*instrumental variable* (4)
Constant	1,994.219***	1,976.826***	545.940***	618.357***
PTG	254.752**	288.742	-104.264	-245.783
PFE	-255.141**	-243.687*	33.461	-14.227
PFI	487.661***	492.453***	-212.120*	-232.070**
PAG	108.357*	114.519*	504.156***	478.502***
Observations	11	11	11	11
R^2	0.919	0.918	0.977	0.970
Adjusted R^2	0.866	0.863	0.962	0.950
F Statistic (df = 4; 6)	17.109***		63.922***	
Note:				*p<0.1; **p<0.05; ***p<0.01

Tables 5.7 through 5.9 represent the results of the chosen African countries' estimates that will be discussed. One difference between the estimates of these African countries and the Asian estimates discussed before is that these estimates have more relevance in the secondary trade-related variables included in the model, PFI and PFE, especially in their effect on the caloric availability of food. Among all the research made, Egypt estimates were among the most significant for the factor of caloric availability, both measured by the OLS model and the IV model.

Except for the case of Malawi, the IV presented resulted in being strong, and in all three countries, when applied the Wu-Hausman test, the most feasible model resulted in being the OLS. Egypt's and Rwanda's estimates for PFI and PFE are moving in the same direction, and both reported statistically significant estimates for both caloric intake and some food supply in Kilograms.

PFE, which is the proportion of food exports over trade, behaves in the same way in Egypt and Rwanda, negatively affecting the caloric availability of these countries and, in Egypt's case, also negatively affecting the food supply in kilograms. This is the behavior expected from exports as they indicate a transfer of domestic supply to outside the countries. This negative effect is more significant in caloric availability and is even more prominent when estimating the model using the proposed IV. As seen in the case of Asia, this could infer exports of high caloric foods. On the other hand, PFI positively affects food availability, both in calories and kilograms in Egypt and only in calories in the case of Rwanda; the estimates of how much this impact is very similar between the two units of measure of food availability.

It is essential to point out that Egypt and Rwanda are main food importers; however, they contrast in other characteristics. For example, Egypt is a low-middle income country, and it is the highest score in terms of food availability under the GFSI, and in the other hand, Rwanda is a low-income country and presents a moderate score of availability. The same behavior of PFE having a negative impact on availability was seen in other African countries not reported, like Cote d'Ivoire and Guinea, being this last one a main food importer as well; however, Cote d'Ivoire is a main food exporter, so a relationship between any of the characteristics discussed cannot be inferred. Malawi, which proportion of food trade is almost similar between imports and exports, behaves differently in terms of PFE, which was the variable with significant results; this causes a positive impact on the calorie supply of the country.

Regarding the control variables, most of them resulted significantly in measuring the factors of food availability, especially the per capita cropland that, for example, negatively affects the food availability of Malawi and positively the food availability of Egypt.

5.1.2.1 Main Points and other findings

The results presented have a large variety of directions and estimates. However, the model presented was able to capture most of the variability in terms of food availability, getting percentages higher than 50% in most of the cases. One relevant aspect of the estimates found is that in most cases, the proportion of trade over GDP is found to affect the food availability of the analyzed countries negatively; however, these variables represent the total trade of merchandise. But in the case of specific food trade, the results are especially variable. None of the analyzed country characteristics (proportion of food trade, regionality, income group, food security score) define how food imports and exports can affect the country's availability.

Another relevant aspect to point out is that, also in most cases, the most considerable effect is found on the food availability represented by kilocalories supply. Some countries' estimates in which the variability explained by the food supply in kilograms was extremely low (Ukraine, Senegal, and Cote d'Ivoire); however, the opposite pattern in which the variability of the kilocalories factor was the minimal was not found; this led to infer that the best factor to measure availability is the kilocalories supply.

The econometric model found a relationship between food availability and trade that was not as accurate by applying inferential statistics such as the t-test used in the previous section; therefore, the relevance of these models to measure this relationship. Also, the use of instruments (IV) created upon exogenous trade factors led to the inference that the OLS regression underestimates the effects of trade on food availability in most cases. This thesis agrees with previous research in which trade, in general terms, harms the food availability (Bezuneh and Yiheyis, 2014; Agcaoili and Rosegrant, 1995) as seen in country estimates; however, food trade effects are inconclusive due to the significant variability of results. To conclude regarding these trade parameters, the following section presents the panel model estimates, including all the data collected for the 37 low and low-middle countries, employing the exact modeling used in this section.

