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Shock transmission in the International Food Trade Network. A Data-driven Analysis

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Abstract

Food Security is a longstanding concern worldwide. The expansion of global food markets brings benefits but also risks, such as shock transmission within the global network of trade relations. We focus on this last issue, from an empirical point of view, by analysing the diffusion of trade shocks — defined as relevant drops in exported quantities — during the period 1986 - 2011, for four major staples (wheat, maize, rice, and soybeans) both at country level and global scale.

We find that: (i) income per capita of importing countries matters in shock propagation; (ii) developing countries tend to absorb most of the negative export variation (i.e., the trade shock), and (iii) global food prices and real (tonnes) fluxes of commodities are only weakly correlated, meaning that a quantity-based investigation provides additional information with respect to a price-based analysis. This work offers a novel framework, complementary to the price-based literature, for the definition and measurement of the propagation of international food shocks.

Keywords: food crisis, shock propagation, food security, international grain trade

1. Introduction

The production and provision of adequate food, in quantity and quality, is a longstanding[1] concern worldwide (FAO, 13-17 November 1996, Fresco, 2009). Food consumption has not grown linearly with population size due to the so called 'Bennett's law', whereby the consumption of fats and proteins tends to increase with income per capita (Tilman et al., 2011). The need to feed

[1] See http://www.fao.org/docrep/005/y4671e/y4671e06.htm for a detailed analysis of the evolution of the official definitions of Food Security.

animals and the use bio-fuels (E.U., 2009, Godfray et al., 2010), are putting additional pressure on the food system. The recent spikes in food prices, occurred in 2007/2008 and in 2010/2011, have pushed food security to the top of the global policy agenda.

From the 1980s onwards, international trade grew substantially, accountin nowadays for about 24% of the food produced for human consumption (D'Odorico et al., 2014). The last OECD-FAO's Agricultural Report (OECD-FAO, 2015) underlines the importance of international trade to overcome local food supply shortages, although it might also expose importing countries to risks from external perturbations (e.g., Sartori and Schiavo, 2015, Tamea et al., 2016, Marchand et al., 2016). Two main strands of literature attempt to face this issue: (i) economic models looking at food crises through the lens of price fluctuations, or (ii) simulations of 'cascading shock' models take the problem from a network science point of view.

Economic analysis use food prices as indicators of the onset and propagation of food crises. However, they are affected by many other factors, beyond demand and supply, such as: GDP growth, monetary expansion, speculative finance, exchange rates (Gilbert, 2010) and energy (Assefa et al., 2014, Lagi et al., 2015). Several studies show complex effects of food price fluctuations prticularly in the developing countries (Ivanic and Martin, 2008).

The second strand focuses on the so called International Agro-Food Trade Network (henceforth IFTN, see Ercsey-Ravasz et al., 2012). Network analysis has been extensively used to analyse bilateral trade flows (Carvalho, 2012) and several indexes have been developed to assess the network vulnerability to exogenous perturbations (e.g., Contreras and Fagiolo, 2014). Recent applications regard the IFTN resilience. Gephart et al. (2016) focused on fish trade and the identified Central Asia and West Africa as the most vulnerable region to external shocks. Tamea et al. (2016) found evidence that: local food-production crises propagate worldwide and that stronger effects of crises are expected in countries with low food availability. Marchand et al. (2016) observed that: (i) trade and stocks make a country more resilient in case of national drop in production, but (ii) high import dependency increases the risk of food shortages following a foreign shock. Overall, both the linkage between increasing international trade and food security, and the identification of the most vulnerable areas, are not yet clear.

We introduce a complemantary approach to the existing literature. We follow the IFTN literature, but we focus on the actual consequences of past export shocks, and we make a comparision with price fluctuation during the crises. We aim at identifying the drivers of shock propagation, by focusing on physical quantities (tonnes), because they provide direct information on the actual availability of food. All in all, we show that price and quantity can provide us with complementary information.

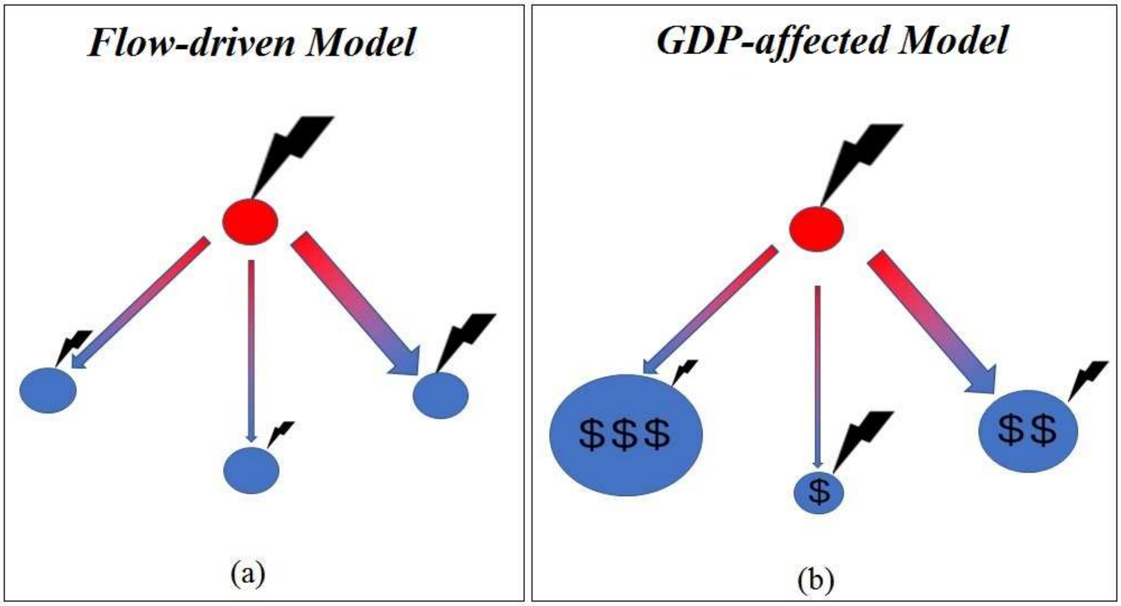

Figure 1: *Network representation of two trade shock (thunderbolt) propagation models. Panel (a) shows a proportional "flow-driven" shock model where negative shocks are higher for big importers (the dimension of the arrow is proportional to the tonnes exchanged). Panel (b) shows our "GDP-affected" model where the GDP per capita (dollar sign) of the importers alters the distribution of the shock. Richer countries have lower reductions (little thunderbolt) than poorer countries (big thunderbolt).*

We present a graphical representation of our model, claryfying the aim and the novelty introduced in this work. The manner how a shock propagates in the IFTN is shown in Figure 1. Panel (a) represents a simple "flow-driven" model (e.g., Marchand et al., 2016) whereby a negative shock (black thunderbolt) hits an exporter (red circle), then propagates in proportion to the (previous) level of bilateral trade flows (arrow size). Hence, each importer suffers from a reduction of food proportional to the share of import from the critical exporter. Panel (b) presents our "GDP-affected" diffusion model, where we include information on the exporter, the volumes of bilateral trade, and per capita income ($) of importing countries. In this case, the economic variable alters the distribution of the negative aftermaths of the shock, so that poorer countries face larger falls in food imports than richer countries. The main research questions we aim at answering are: (a) How do local shocks transmit (in the short-term) to direct importers in the international food trade system? (b) What are the main drivers of shock propagation? (c) What is the effect of cross-country income inequalities? (d) What is the relation between export fluctuations and price dynamics?

We address these questions with an approach with the following features: (i) it is a data-driven study, (ii) it provides direct information on the potential lack of food, that can be hidden when looking only at prices, and (iii) it assesses the link between export-volume variations and price fluctuations in order to offer a wider framework to debate food security.

The structure of the paper is as follows. Section 2 describes the database. Section 3 describes the methods and the econometric equation. Section 4 presents the results of the regression. Section 5 focuses on global trade shocks, it makes a comparison between export fluctuations and price dynamics and it discusses the main implications. Finally, Section 6 draws the main conclusions.