5.1.2 Empirical regression panel results (OLS and IV)

This section presents the results of the same model used in the previous section but using panel data from all the 37 countries in which the availability model was applied. The data used was a panel of 37 countries with time series from 2008 to 2018. The estimates reported include the OLS panel estimates and the IV panel estimates; the results are presented for food kilocalories availability and food supply in kilograms. Fixed effects for time and countries were applied to the regressions.

This section's purpose is trying to estimate and conclude the overall effect of trade on food availability due to the variability found in the country-by-country estimates, especially for the case of the variables PFI and PFE; these compiled results are presented in tables 5.10, for the factor of food supply in kilograms and table 5.11 for the kilocalories availability factor.

Table 5.10. Availability (Kg) Panel Estimates

	Dependent variable:	
	Food_B	
	Panel OLS	Panel IV
	(1)	(2)
PTG	59.391^{***}	
	(22.606)	
PTGIV		-17.563
		(22.508)
PAG	24.778	36.731
	(39.597)	(39.957)
PFI	65.958	11.849
	(56.001)	(53.262)
PFE	-0.171	-8.877
	(49.570)	(51.195)
PCC	295.221^{*}	313.687^{*}
	(154.112)	(160.475)
Observations	407	407
R^2	0.916	0.915
F Statistic (df = 42; 364)	94.481^{***}	92.731^{***}
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

Table 5.11. Availability (Kcal) Panel Estimates

	Dependent variable:	
	FoodKCAL	
	Panel OLS	Panel IV
	(1)	(2)
PTG	-26.388	
	(42.906)	
PTGIV		-116.391^{***}
		(41.938)
PAG	150.098^{**}	165.172^{**}
	(75.157)	(74.448)
PFI	-38.946	-40.712
	(106.292)	(99.240)
PFE	-259.585^{***}	-182.804^{*}
	(94.086)	(95.389)
PCC	729.170^{**}	942.787^{***}
	(292.512)	(299.003)
Observations	407	407
R^2	0.945	0.946
F Statistic (df = 42; 364)	148.860^{***}	152.026^{***}
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

The tables above represent the panel estimates including the total of 37 countries analyzed individually, the variability captured by the model is high and around the same value as the by country's variability captured, this measure is given by the R-square. By using year and country fixed effects the estimates are isolating the individual characteristics of those years and countries and could be considered as more accurate. It can be noticed when analyzing both tables that the results of the food availability measured in Kilocalories are more statistically significant that those found in availability measured in food supply in kilograms, so some conclusions can be drawn for these results. Starting with a brief analysis of the effect of the reported control agricultural variables, the main pattern observed in both units of measure is that PAG (Proportion of Agricultural production over GDP) and PCC (Per capita cropland) both affect food availability positively and in most of the cases, these estimates are statistically significant.

Moving on to the analysis of the main variables that analyze the relationship between trade and food availability, it can be observed that the results for the PTG variable are variable among the analyzed scenarios. From these estimates conclusions can be drawn regarding the two statistically significant results reported; first in the case of food supply in Kg, the total merchandise trade seems to have a positive effect on this measure of food availability. By this result, the present thesis agrees with some literature that has estimated a positive direct and indirect effect of trade on food security, specifically food availability (Dinh Ly et al., 2020; Baldos and Hertel, 2015). The second statistically significant estimate reported has an opposite conclusion, in the case of food supply measured in dietary energy consumption (Kcal) reported a high negative estimate indicating as in the majority of by-country results that the total merchandise trade harms food availability in kilocalories, the reasoning why the effect changes from one unit of measure to the other is out of the scope of this research however one main difference is that the estimate for food kilograms is coming from the regular PTG measure and the estimate analyzed for food kilocalories is coming from the estimated IV.

Regarding the other two main trade variables analyzed, not many conclusions can be drawn from the PFI variable which affects positively the food supply in kilograms whereas negatively affects the food kilocalories, however none of these estimates are statistically significant. In the case of PFE which is the proportion of food exports over total trade the estimates for food supply are small and negative, but the main point of discussion can be observed for food availability measured in kilocalories. The estimates in this case are negative and high compared with other variable's estimates indicating that PFE has a greater negative impact on the availability of foods (in calories measure) in the panel of countries analyzed, relating to some of the by-countries estimates (Rwanda, Egypt, Cote d'Ivoire, and Guinea) essentially concluding that exports harm food calories availability.