2. Data

Trade data are taken from a revised[2] version of the publicly-available Food and Agricultural Organization online database (FAOSTAT, 2012), which reports the yearly trade flows among countries for several commodities, from 1986 to 2011. This is the most, currently available, complete and reliable database for agri-food both in terms of items (more than 300) and countries (more than 200).

It provides information on: Import (M), Export (E), Gross Domestic Product (GDP), GDP Deflators (d), Population (POP), and Production Quantity (Q). Import and Export of food (tonnes) are reported both at bilateral and aggregate level. We use the World Bank Data on Gross National Income (GNI) and on the income threshold to distinguish between Low, Medium-Low, Upper-Medium, and High income countries. This study concentrates on four major crops (wheat, maize, rice, and soybeans) because they cover more than 50% of the global calories intake.[3] In particular, wheat ensures the 20%, rice the 16%, maize the 13%, and soybeans the 8% of the global human calorie intakes(D'Odorico et al., 2014).

The bulk of data at hand allows us to analyse the main determinants and the evolution of recent export crises in order to improve the understanding of food insecurity. Note that each monetary amount is expressed in real US dollars computed using the GDP deflators provided in FAOSTAT

[2]We thank Stefania Tamea for the provision of data. The original data reported some inconsistencies between the declaration of importers and exporters, so that the aggregate values differ. To solve this problem, Tamea has developed an algorithm to pick the data from the most reliable countries.

[3]Rice is expressed in milled equivalent. See http://faostat3.fao.org/home/E for a description.

(base year 2005).[4]

3. Methods

We define a "IFTN Shock" any (relevant) country-level drop in food export occured over a short period of time. We focus on the first-round shock transmission impact, by looking at the consequences on the direct trading partners (importers) with no inclusion of indirect effects. Our choice is motivated by the fact that the system at hand is so complex that a clear assessment of second-round effects would be too complicated and results could be spurious. Since the IFTN is influenced by so many factors (economic, political, climatic, dietary, and so on), we rely on statistical inference, instead of defining absolute cause-effect relations.

The current study aims at finding the building blocks for the future definition and modelling of trade shock propagation within networks. Indeed, most of the current studies assume that, after a shock, any node (importer) should reduce the volume of imports in proportion to its node degree (average number of links) or weighted degree (average volume associated to each link). We then try to find the variables, both endogenous and exogenous to the IFTN, that provide information about how country-driven trade shocks transmit. For this reason we perform an econometric analysis to find statistically significant relations, as described below.

We define a trade shock[5] as the difference between any sequence of local maxima and succeeding local minima in the time series of food exports by each country j (E_j), such that:

$$\Delta E_j(\tau) = E_j(t_1) - E_j(t_0) < 0, \tag{1}$$

where $\tau \equiv \Delta t = t_1$ - t_0 (with $t_1 > t_0$) is the duration of the crisis, t_1 is the year of the local minimum and t_0 the year of the local maximum level of export from country j. To clarify our procedure consider the following example: an exporter j shows the following trend of exports $\{100, 110, 80, 70, 90, 60, 75\}$. The series shows two local maxima (110 and 90) and two local minima (70 and 60) so that country j suffers a drop of 40 tonnes (110-70) during two years and a reduction

[4]See http://faostat3.fao.org/download/P/*/E for a description.

[5]Note that, to the best of our knowledge, an univoque definition of "Food Crisis" is not available in the literature. Scholars usually use it to indicate price spikes and/or high price volatility, lead by the implicit assumption that price is always a proper signal of scarcity. However, we show that this assumption not always holds and then, in order to avoid any confusion in the meaning of the terms, we opt for "Trade Shock".

of 30 tonnes (90-60) over only one year.

Note that we do not investigate the causes of the drop in exports, but we take export variations as given and explore their short-term effects. Given the international market structure (see Section A of the Supporting Information), we think that is reasonable to assume that the observed trade slumps are associated to supply, rather than demand, factors. Indeed, demand is typically highly fragmented and a single country should not be able to influence global demand. Moreover, the time span of each trade shock observed (around 2 years), the increasing food demand, the long time need for agricultural policy reforms, and dietary habits (that are rather stable in the short-term), lead us to assess shock transmission from a supply-side point of view (that justifies the form of equation (3)). Indeed, in the last decades there have been several cases of supply-driven export shocks due to lean production (for instance in Ukraine in 2002), export bans, as happened in case of rice in several Asian countries (e.g., India, Vietnam) in the aftermath of the financial crisis of 2008, or again due to the climate conditions (as the drought in Australia, see Headey, 2011). A notable exception is demand for soya, where China plays a major role accounting for almost 70% of global demand in 2011 (Section A in the Supporting Information). Interestingly, empirical results for soya differ from those relative to the other crops, thus corroborating our hypotheses.

For each country-level trade shock, we compute the ratio between the export decrease in the critical country j and the total (including j) variation in global exports ($\Delta E^w(\tau)$), during the same time span, to verify the global impact of the local shock. The ratio reads

$$\Theta_j(\tau) = -\frac{\Delta E_j(\tau)}{\Delta E^w(\tau)} \tag{2}$$

Note that, by construction, $\Delta E_j(\tau) < 0$, while the denominator can take both positive and negative values. With this in mind, we distinguish three possible alternatives: if $\Theta_j(\tau) \geq 0$, other countries offset the loss in export from j (that is $|\Delta E^w(\tau)| > |\Delta E_j(\tau)|$); if -1< $\Theta_j(\tau) < 0$, alternative suppliers have reduced their exports as well in the same time span; while if $\Theta_j(\tau) \leq -1$, the other countries have partially compensated the loss in export due to j, and therefore the main driver of global export reduction, in that period, was country j.

When looking at bilateral trade, we define the flow of commodities (tonnes) from exporter j to importer k as F_{jk}. We consider variables possibly affecting the impact of an export drop on each of the trade partners of country j. For this purpose, we compute the following power-law econometric equation:

$$\Delta F_{jk} \sim \beta_0 \cdot gdp_k(t_0)^{\beta_1} \cdot F_{jk}(t_0)^{\beta_2} \cdot E_j(t_0)^{\beta_3} \cdot (-\Delta E_j(\tau))^{\beta_4} \tag{3}$$

where $\Delta F_{jk} = F_{jk}(t_1) - F_{jk}(t_0)$ is the import variation (either positive or negative) after the export trade shock, gdp_k is per capita GDP of the importing country, $E_j(t_1)$ is the level of the exports from j after the shock, and $\Delta E_j(\tau) = E_j(t_1) - E_j(t_0)$ is the whole export variation from country j during the crisis. Each driver should affect the magnitude of $\Delta F_{jk}(\tau)$ differently:

- $F_{jk}(t_0)$: it is the pre-crisis level of import and represents the trade dependency of k from j. It is crucial for two reasons: first, a big importer has higher variations in absolute terms (tonnes); second, it should have more bargaining power so that it could keep its level of imports from j;
- ΔE_j and E_j are included because: (i) a large trade shock is likely to have a larger impact on each bilateral trade flow, and (ii) a big exporter might be able to grant more stable bilateral trade flows;
- per capita income of importer countries (gdp_k), that is a proxy of purchasing power. Note that this variable does not depend on the network structure, but is exogenous to the IFTN. The main idea is that a rich country is able to face the detrimental effects of the crisis by paying a higher price and to have a higher bargaining power.

Note that here we deal with tonnes variations, that can be either positive or negative (so that it is not possible to linearise the expression via a logarithmic transformation) and then we opt for a mathematical specification which better fits our purposes. The non-linear least-squares estimation is run by pooling together data from the ten crises selected, and looking at those importers with an import share of at least 0.5% from critical country j. The resulting sample covers more than 95% of the total export (for each commodity). Note that the βs are exponents, so that when they are negative, the associated variable should be read as a denominator, because we are dealing with a multiplicative model. This means that if the regressor (x) increases and $\beta_x < 0$, then the absolute value of $\Delta F_{jk}(\tau)$ should be closer to zero. While if $\beta_x > 0$, then the import variation will be large.

4. Results

We mainly focus on a specific commodity (wheat) for which we provide a detailed discussion of the results, while for the other commodities we report only a summary. Table 1 reports the basic information on the 10 largest country-level export shocks[6] that hit the international trade of wheat from 1986 to 2011.

[Table 1 about here]

These shocks hit the biggest exporters, in particular the USA, Canada, Ukraine and Australia with consistent losses. The USA reported the most severe one, with a peak of around $-15{\cdot}10^6$ tonnes from 1988 to 1990. The relative reductions go from around -28% (USA) to around -80% (Ukraine, due to a lean year, see Kobuta et al., 2012). Each crisis has an average duration of around 2 years. Half the time the global variation of exports (during the same period of the country-level crisis) followed the same trend, meaning that a single big exporter can generate a worldwide lack of supply. Values of $\Theta_j(\tau) <$ -1 appear in four out of five cases, implying that in most of the cases other exporters have partially offset the reduction due to country j.

When looking at other products (see Section B of the Supporting Information), one observes heterogeneous tendencies. The average duration of each crisis is around 2-3 years. In case of maize and soya, the ten most severe crises are caused only by three countries, of which the USA and Argentina are present in both the commodities. Rice shows a more diversified picture, with five (Asian) countries acting as epicenters of the crises. The different market structures are reflected in the values of $\Theta_j(\tau)$. Maize shows a negative $\Theta_j(\tau)$ in only four cases, while soya and rice show an opposite proportion, probably due to lower international competition.

[Table 2 about here]

Table 2 provides a summary of the estimated coefficients for the different commodities. The sign of β_1, associated with gdp[7], is always negative and statistically significant (at least at 99%) for three commodities with a value around -0.28 for wheat and about -0.6 for maize and rice. This confirms that a higher gdp makes a country more resilient in case of a negative trade shock, and the volume of imports is less affected[8]. Soya is the only exception with $\beta_1 > 0$. To understand this

[6] We also perform the very same analysis for the first 50 crises, obtaining very similar results. For the sake of space, we opt to present the first 10 cases only.

[7] We also perform the very same regression with alternative economic indicators, such as: Gross Net Income (GNI), Purchasing Power Parity (PPP) adjusted GNI and PPP-adjusted GDP. Results are quantitatively similar.

[8] Note that to check the robustness of these estimations and to avoid spurious results, we also performed the

anomaly is crucial to interpret the result under the lens of market structure dynamics. As shown in the Supporting Information, from the 2000s onward, soya demand is dominated by China which increased imports by almost $30{\cdot}10^6$ tonnes. Since China is a country with a relatively low *gdp* per capita (around 3150$ in real terms, in 2011), but with a level of imports larger than any other country, the coefficient associated with *gdp* is positive.

Note that: (i) results reported in Table 2 hold without any consideration of price fluctuations, during the period of trade shocks, and (ii) the regressions are run on data coming from all the crises pooled together; therefore these relations are time-independent. This last outcome is further confirmed by the fact that our trade shocks are not concentrated in a specific time window, nor they show cycles, rather they hit the IFTN system without any regularity over the time span considered. These outcomes highlight that poor countries (with the exception of soya for the reasons explained above) suffer from higher negative import variations than rich countries in case of negative trade shocks.

For what concerns trade-related variables, the sign of β_2 (corresponding to $F_{jk}(t_0)$) is always positive and significant, with values around 1.3. Hence, if a country has high volumes of pre-crises imports, then the variations in level should be higher as well. The information about the exporter are significant as well and, in general, a more severe negative shock has a bigger impact because the flows of goods are remarkably lower. The overall statistical significance of the estimations is high and robust, with an (adjusted) R^2 of around 75% for each product, with the exception of wheat for which it is around 56%. To summarize we find that:

1. in (almost) each case the exponent signs are significant and common to each product;
2. in case of Soybeans the analysis of the market structure (see Supporting Information A) allows one to explain the seemingly inconsistent result;
3. a cross commodity comparison confirms that: *i)* poor countries suffer more from a negative trade shock, *ii)* the market structure (see details on the Supplemetary Information) is crucial to understand the possible diffusion (worldwide) of local crises, and *iii)* that the export behaviour of the country hit by the shock (the “epicentre”) is relevant as well (coefficients β_3 and β_4).

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same regressions with other variables, such as the stock variations, the number of trading agreements signed by each country, and the distance between the country of origin and destination. These were not significant and did not alter our results.

5. Discussion from a global perspective

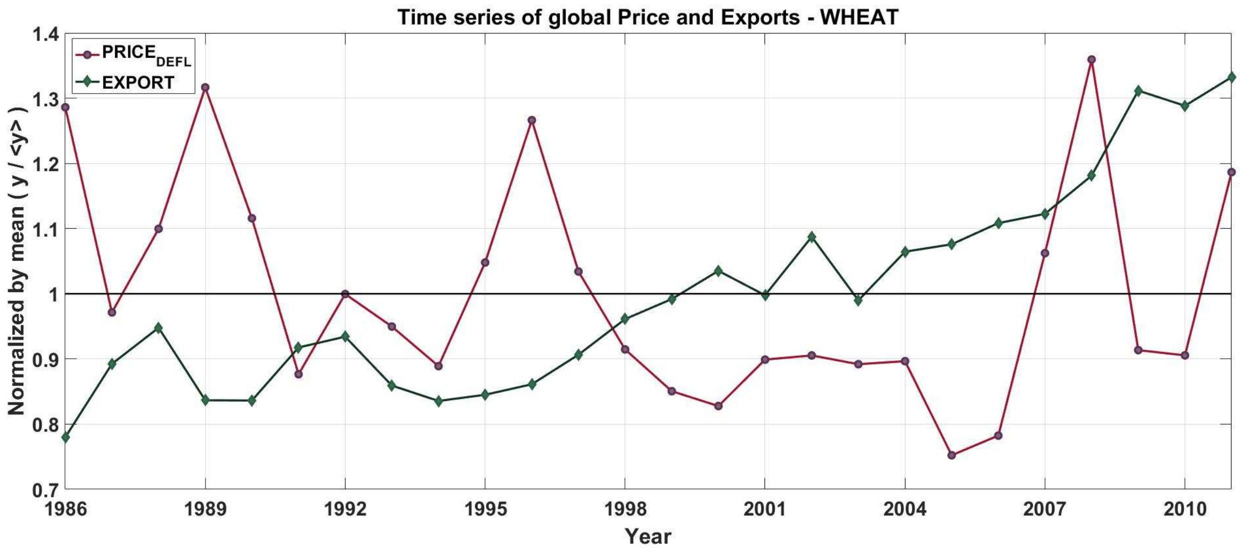
In this section we offer a wider framework in which analysing the overall effects of trade shocks and the relations between tonnes flows and price fluctuations. We compare the time series of the average commodity price and export levels at global level. In order to put more importance on the price applied by the big exporters we compute the global weighted average export price per ton (ρ), as (neglecting the time specification):