One relevant aspect of comparing country-by-country estimates and the panel estimates comes from the point of view of data availability. The country-by-country estimates could be biased given the lack of data available; however, the models used seem to have an impactful measure of the relationship between trade and food availability; therefore, it would be essential to run this same analysis once more data becomes available, or other data sources are found.

5.2 Food Affordability

This section provides the results and discussion regarding this thesis's second specific objective, which was to analyze the relationship between international trade and food affordability. For this model, as previously mentioned in the methodology section, generalized least square models were run in combination with the autoregressive model AR1 to obtain by-country estimates and an OLS and IV panel regression like the one seen in the previous main section (food availability) to get panel estimates. Due to lack of data availability, only 16 countries were analyzed using these methods. This section is divided into two subsections regarding the model applied, first presenting the GLS-AR1 by country estimates of the most relevant results obtained and then the panel regression of the 16 countries analyzed.

5.2.1 Empirical regression country-by-country results

For the country-by-country estimates, a set of eight results will be the ones discussed in this subsection; those contain the most relevant results found in this model; contrasting with the availability model, only one GLS-AR1 estimate is reported by country, and no IV was introduced to analyze this factor of food security in a country-by-country basis. The results reported are for the countries of Uganda, Mozambique, Philippines, Cameroon, Cote d'Ivoire, Guatemala, India, and Laos; these are reported in table 5.12.

The discussion will explain how the trade-related variables affect the ratio of the diet cost of food with respect to per capita income in those countries. It is important to remember that in this case, the control was not made through variable inclusion but by converting the data used to real terms using the CPI. The primary variable of analysis is the ratio of diet cost with respect to income; therefore, a negative estimate will positively affect this variable. As in the availability model, some country characteristics will add to the discussion.

Table 5.12. Affordability Model By-Country Results

	Dependent variable:							
	RatioFEI							
	Uganda	Mozambique	Philippines	Cameroon	Cote d'Ivoire	Guatemala	India	Laos
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	0.669***	0.625***	-1.832***	-0.936**	1.022***	0.636	0.175***	0.360***
	(0.172)	(0.100)	(0.480)	(0.412)	(0.278)	(0.729)	(0.030)	(0.008)
TR		-0.051***		-0.013**	0.027***		-0.00001	
		(0.013)		(0.007)	(0.006)		(0.00001)	
FT	-0.108***	0.122***	-0.005***	0.170***	-0.054***	-0.008***	-0.0005***	-0.063***
	(0.037)	(0.043)	(0.001)	(0.033)	(0.005)	(0.002)	(0.0002)	(0.003)
AgT	0.033	-0.005	-0.005	0.042**	-0.043**	-0.034	0.0001	0.001**
	(0.074)	(0.037)	(0.007)	(0.020)	(0.018)	(0.072)	(0.001)	(0.001)
TOTC	-0.013*		0.207***	-0.023	-0.369	-0.010	-0.025***	-0.033***
	(0.007)		(0.050)	(0.018)	(0.113)	(0.020)	(0.002)	(0.011)
TT		0.021***		-0.012***				
		(0.005)		(0.002)				
Observations	10	10	10	10	10	12	10	10
Log Likelihood	23.371	22.058	40.062	35.466	25.507	32.641	45.101	36.395
Bayesian Inf. Crit.	-32.927	-27.997	-66.308	-52.511	-34.896	-50.372	-74.084	-58.974
Note:								*p<0.1; **p<0.05; ***p<0.01

Some of the estimates are not present in all country estimates due to multicollinearity issues detected in the data of that specific country. It is important to recall that the primary analysis variable was constructed specially for this research, so, given the assumptions presented in the methodology chapter, some data constraints cut the number of observations per country. An exception was made to the country of Guatemala, which had more historical data, so the period analyzed is different from the rest (2009-2020).

There are two main trade-related variables of analysis in this model: total trade merchandise (TR) and total food trade (FT). For the first one, it can be noticed that in most of the results, the estimate is negative; this means that, for example, in the estimate for Mozambique, an increase in total trade would cause the ratio of diet cost to income to be reduced by 5.1% which means a gain from trade, meaning that more trade flow in all types of merchandise would make food more affordable on those countries.

The variable of food trade behaves similarly except for two cases, Mozambique, and Cameroon; more food trade would cause the calculated diet cost to be more affordable to the analyzed countries. This contrast with previous research like Antamoshkina and Rogachev (2021) where import substitution policies to increase local production improved economic affordability.

In the analysis of affordability, food trade was not separated between imports and exports; however, the variable of terms of trade in the trade of cereals is one assessment of how import and exports prices ratios affect the affordability of this particular food group which constitutes the most significant percentage of the diet in most countries. These terms of trade in cereals (TOTC) estimates are negative in almost all countries except for the Philippines; this means when the export price is greater than the import price of cereals (meaning TOTC is greater) or in the case import prices are reduced, both scenarios affect the affordability of the calculated diets positively. These also happen in countries that were not reported (Egypt, Indonesia, Bolivia, and Cambodia).

In contrast with the results found in the availability model, it seems to be less variability in the direction of the effect of these trade-related variables on food affordability; this is the case most of the time, except for the variable of agricultural tariffs in which the direction of the effect is more variable among the countries analyzed, many agricultural tariffs estimates are negative. However, this is against what is expected; an increase in AgT should negatively affect food security given the increased import prices as seen in the literature by Herath, Liang, and Yonbing (2014) and Warr (2014), where high import prices affected the food affordability on the set of countries, especially developing countries. However, it is hard to assess the accuracy of this estimate because agricultural tariffs sometimes are not time-variant or are repeated in years where a trade policy has not been introduced. Other affordability research like Capone et al., 2014 cannot be compared to this thesis estimates due to the different modeling and purpose of the study.

Regarding the country characteristics discussed, there is no apparent pattern between these and the directions of how the modeled trade variables affect their affordability. Uganda and Mozambique are the only low-income countries reported, also the ones with the lowest affordability score by the GFSI; however, the effect of variables like food trade, agricultural tariffs, and cereal terms of trade is similar to India, a low-middle income country with the third-highest score in affordability among the countries reported. Other characteristics like regionality seem to have even less effect on how the estimates behave.

In the next step to analyze how trade affects affordability in these countries jointly, OLS and IV models were run in a panel set up, using the 16 countries that the GLS-AR1 model was applied. In general terms, these results will vary due to the different methodology used and how this is generated in the IV case.

5.2.2 Empirical regression panel results (OLS and IV)

Although the results described in the previous subsection are similar regarding the magnitude of trade-related variables in the proposed ratio of food diet costs with respect to the per capita income of the analyzed countries, the purpose of this subsection is to provide a panel estimate of the 16 countries in which the GLS-AR1 model was applied—this time using the OLS and IV methodology that was applied in the availability factor analysis, to analyze how a group, estimate of the trade-related variables affect the food affordability. Through this model, the IV is obtained by measuring a country's trade-related to exogenous factors of that country that are not related to possible causality issues between food affordability and trade. The affordability model's difference relies on the primary variable used for the IV is the total merchandise trade and not a ratio of this over GDP as in the availability model. This subsection presents the results of equation 10, described in the methodology section.

Table 5.13 presents the results of the panel model using the standard measure of the OLS model, which is the total trade, and by using the IV generated through the gravity models, one of which presents the panel countries as exporters and the other presents them as importers. The variable TRIV is just the sum of the predicted values of both gravity models. As the main scope of this subsection is to analyze food affordability, the gravity models used will not be included in the discussion; however, their results can be found in Table 2 in appendix B.

Similar to what was observed in the food availability panel model, the variation captured by this model is high, reaching around 91% of the variation in the RatioFEI variable. Also, the significance of the results is not relevant because from the models run; only one variable resulted in statistically significant. Putting aside the levels of significance obtained, one relevant aspect of the results obtained is how the variables behave similarly in both models, at least in the direction of their effect. The total trade variable has a negative estimate, indicating that with a $1 billion increase in total merchandise trade, food becomes more affordable (the ratio is reduced) by 0.02% for the OLS model and 0.6% for the IV model. The terms of trade for cereals behaves similarly in the direction; this was the expected behavior of these variables. The coefficient estimates of food trade in the panel regression are positive, which is unexpected. But these estimates are not statistically different from zero. In the case of agricultural tariffs, they also obtained coefficient directions as the one expected; a 1% increase on them would harm the affordability of food.

Table 5.13. Food Affordability Panel Model Results - OLS and IV

	Dependent variable:	
	RatioFEI	
	Panel OLS	Panel IV
	(1)	(2)
TR	-0.00002	
	(0.0002)	
TRIV		-0.005^{*}
		(0.003)
FT	0.0005	0.0004
	(0.001)	(0.001)
AgT	0.002	0.002
	(0.003)	(0.002)
TOTC	-0.003	-0.003
	(0.004)	(0.004)
Observations	112	112
R^2	0.907	0.910
Adjusted R^2	0.886	0.891
F Statistic (df = 20; 91)	44.156^{***}	46.195^{***}
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

Due to only one of the estimates resulted in statistically significant, it is hard to infer that this is the actual effect of the trade-related variables in food affordability. There is a more marked effect in the GLS-AR1 by country estimates, so at some level, opening to trade seems to have a positive impact on how affordable foods are.