$$\rho = \sum_{j}^{N} (p_j \cdot m_j) \tag{4}$$

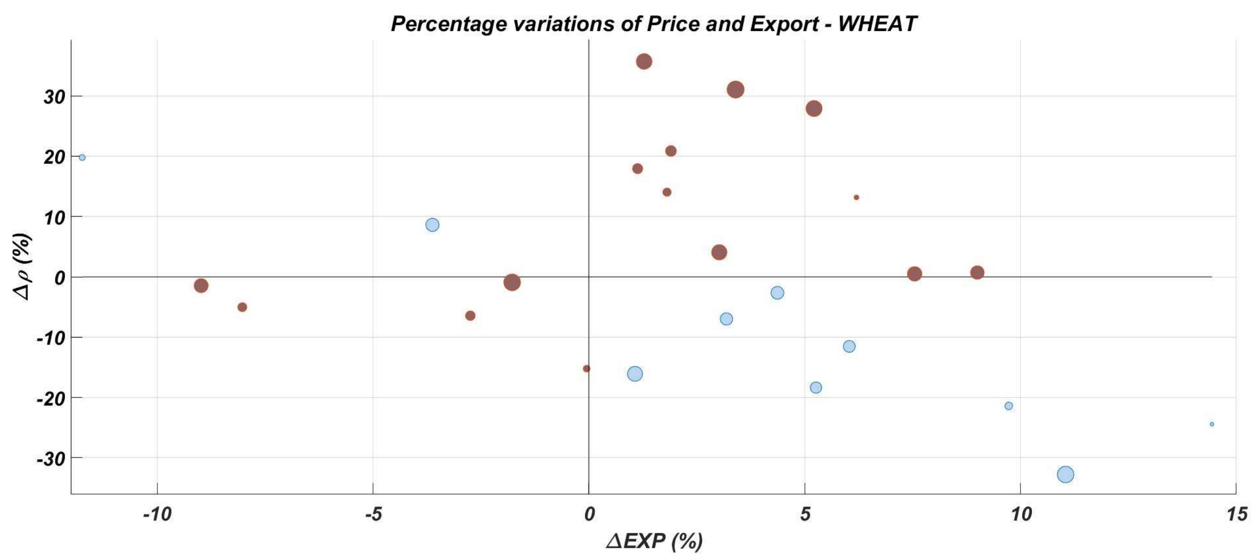
where p_j is the average export price per ton of exporter j - calculated as the ratio between the total monetary value (in US dollar deflated by d) and the aggregate volume (tonnes) of export of country j in each year - and m_j is the market share of country j.

Figure 2 shows the time series of the wheat global price (ρ) and the yearly global export (E^w), and the scatter plot of the percentage variation of ρ and E^w computed with respect to the previous year. The left panel compares the dynamics of prices and exports, normalised by their weighted (by country market shares) averages to make the comparison easier. From year 1994, E^w grew almost constantly, while the prices followed an irregular path with several peaks and spikes. The two series are only slightly negatively correlated (-0.19). Panel (a) shows that the relationship between the two variables is not always the same. For instance, from 2006 to 2007 E^w slightly decreased (about -0.4 kg per capita, about $-3{\cdot}10^6$ tonnes) while the price surged of almost +60$/ton (where the global price was about 150$ per ton). Conversely, in the time span 2008-09 E^w grew of about +12% while the price suffered a dramatic decrease of about -85$ per ton (-32%) going from 263$ per ton to around 177$ per ton.

Panel (b) shows that almost half of the times (11 out of 25, red dots) $\Delta\rho\%$ and $\Delta E^w\%$ show the same sign, implying that in case of increasing (decreasing) supply the price grew (decreased) as well. The other commodities show similar results. In case of maize and soya the correlation coefficient between ρ and E^w was even positive, of about +0.15 and +0.05, respectively; while rice showed a coefficient close to that of wheat (-0.19). The weak relation between price and quantity found here is not surprising given that many other factors influence the monetary measure, as explained above. Therefore, based on our results, we think that the current food price literature might find useful information in the analysis of the real (tonnes) flows of commodities, because food prices do



(a)



(b)

Figure 2: *Panel (a): Time series of average global price and global export, normalised by mean, for wheat. Panel (b): scatter plot of yearly percentage variations of global price and export, where the bubble size is proportional to the time, that is the most recent data have a bigger diameter. Red dots stand for positive correlations and blue dots for negative ones.*

not always properly signal scarcity in the global market.

We now evaluate the effects of global export drops, to verify if poor countries are more vulnerable and if global prices identify the crises properly. Note that, differently from the country-level shocks described in Section 3, here there is necessarily a lack of food in the whole IFTN, because no compensation (that is by buying the same product from a different supplier) is possible at the global level. For each commodity we pick the five worst global trade shocks that, in general, correspond to a slump of at least 1 million of tonnes of food less in the IFTN. Here again, we describe the main results for wheat and we only provide a summary for the other commodities (see Supporting Information). We divide the importers hit by the crisis in four categories depending on their income per capita. The World Bank (henceforth WB) divides the countries into four income groups: Low, Lower-Middle (ML), Upper-Middle (UM), and High, based on Gross National Income (GNI) per capita per year (henceforth gni, in U.S. dollars, converted from local currency).[9] Each year these thresholds are updated, with an adjustment for inflation; on average (with a variation around $\pm$ 10%), they correspond to: Low if gni (real terms, deflated) $<$ 840\$, ML if $gni <$ 3350 \$, UM if $gni <$ 10200 \$, and High otherwise. To obtain these values, we compute the average of the deflated values of each threshold (real gni) from 1986 to 2011. Table 3 summarizes the main information on the distributional effects after a drop in global exports, and the price reactions in the same period.

[**Table 3 about here**]

During the most severe global export dearth, the IFTN faced an overall drop of about -42.5 million of tonnes of wheat, mostly concentrated in the top three crises (about -35.5 million of tonnes, almost the 85%). The average duration is around 2 years, similarly to the local crises seen above. In line with our previous findings, most of the loss of food is transmitted toward poor countries. *Low* and ML income groups, pooled together, faced a reduction of about $-25{\cdot}10^6$ tonnes (almost the 60% of the overall variation), that corresponds to about the 15% of their pre-crisis level of import, and to a loss of about -14 kg per capita of food.

However, the picture is even worse if one looks at the income thresholds and into the crises in more details. Indeed, the range of variation of the UM income cohort is quite large, where the maximum is about three times the minimum (i.e., [3350\$, 10200\$], on average), and we might imagine that the living standard of people who lives in a country closer to the lower bound (3350\$) might be very different from that of people living in a richer country, with a gni close to 10000\$. If we slightly shift the lower bound of UM to about 4500\$, the condition of the poorer becomes far worse. In this case, the main loss of wheat is concentrated exclusively in the *Low* and ML income groups, while the other two classes face an increase in imports of almost 2 million tonnes,

[9] See the website https://datahelpdesk.worldbank.org/knowledgebase/articles/378833-how-are-the-income-group-thresholds-determined for a description.

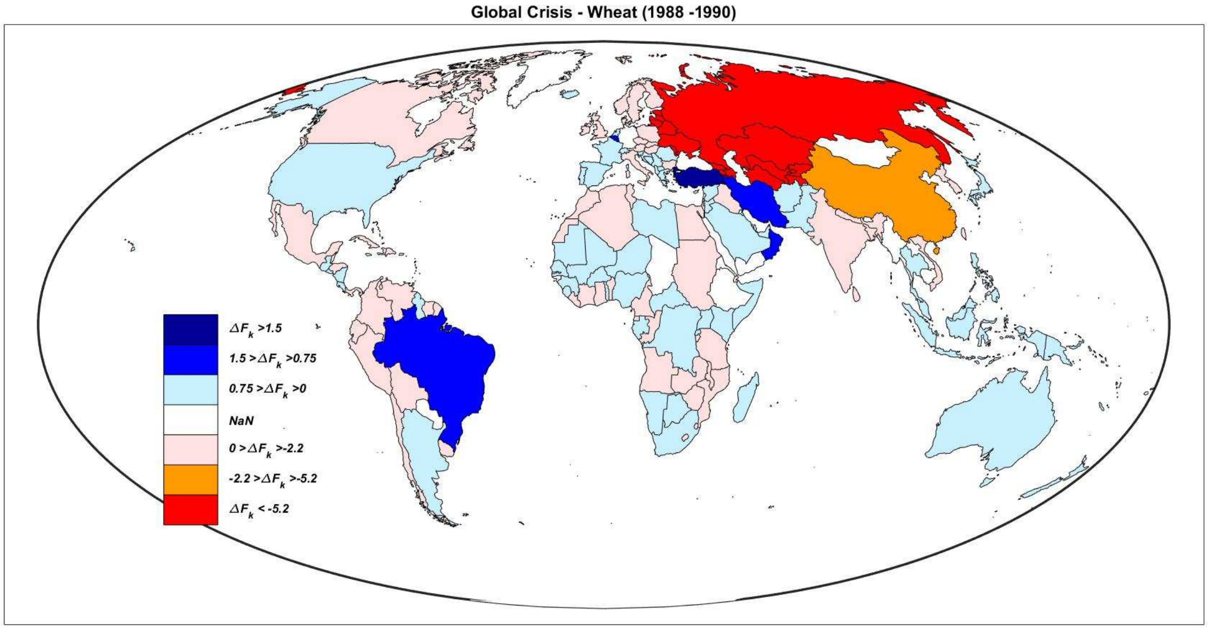
despite a global drop in exports. This suggests that most of the shock that hits the UM income group is actually concentrated around its lower bound, and behaviour within each income group is not homogeneous. Such finding is relevant when looking at riskier countries in case of trade shocks (Bussolo et al., 2011). Note that global export drops include the overall effects, so that the results are even stronger than local crises, in which an importer could compensate by buying from different exporters.