5.3 Limitations and Future Research

This thesis provides several additions to the literature around international trade and its relationship with food security, however, there were several factors affecting the efficiency of this research that can be improved to generate more research by either replicating the methods used with more data or improving those methods.

The first limitation and the most important was the data availability. International trade data is available through different sources; specific food trade data is more limited in the reported years. The same happens when analyzing food availability measures; both are available at least two years behind which created a limitation of the timeline analyzed, which was narrowed to 2008-2018. Some data to get the food supply in kilograms is available (food trade and production) for some additional years, but a decision was made not to attempt to get the data for the rest of the years as it would not be constant across the years, therefore creating bias on the research.

For food affordability, there were many assumptions and limitations in data for creating the independent variable. First, consumption patterns data were available every three to five years; therefore, consumption is repeated for the years between two data points; however, the retail prices are reported twice a month, so a year average was used to obtain a yearly price. Second, the data limitation mainly was found in the retail prices data by the WFP; some countries fail to report prices for a variety of products or started recently to report some relevant products for a cost of diet construction like vegetables, meats, and eggs, among others, this limitation caused that the analysis for food affordability is limited to only 16 countries. The limitation in the retail price data also caused a limitation in the number of years analyzed for food affordability, which simultaneously caused a restriction to the inclusion of the instrumental variable into the country-by-country model. The gravity model data is up to 2018, which would shorten the period, and it wouldn't be feasible to run the model; thus, the IV was only included in the panel analysis.

In the case of food availability, the data limitation was less severe so that the study could be updated in time with more data available for more years. In total, from the original set of countries planned to analyze, only 39 were analyzed; these 39 countries are divided into the two factors of food security studied: 37 for food availability and 16 for food affordability.

Looking towards potential research, when studying the retail prices data reported by the WFP, it was noticed that in the last few years, many countries have started to report a wider variety of food products which in the medium term would provide more observations for the analysis of the food affordability model and potentially the inclusion of more countries. At the same time, the increase in the number of observations could cause the VAR or VECM model that was not feasible due to the limited data could become viable for this analysis. Also, if found, a more detailed consumption data base would improve the food affordability research.

Another potential research with a similar idea of studying the effects of international trade on food security within the affordability factor could be price transmission research, as described in the literature review chapter. For this, the price data from the WFP could be a reliable source to study the difference between international and retail prices and how trade contributes directly or indirectly to the gap between those prices.

Chapter 6 - Conclusions

This research aimed to identify whether international trade had a relevant impact on the state of food security for low and low-middle countries. This impact was evaluated using two significant main factors to measure food security, food availability and food affordability. Food availability was measured through two units of measure, kilograms, and kilocalories. Countries' selection was made through the income group definition of the UN and the classification of the GFSI.

Literature studying both food security factors was analyzed, among the principal missing pieces in this research were found that in the case of food availability, most of the literature applied simple descriptive analysis and did not considered a wider range of trade-related variables to report the relationship, previous research only accounted for one measure of availability, and finally the causality issue was not taken in consideration when econometric models were used to study food availability. In the case of food affordability, most of the research found was focused on studying this factor in terms of macroeconomic variables and not trade variables, causality issues were ignored as well.

For food availability, the models applied were first, inferential statistics, and second, OLS regressions with a combination of trade-related variables and agricultural production control variables. In the case of food affordability, the methodology consisted of GLS regressions using AR1 errors. Reverse causality issues were assessed in this research through an IV for the main trade variables in both factors. The IV was used in the by-country and panel analyses for availability and only introduced in the panel analysis for the case of the food affordability. The IV was obtained through a gravity model of trade using variables that are exogenous to the models of food availability and food affordability.

From the results obtained in both factors, it is inferred that international trade does affect the food security state in the analyzed countries. In the case of availability, this first was not captured through the inferential analysis, except when applying the sensitivity analysis, however it was better observed through the OLS and IV results. The effect was negative in the primary variable of analysis (PTG) and more diverse through the countries when measuring the food imports and exports effect. One of the important additions of this research was the introduction of two availability measures into the analysis, this was relevant because there was a difference in how trade affects both measurements being higher in the case of food kilocalories when compared to food supply (kg), this could indicate implications on the types or the nutritional contents of the foods these countries trade.

Another main contribution made was the introduction of the IV method to deal with possible reverse causality issues, the relevance of this was detected when comparing the OLS and IV results, the IV method resulted in higher estimates, inferring that OLS could underestimate the impact of trade on food availability, although, most of the time, when appropriate weak instruments and Wu-Hausman tests were applied, the results leaned more toward the OLS estimates presenting both estimates makes the present research more reliable. The panel results with all countries indicated, for food supply (Kg) that the proportion of trade over have a positive impact on this measure of availability, whereas a negative impact in food kilocalories. The proportion of food exports negatively impact both measures of food availability.

For food affordability, the variable of interest was the ratio between the diet cost constructed through retail price data and consumption data and the per capita income. The GLS-AR1 regressions results were constant among the reported countries, where a negative estimate indicated a diminution of the ratio, thus a positive impact. The variables analyzed included the total trade, food trade, the terms of trade in the cereal's food group, and agricultural tariffs. The first four variables in most estimates resulted in a negative estimate, making foods more affordable, and agricultural tariffs were found to negatively affect how affordable foods are. By these results, the present research achieves its contribution to the literature making a direct relationship analysis of how international trade affects food affordability, concluding that, under the assumptions made in the model, trade in general terms makes food more affordable. The contribution made by incorporating an IV model in a panel set-up was not able to obtain significant results but, except for the food trade variable, the panel estimates obtained the same conclusions as the country estimates. This thesis also achieves to introduce a method to incorporate consumption and retail price data to analyze the affordability of foods.

The data used for this research was constrained in many parts; therefore, the relevance of the third factor, as this research and methods can be replicated with more robust datasets and add more countries into the equation in the future. The main message found on this research is that promoting food trade could positively affect the food security state of the analyzed countries, especially when measuring the affordability factor.

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Appendix A - Global Dietary Database definitions

Table 6.1. GDD definitions used on Affordability Model

GDD Variable Label	Numeric Code	GDD Variable Unit	GDD Definition	GDD Alternative Definitions Considered
Fruits	v01	grams per day	Total fruit intake, including fresh, frozen, cooked, canned, or dried fruit, excluding fruit juices and salted or pickled fruits.	Total fruit intake including fruit juices, nuts/seeds, vegetables, salted/pickled, preserved and processed fruits (jams).
Non-starchy vegetables	v02	grams per day	Total vegetable intake, including fresh, frozen, cooked, canned, or dried vegetables. This definition excludes salted or pickled vegetables, vegetable juices, starchy vegetables (e.g., potatoes, taro, cassava, manioc, yucca,	Total vegetable intake including vegetable juices, starchy vegetables, nuts/legumes, nuts/beans, beans/legumes, salted/pickled vegetables and salted/pickled beans/legumes.
Potatoes	v03	grams per day	Total intake of white potatoes, including cooked (e.g. boiled, baked, mashed, fried), frozen, canned, dehydrated potatoes. This definition includes french fries, chips, and crisps.	Includes other starchy vegetables.
Other starchy vegetables	v04	grams per day	Total intake of non-potato starchy vegetables, including fresh, frozen, cooked, canned, or dehydrated starchy vegetables. Examples of starchy vegetables include green peas, corn (including corn flour/corn meal), yam, sweet potatoes, taro, plantain, cassava,	Includes starchy fruits or potatoes and starches refined from starchy vegetables. May include non starchy vegetables such as carrots and/or fruits such as mangos, sweet potatoes and hard squashes.
Beans and legumes	v05	grams per day	Total intake of beans and legumes (beans, lentils), including fresh, frozen, cooked, canned, or dried beans/legumes. This definition excludes peanuts and peanut butter. This	Includes nuts/seeds, soy protein, soy products, peanuts and peas.
Nuts and seeds	v06	grams per day	Total intake of tree nuts (e.g. walnuts, almonds, hazelnuts, pecans, cashews, pistachios), seeds (e.g. sesame seeds, sunflower seeds, pumpkin seeds), and	Includes pulses, beans, legumes and foods primarily (>51%) from nuts or seeds.