Figure 3 shows which countries increased (blue) or decreased (red) their imports during the worst global trade shock. We observe that Asian countries together with other African countries (however Africa during the 1990s was scarcely participating to the IFTN), and alternative countries from Latin America seem to suffer more.

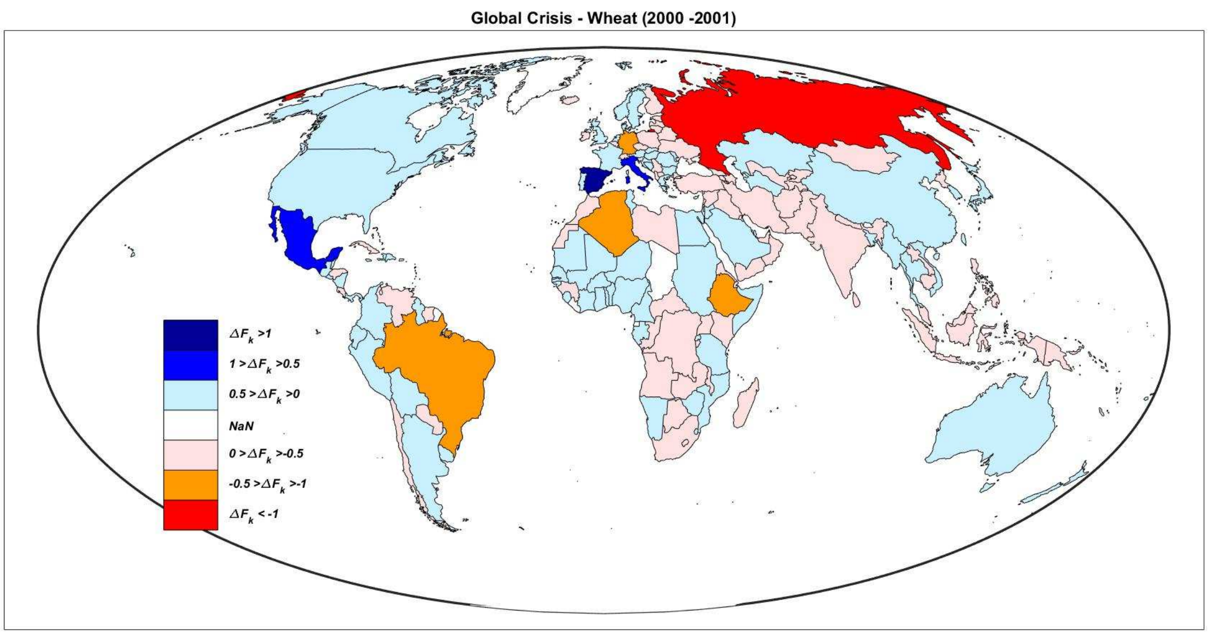
When looking at price variations we find results that further confirm the weak tie between export and prices, as reported above (see Figure 2). In three cases (Crisis I, III, and V) real global prices show almost no variation, floating around ± 3\$/ton. While only two cases shows price spikes: one positive (+14\$/ton) and one even negative (-21\$/ton). However, in any case poor countries almost absorbed the entire loss of food in the IFTN. Again, prices seems to be weakly tied with the real flows of food, even in the aftermaths of a supply shock. If prices do not always identify trade shocks, why are poor countries still the most vulnerable to (local and global) export slumps, even when prices are stable?

We conjecture that one possible explanation might be found in the governance of the world trade and, more specifically the setting and evolution of International Agreements on Agriculture (IAoA). Recently, emphasis has been placed on how to set food policies in response to trade shocks (Anderson and Nelgen, 2012, Štefan Bojnec and Fertő, 2012, Candel and Pereira, 2017). Starting from the General Agreement on Tariffs and Trade (GATT), signed in 1947, and moving through the Uruguay (spanning from 1986 to 1994), the Doha (2001) and the Nairobi (2015) WTO Rounds (Athukorala and Jayasuriya, 2003), an increasing number of countries has been involved in the definition of international rules on food trade, government subsidies, and tariffs. The broad trend are toward an increasing liberalization of trade (market-oriented), the elimination of export subsidies, the stabilisation of prices, the harmonisation of agricultural policies, and the definition of a scheme to guarantee food security in Developing-Less Developed Countries (LDC).

Many scholars and ONGs claim that historical multilateral IAoA have distributed commercial opportunities disproportionately to the largest players (e.g., Kahler, 2013, Palit, 2015). Several



(a)



(b)

Figure 3: *Comparison between the worst global crisis of wheat (1988-1990, top), and the forth one (2000-2001, bottom). The negative variations red (the darker the worse), while positive variations are reported in blue (the darker the higher).*

studies have tried to evaluate the effect of IAoAs on developing countries, with mixed results (e.g., Konandreas and Greenfield, 1996, Rutten et al., 2013, Mujahid and Kalkuhl, 2016). As a very preliminary step, we compute the correlation coefficient between the level of GDP per capita, with the number of bilateral trade agreements signed by each country in each year.[10] We find a positive correlation of about +0.35 in each year, meaning that, on average, richer countries sign more bilateral agreements. If trade agreements are effective in establishing preferential and/or long-term relationships, this correlation —far from being a definite test of any hypothesis— might provide an additional reasons why poor countries tend to be more severely affected by export drops. The other commodities show results in line with the previous findings, with the only exception of soya.

6. Conclusion

Food Security is a complex matter both to evaluate and to manage. The increasing relevance of global trade as a channel to meet rising food demand raises the question of how international crises transmit. Our study offers a novel view of the problem. There are some key messages that deserve attention when debating on food "crisis" and on the policy intervention:

- looking at real fluxes (tonnes) allows one to directly evaluate the lack of food in the IFTN. It emerges that trade shocks are more frequent and severe than expected, and that price changes alone sometimes fail to identify them;

- income per capita plays a key role in the mechanism of transmission of trade shocks. The fact that income per capita matters, even when prices do not change significantly, suggests that income levels may not only capture purchasing power but may also reflect bargaining power or market access;

- poor countries tend to suffer larger import drops in the aftermath of a negative trade shocks, either local or global. This feature has not changed over time. In case of rice, wheat, and maize *low* and $medium - low$ income countries absorb most of the loss of food during the most severe crises. These circumstances call for an increasing effort toward the definition of a set of tools to ensure food security worldwide. Otherwise, developing countries might be doomed to serious risks of instability in the provision of food;

[10] The data are available from the website http://jdesousa.univ.free.fr/data.htm, for a description of the data see de Sousa (2012).

- prices are a useful but incomplete tool to detect crises (identification of trade shocks) and to evaluate their effects. Prices matter but cannot be the only way through which one assesses and manages risks. Our approach confirms previous findings about the possibility that food prices may not always send the right signals about scarcity (Timmer, 1995). Therefore, an analysis based on real flows (tonnes) is required to provide a complementary framework about the distributional effects at the aftermath of a crisis.

These points, in addition to suggesting new insights on the transmission of trade shocks, open new questions for future research. The integration of quantity-based analysis with price-based indicators, in the direction of a multi-dimensional approach that include access to food, caloric intake, food quality, and so on) can provide us with additional insights to the understanding and measurament of food security. Second, cross-country income inequality may have serious consequences for developing countries. Hence, trade negotiations should take into account the vulnerability of poorer countries to trade shocks. The recent WTO Nairobi Round (2015) is an example along these lines, but additional efforts are needed.