Refined grains	v07	grams per day	Total intake of refined grains, defined as grains which have been milled to remove the bran and germ. Examples include white or polished rice, and products made with refined (white) flour, including white bread, pasta/noodles, cereals, crackers, and bakery products/desserts containing	Includes corn products, soybeans, sweetened cakes and breads with grain as the main ingredient. May include whole grains.
Whole grains	v08	grams per day	Total intake of whole grains, defined as a food with ≥1.0 g of fiber per 10 g of carbohydrate, in which all components of the kernel (i.e. bran, germ, and endosperm) are present in the same relative proportions as the intact grain. Examples include whole grain bread, brown rice, whole grain pasta, whole grain breakfast cereals, oats, rye, barley, millet, sorghum, and bulgur.	Includes wholegrain breads, cereals, rice/pasta, bread and other products such as biscuits.
Total processed meats	v09	grams per day	Total intake of processed meat, defined as any meat (including poultry) that has been cured, smoked, dried, or chemically preserved. Examples include bacon, salami, sausages, hot dogs, and processed deli or luncheon	Includes sausages and unprocessed meats.
Unprocessed red meats	v10	grams per day	Total intake of unprocessed red meat, defined as beef, pork, lamb, mutton, or game that has not been cured, smoked, dried, or chemically preserved. This	Includes processed red meats, poultry, fish and organ meats.
Total seafoods	v11	grams per day	Total intake of fish and shellfish. Examples include salmon, tuna, trout, tilapia, shrimp, crab, oysters, and	Includes salted fish, processed fish and other animal products.
Eggs	v12	grams per day	Total intake of eggs produced by poultry/birds, including chicken, goose, or duck eggs. This definition excludes	

Cheese	v13	grams per day	Total intake of cheese derived from the milk of livestock (e.g. cows, buffalo, yak), including hard cheese (e.g., cheddar, mozzarella, Swiss), soft cheese (e.g. ricotta, cottage cheese,	Includes yogurt, milk products and cheese.
Yoghurt (including fermented milk)	v14	grams per day	Total intake of yogurt and fermented milk, including reduced-fat and full-fat	Includes dairy curd, buttermilk, paneer, cheese and milk.
Sugar-sweetened beverages	v15	grams per day	Total sugar-sweetened beverage intake, defined as any beverage with added sugars having ≥50 kcal per 8 oz (236.5 g) serving, including commercial or homemade beverages, soft drinks, energy drinks, fruit drinks, punch, lemonade, and frescas. This definition	Includes fruit and vegetable juices. May also include coffee, tea and milk.
Fruit juices	v16	grams per day	Total intake of 100% fruit juice, excluding sugar-sweetened fruit juice	Includes fruit juices, vegetable juices and sweetened juices.
Coffee	v17	cups/day (1 cup=8 oz)	Total coffee intake including caffeinated, decaffeinated, sweetened,	Includes tea.
Tea	v18	cups/day (1 cup=8 oz)	Total green or black tea intake, including caffeinated, decaffeinated, sweetened or unsweetened tea. This	Includes coffee.
Reduced fat milk	v19	grams per day	Total reduced-fat dairy milk intake, including non-fat, low-fat milk and skim milk. This definition excludes yogurt, fermented milk, and soy or plant-	Includes sweetened reduced fat flavored milk.
Whole fat milk	v20	grams per day	Total whole-fat dairy milk intake. This definition excludes yogurt, fermented milk, and soy or other plant-derived	Includes sweetened whole fat flavored milk.
Total Milk	v57	grams per day	Total intake of dairy milk including non-fat, low-fat, skim, and whole-fat milk. This definition excludes yogurt, fermented milk, and soy or other plant	Includes yogurt, dairy drinks, cheese and dairy products.
Total energy	v21	kcal per day	Total energy intake.	

Appendix B - Gravity Models Results – Equations 3 and 10

Table 6.2. Gravity Model Results – IV for Availability Model

	Dependent variable:	
	log(Trade_GDP)	
	Importer Model	Exporter Model
	(1)	(2)
[11]log(dist)	-1.330***	-1.349***
	(0.018)	(0.018)
contig	1.374***	1.538***
	(0.068)	(0.068)
comlang_off	0.912***	0.864***
	(0.029)	(0.029)
rta	0.815***	0.775***
	(0.034)	(0.035)
Constant	-2.162***	-3.356***
	(0.258)	(0.277)
Observations	59,295	58,407
R^2	0.717	0.639
Adjusted R^2	0.716	0.637
Residual Std. Error	2.203 (df = 59045)	2.220 (df = 58157)
F Statistic	600.437*** (df = 249; 59045)	412.679*** (df = 249; 58157)
Note:		*p<0.1; **p<0.05; ***p<0.01

[11] Fixed effects were omitted from table

Table 6.3. Gravity Model Results - IV for Affordability Model

	Dependent variable:	
	log(Trade_Billions)	
	Importer Model	Exporter Model
	(1)	(2)
[12]log(dist)	-1.294***	-1.410***
	(0.035)	(0.032)
contig	1.317***	1.802***
	(0.128)	(0.116)
comlang_off	0.776***	0.736***
	(0.056)	(0.051)
rta	0.771***	0.448***
	(0.062)	(0.056)
Constant	-1.912***	-0.674
	(0.479)	(0.439)
Observations	16,958	17,261
R^2	0.748	0.753
Adjusted R^2	0.745	0.750
Residual Std. Error	2.208 (df = 16730)	1.998 (df = 17033)
F Statistic	219.029*** (df = 227; 16730)	229.295*** (df = 227; 17033)
Note:		*p**p***p<0.01

[12] Fixed effects were omitted from table

Appendix C - Additional by-country Results – Availability Model

Table 6.4. Availability Model Results - Cote d'Ivoire

	Dependent variable:			
	FoodKCAL		Food_B	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
PTG	-73.001	-1.231	14.350	-9.028
	(88.633)	(164.157)	(38.592)	(69.627)
PFE	-474.398	-411.702	-49.329	-69.752
	(259.912)	(300.327)	(113.168)	(127.384)
PFI	-262.767	-334.450	145.817	169.166
	(338.505)	(384.226)	(147.388)	(162.970)
PATP	31.267	25.356	-7.771	-5.846
	(67.057)	(72.173)	(29.197)	(30.612)
PCC	-3,391.268**	-3,734.563**	114.852	226.673
	(905.405)	(1,157.800)	(394.222)	(491.081)
Constant	4,242.562***	4,304.041***	627.123**	607.097**
	(372.607)	(412.669)	(162.237)	(175.034)
Observations	11	11	11	11
R^2	0.882	0.866	0.571	0.540
Adjusted R^2	0.763	0.732	0.142	0.079
Residual Std. Error (df = 5)	25.006	26.595	10.888	11.280
F Statistic (df = 5; 5)	7.453**		1.331	
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 6.5. Availability Model Results – Guinea

	Dependent variable:			
	FoodKCAL		Food_B	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
PTG	324.787	953.667	23.259	470.307
	(272.630)	(653.843)	(186.408)	(455.480)
PFE	-1,066.086	-1,066.065	-59.333	-59.318
	(747.825)	(1,027.225)	(511.318)	(715.585)
PFI	855.564*	1,445.417*	28.592	447.897
	(374.987)	(719.747)	(256.393)	(501.390)
PCC	-3,552.855*	-93.171	-2,146.310	313.051
	(1,725.601)	(3,783.184)	(1,179.862)	(2,635.441)
Constant	3,523.554***	1,871.830	1,234.932*	60.782
	(773.434)	(1,763.617)	(528.828)	(1,228.571)
Observations	11	11	11	11
R^2	0.879	0.771	0.739	0.489
Adjusted R^2	0.798	0.619	0.565	0.149
Residual Std. Error (df = 6)	45.537	62.550	31.135	43.574
F Statistic (df = 4; 6)	10.875***		4.254*	
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 6.6. Availability Model Results – India

	Dependent variable:			
	FoodKCAL		Food_B	
	OLS	*instrumental variable*	*OLS*	*instrumental variable*
	(1)	(2)	(3)	(4)
PTG	-169.245	-361.386	-198.173	-408.789
	(254.250)	(612.555)	(115.742)	(331.942)
PFE	640.603	791.517	912.665	1,078.091
	(1,248.749)	(1,376.810)	(568.467)	(746.090)
PFI	-1,164.338	-1,984.555	-897.709	-1,796.799
	(1,783.355)	(3,005.108)	(811.835)	(1,628.460)
PAG	-2,405.682**	-2,296.804**	-1,262.421***	-1,143.073**
	(720.487)	(816.250)	(327.987)	(442.324)
Constant	2,978.172***	3,056.994***	793.533***	879.935***
	(189.134)	(300.682)	(86.099)	(162.939)
Observations	11	11	11	11
R^2	0.777	0.756	0.889	0.828
Adjusted R^2	0.628	0.593	0.815	0.713
Residual Std. Error (df = 6)	34.156	35.744	15.549	19.370
F Statistic (df = 4; 6)	5.224**		12.021***	
Note:			*p<0.1; **p<0.05; ***p<0.01	