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Tables

Table 1: *Top 10 country-level trade shocks for wheat, from 1986 to 2011. The table reports the volume ($\Delta E_j(\tau)$ in 10^6 tonnes) and shares of reduction, the period of each crisis, the global variation (ΔE^w), and the ranking of the critical exporter j before (t_0) and after (t_1) the shock. The index $\Theta_j(\tau)$ refers to Eq. (2).*

Country	$\Delta E_j(\tau)$	$\frac{\Delta E_j(\tau)}{E_j(t_0)}$%	**Years**	$\Delta E^w(\tau)$	$\Theta_j(\tau)$	Ranking $t_0 \rightarrow t_1$
USA	-14.9	-36.32	1988 - 1990	-12.7	-1.17	$1 \rightarrow 1$
Canada	-11.7	-50.22	1987 - 1989	-6.3	-1.83	$2 \rightarrow 3$
USA	-10.6	-33.02	2007 - 2009	21.6	0.49	$1 \rightarrow 1$
USA	-8.9	-28.69	2004 - 2006	5.1	1.77	$1 \rightarrow 1$
Ukraine	-8.8	-68.57	2009 - 2011	2.3	3.76	$6 \rightarrow 8$
Australia	-8.5	-55.66	2006 - 2007	1.6	5.23	$4 \rightarrow 6$
Australia	-8.4	-47.34	2000 - 2003	-5.2	-1.62	$4 \rightarrow 4$
Australia	-7.3	-44.88	1986 - 1988	19.2	0.38	$3 \rightarrow 4$
Canada	-7.1	-37.83	2000 - 2003	-5.2	-1.36	$2 \rightarrow 3$
Ukraine	-6.9	-80.12	2002 - 2003	-11.1	-0.63	$7 \rightarrow 12$

Table 2: *Non-linear Least Square estimators of the exponents of equation (3), where * means significant at 90%, ** at 95% and *** at 99% level, with in brackets the p-value.* R^2_{adj} *is the adjusted coefficient of determination, and Obs. is the number of the importers directly hit by the trade shocks.*

Parameters	**wheat**	**soya**	**maize**	**rice**
Const.	- 0.0015	-4e^{-6}	-3e^{-8}	-2e^{-6}
	(0.72)	(0.71)	(0.78)	(0.71)
gdp_k	- 0.282***	0.134**	-0.689***	- 0.522***
	(8e^{-6})	(0.02)	(2e^{-4})	(1e^{-18})
F_{jk}	1.359***	0.921***	1.570***	1.381***
	(5e^{-37})	(7e^{-32})	(3e^{-10})	(8e^{-47})
$E_j(t_0)$	0.413*	- 0.612***	-0.344*	- 0.379**
	(0.05)	(2e^{-7})	(0.088)	(0.04)
$-\Delta E_j(\tau)$	-0.364	1.314***	1.005***	1.088***
	(0.28)	(3e^{-18})	(7e^{-4})	(4e^{-9})
$R^2_{adj.}$	**0.56**	**0.77**	**0.7**	**0.76**
Obs.	266	154	186	261

Table 3: *Income Group comparison for the 5 worst global trade shocks of wheat in the period 1986-2011.* $\Delta F_k(\tau)$ *and* ΔE^w *are expressed in million of tonnes, while* $\frac{\Delta F_k(\tau)}{POP}$ *in kg per capita. Price are deflated and computed following equation (4). The average percentage* $\phi_k = \frac{\Delta F_k(\tau)}{F_k(t_0)}$ *for each income group are in brackets.* **The values corresponds to what we would obtain with the modified WB thresholds.*

Global	$\Delta F_k(\phi_k)$				ΔE^w	$\frac{\Delta F_k(\tau)}{POP}$				**Price** ($/$ton$)		
Crisis	*Low*	*ML*	*UM*	*High*		*Low*	*ML*	*UM*	*High*	ρ_{t_0}	ρ_{t_1}	$\Delta\rho(\tau)$
I. (1988-90)	-4.5	-10	0.1	1.3	*-13.1*	-1.60	-12.36	0.18	1.61	214	217	**3**
	(-18%)	(-24%)	(1%)	(6%)								
II. (1992-94)	-4	3.7	-16.5	5.4	*-11.4*	-1.21	6.64	-24.96	5.98	194	173	**-21**
	(-15%)	(17%)	(-56%)	(19%)								
III.(2002-03)	-0.4	-4.8	2.2	-7.9	*-11*	-0.19	-2.21	2.79	-8.20	176	173	**-3**
	(-3%)	(-12%)	(11%)	(-16%)								
IV.(2000-01)	-1.7	-1.6	-3.3	2.2	*-4.3*	-0.69	-0.79	-4.48	2.25	161	175	**14**
	(-9%)	(-4%)	(-16%)	(6%)								
V.(2009-10)	-1	-0.9	-1.3	0.6	*-2.7*	-1.05	-0.38	-0.56	0.53	177	176	**-1**
	(-7%)	(-2%)	(-3%)	(1%)					177			
TOT	*-11.6*	*-13.6*	*-18.8*	*1.5*	**-42.5**	-4.75	-9.10	-27.03	2.18	-	-	-
	(-10.3%)	(-4.8%)	(-12.6%)	(3.0%)								
TOT*	*-11.6*	*-32.7*	*+0.3*	*1.5*	**-42.5**	-4.75	-27.13	+0.52	2.18	-	-	-
	(-10.3%)	(-14.1%)	(+0.07%)	(+3.0%)								

Supporting Information

A) The Market Structure

Export (E) represents an increasing portion of Production (Q) that goes from around 13% (maize) at the beginning of the period, to more than 45% (soybeans, henceforth soya) in 2011. Table 1 resumes the main information on production and exports, at the beginning (1986) and at the end (2011) of the time window considered.

Table 1: *Cross commodity comparison (between 1986 and 2011) of: the percentage of variations of production (Q) and exports (E), the ratio of exports to production ($S = E/Q$), the yearly growth rate (g) of Q and E, and the levels of Q and E, both in millions of tonnes (mmt) and in kg per capita.* **Data on rice production in 2011 is recovered by Piesse and Thirtle (2009) (pag. 128), based on their forecast for 2009.*

Item	Production			Export			Ratio	
	$\mathbf{Q}_{1986}^{mmt}$ (kg_{CAP})	$\mathbf{Q}_{2011}^{mmt}$ (kg_{CAP})	$\Delta Q\%$	$\mathbf{E}_{1986}^{mmt}$ (kg_{CAP})	$\mathbf{E}_{2011}^{mmt}$ (kg_{CAP})	$\Delta E\%$	$\mathbf{S}_{1986}$ ($\mathbf{g}_{Q\%}$)	$\mathbf{S}_{2011}$ ($\mathbf{g}_{E\%}$)
maize	406.2 (83)	694.3 (99.7)	+70.9	55.7 (11.4)	127.1 (18.3)	+128	13.7% (2.65)	18.3% (3.68)
rice	-	450* (64.6)	-	8.44 (1.7)	27 (3.9)	+219.9	- -	- (5.94)
soya	94.4 (19.3)	261.6 (37.6)	+177.1	27.7 (5.6)	118.2 (17)	+326.7	29.3% (4.39)	45.2% (6.55)
wheat	527.9 (107.8)	695.7 (99.9)	+31.8	89.4 (18)	152.7 (21.9)	+70.8	16.9% (1.26)	21.9% (2.35)

The growth rate of E is always higher than that of Q for each product, meaning that a growing proportion of food production is traded. It is thus sensible to focus on the potential risks of the international food trade network. The share of E/Q is floating around 20% in 2011 for maize and wheat, while soya presents a much greater share, where almost half of Q is not consumed in the place of production but is traded worldwide. Soya experienced a striking growth in production, which is almost tripled, while the export increase was even faster, with a total variation of +328% in 26 years. The production of wheat is the most important, providing an average of almost 108 kg per capita worldwide (although it slightly declined in the last 26 years), of which almost 22 kg are exchanged in the international trade system. Timmer (2010) reports that only the 7-8% of rice produced crosses an international border, which is a relatively low share if compared with the other staple foods, confirming that the international rice market is thin (Piesse and Thirtle, 2009), both in percentage and absolute terms.

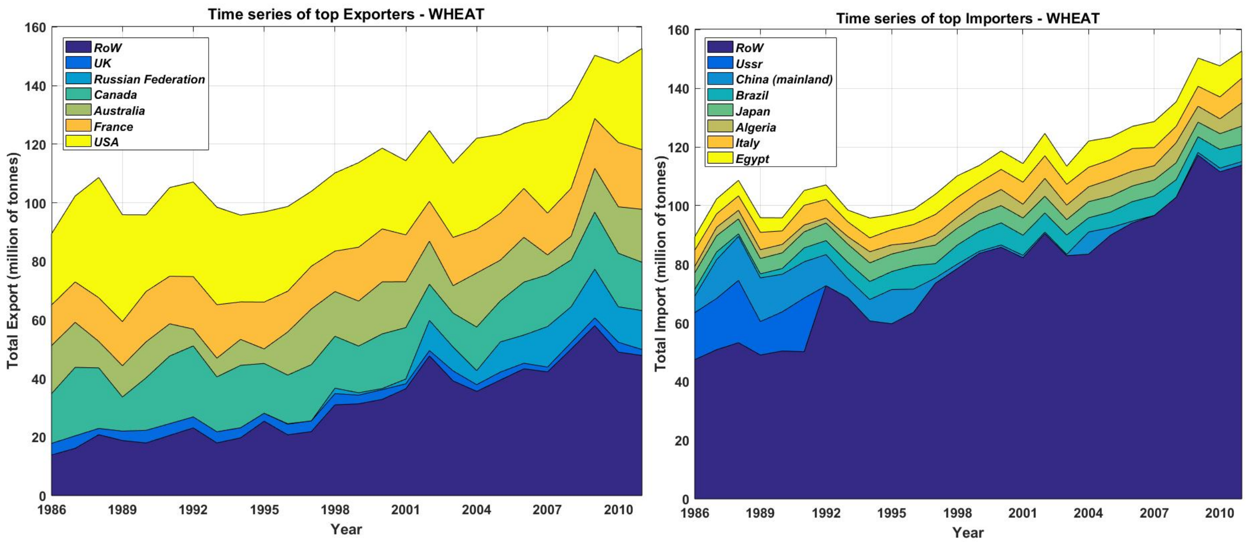


Figure 1: *Historical trend of the main export fluxes (left) and import fluxes (right), from 1986 to 2011, in million of tonnes. The Figure shows the time series of the exporters and importers which were among the top 5 in 1986 and/or in 2011.*

Figure 1 shows the evolution of the market structure for wheat, with the volume of exports of the biggest importers and exporters from 1986 to 2011, compared with the Rest of the World (RoW). From the supply side, we observe a sharp decrease of the market share of the top 5 exporters, which passed from handing more than 80% of the market in 1986, to less than 70% in 2011, with a minimum of 60% touched in 2002 and 2009 (after the crisis). Figure 1 (left side) confirms the historical leadership of the USA which supplied, in 2011, about $35{\cdot}10^6$ tonnes (22.6%), followed by France (13.3%), Australia (11.8%), and Canada (10.8%) which was the second most important exporter in 1986 (accounting for the 20% of the market) but is losing share over time. Recently, the Russian Federation has become a relevant exporter, with a market share of 8.7%, due to the revision of its agricultural structure and policy, shifting from being the first importer worldwide in 1996 to becoming among the top exporters in 2011. Headey (2011) explains how the composition of the top exporters is relevant in the transmission of international trade shocks. He states that the emergence of new big exporters might causes instability on the IFTN.

Players as Russia and Ukraine are more volatile due to export restrictions (mostly in 2006 and 2008), while Australia is more exposed to drought. However, we show that export crises might happen even in those countries that do not suffer from this kind of constraints. A signal of global trade expansion comes from the sheer number of active players in the market that for the exporters (importers) goes from 59 (154) in 1986 to 120 (180) in 2011.

From the demand side, the picture is more mixed and, in general, the market is less concentrated. The top 5 importers cover only a relatively small (and decreasing) shares of demand (about 25%), each one representing around 5% of global demand, in 2011. This also means that it is less probable that a drop in global export is induced by a fall in demand from a single country.

When looking at rice, maize, and soya (Figure 2) we observe mixed results with the common feature of the markets - both from the demand and supply side - of being more concentrated than that of wheat. Maize has a demand structure dominated by Japan and China, which emerges only in very recent years, which cover together the 21% of the demand, that is moderately fragmented. The supply side, instead, is experiencing an openness to more competition, where more countries are participating to the IFTN. The glaring leader are the USA which exported about $55{\cdot}10^6$ tonnes (43.9%), followed by Argentina (14.4%) and Brazil (9.3%). Rice shows a demand structure close to that of wheat and highly fragmented.

The supply side (in 2011) is heavily dominated by the Asian exporters that account for the 77% of global trade, with the leadership of Thailand (38.4%), followed by Vietnam and India (14%), and Pakistan (11%). Finally, the global market of soya shows a demand heavily concentrated where the top 5 cover around 80% of the whole market. However, in 1986 the demand was more fragmented with a peak of 12% due to the Netherland, while in 2011 China Mainland alone covers almost the 67% of the demand. Even the supply side is still highly concentrated notwithstanding a descending trend toward more openness. The USA provided $61 \cdot 10^6$ tonnes in 2011, supplying more than half of the global market (52,3%), followed by Brazil (26,8%) and Argentina (8,3%).

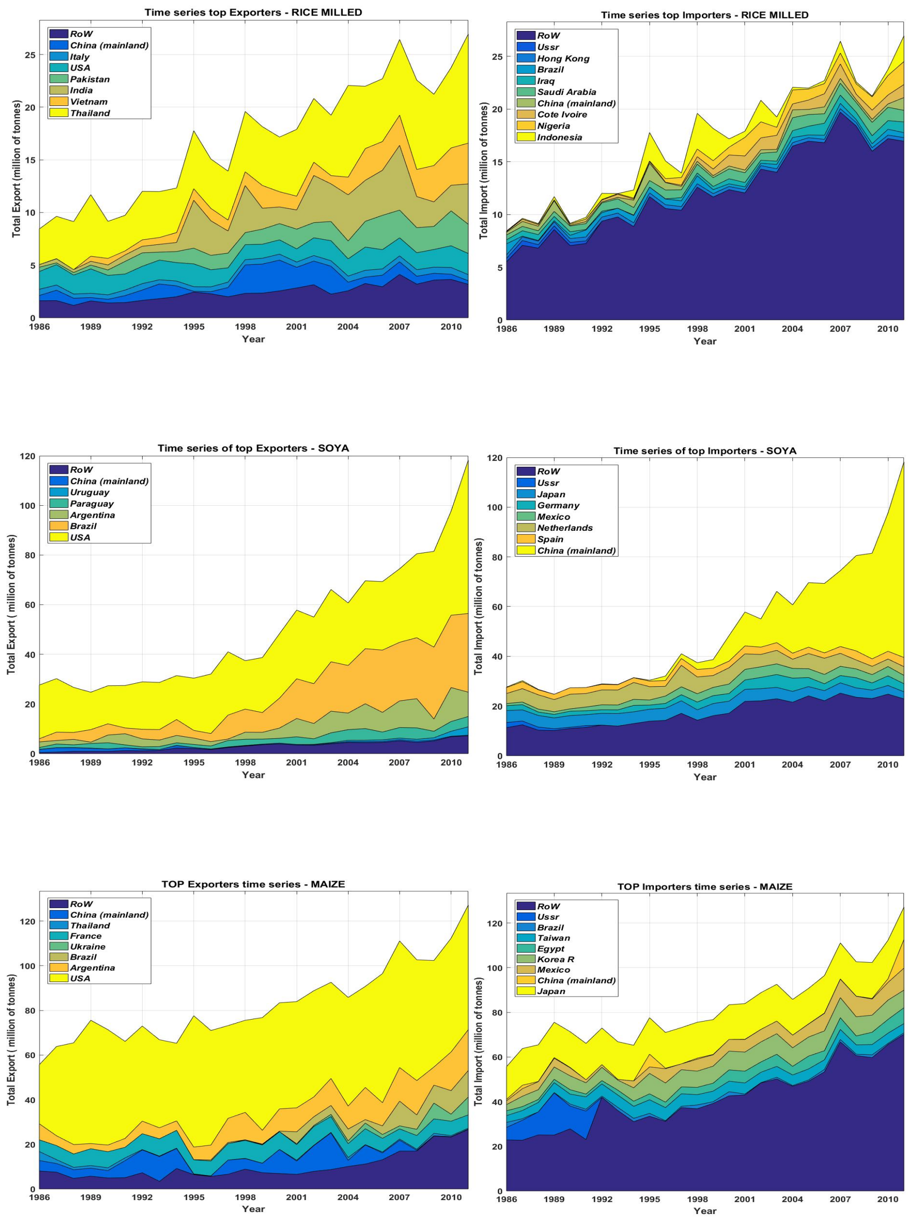


Figure 2: *Historical trend of the main export fluxes (left) and import fluxes (right), from 1986 to 2011, in million of tonnes. The Figure shows the time series of the exporters and importers which were among the top 5 in 1986 and/or in 2011 for rice (top), soya (center) and maize (bottom).*

B) Country-scale Trade Shocks

Table 2 reports the top 10 historical country-level trade shocks in the IFTN of rice, soya and maize from 1986 to 2011. It reports the volume and shares reduction, the years and duration of the crisis, and the effect on the ranking after the shock. The $\Theta_j(\tau)$ index indicates whether the shock propagates worldwide or whether the competitors offset the country-level trade shock.

Table 2: Summary of the main indicators of the top 10 country-level crisis for rice.

rice	$\Delta E_j(\tau)$	$\frac{\Delta E_j(\tau)}{E_j(t_0)}$ %	**Years**	$\Delta E^w_j(\tau)$	$\Theta_j(\tau)$	Ranking $t_0 \rightarrow t_1$
India	-3.8	2007 - 2009	-62.1%	-5.2	-0.73	$2 \rightarrow 3$
India	-2.9	1998 - 2000	-64.6%	-2.4	-1.19	$2 \rightarrow 3$
Thailand	-2.8	2004 - 2005	-32.0%	-0.1	-37.29	$1 \rightarrow 1$
Thailand	-2.5	1989 - 1991	-42.3%	-2.0	-1.26	$1 \rightarrow 1$
India	-2.4	1995 - 1997	-53.8%	-3.8	-0.64	$2 \rightarrow 2$
China	-2.1	2003 - 2005	-77.1%	2.8	0.75	$3 \rightarrow 8$
Thailand	-1.7	2008 - 2009	-20.2%	-1.3	-1.28	$1 \rightarrow 1$
Vietnam	-1.4	1999 - 2003	-63.7%	1.1	1.27	$3 \rightarrow 6$
China	-1.3	1993 - 1995	-94.4%	5.8	0.23	$3 \rightarrow 15$
Pakistan	-1.1	2006 - 2009	-32.8%	-1.5	-0.73	$3 \rightarrow 4$

Table 3: Summary of the main indicators of the top 10 country-level crisis for soya.

soya	$\Delta E_j(\tau)$	$\frac{\Delta E_j(\tau)}{E_j(t_0)}$ %	**Years**	$\Delta E_j^w(\tau)$	$\Theta_j(\tau)$	Ranking $t_0 \to t_1$
Argentina	-6.8	2008 - 2009	-57.9%	1.0	7.1	$3 \to 3$
USA	-6.6	1986 - 1989	-30.4%	-2.9	-2.3	$1 \to 1$
USA	-6.0	1997 - 1998	-23.5%	-3.6	-1.7	$1 \to 1$
USA	-4.0	2003 - 2004	-13.6%	-5.4	-0.7	$1 \to 1$
Argentina	-3.9	2010 - 2011	-28.4%	20.5	0.2	$3 \to 3$
Brazil	-3.3	1994 - 1995	-51.5%	-1.0	-3.2	$2 \to 2$
Brazil	-2.7	1989 - 1991	-54.1%	2.7	1.0	$2 \to 3$
Argentina	-2.4	1994 - 1997	-81.6%	9.6	0.3	$3 \to 6$
Argentina	-2.1	2005 - 2006	-20.9%	-0.3	-6.2	$3 \to 3$
Argentina	-2.1	2003 - 2004	-23.6%	-5.4	-0.4	$3 \to 3$

Table 4: Summary of the main indicators of the top 10 country-level crisis for maize.

maize	$\Delta E_j(\tau)$	$\frac{\Delta E_j(\tau)}{E_j(t_0)}$ %	**Years**	$\Delta E_j^w(\tau)$	$\Theta_j(\tau)$	Ranking $t_0 \to t_1$
USA	-20.5	1989 1994	-37.1%	-10.3	-2.0	$1 \to 1$
USA	-17.6	1995 - 1998	-29.9%	-2.0	-8.6	$1 \to 1$
China	-13.7	2003 - 2004	-83.3%	-6.8	-2.0	$2 \to 5$
China	-10.9	1993 - 1996	-98.5%	4.1	2.6	$2 \to 15$
USA	-10.1	2006 - 2009	-17.5%	5.9	1.7	$1 \to 1$
Argentina	-7.3	2008 - 2009	-47.3%	-0.3	-23.1	$2 \to 2$
Argentina	-6.1	1998 - 1999	-49.7%	1.2	5.1	$2 \to 3$
China	-5.5	2005 - 2006	-64.0%	5.7	1.0	$3 \to 5$
Argentina	-4.9	1986 - 1989	-67.8%	19.9	0.2	$2 \to 4$
China	-4.8	2000 - 2001	-44.7%	0.5	9.1	$2 \to 4$

C) Global-scale Trade Shocks

Here we report the same information contained in the Table 3, of Section 5 for rice, soya, and maize about the cross income area comparison for the top 5 worst global trade shocks. The ranking of the crises follows the magnitude of food loss in the IFTN. $\Delta F_k(\tau)$ and ΔE^w are expressed in million of tonnes, while $\frac{\Delta F_k(\tau)}{POP}$ in kg per capita. Price are deflated and computed following equation 4. The total percentage variation is computed as an average, based on the whole pre-crisis import level of each income group. *The second row of total values corresponds to what we would obtain with the modified WB income thresholds (only in case of maize).

In the years 2010-11 the global average price of maize surged of almost +40% and E^w grew as well (+13%), while in the 1992-93 in view of a lack of global supply (-8% of E^w) the global price decreased of almost -5%. Soya exports rose of more than +8% in view of a global price spike of almost +50% in only one year (2007-08), while an export crisis, -9% from 1997-98, was not captured price dynamics (-19% in the same time span).

Table 5: Cross Income Area comparison for the top 5 worst global trade shocks of rice in the period 1986-2011. $\Delta F_k(\tau)$ and ΔE^w are expressed in million of tonnes, while $\frac{\Delta F_k(\tau)}{POP}$ in kg per capita. Price are deflated and computed following equation (4). The average percentage $\phi_k = \frac{\Delta F_k(\tau)}{F_k(t_0)}$ for each income group are in brackets.

Global	$\Delta F_k(\phi_k)$				ΔE^w	$\frac{\Delta F_k(\tau)}{POP}$				**Price** (ρ_t)		
Crisis - soya	*Low*	*ML*	*UM*	*High*		*Low*	*ML*	*UM*	*High*	ρ_{t_0}	ρ_{t_1}	$\Delta\rho(\tau)$
I.(2007-2009)	-2.9	-2.3	0.2	-0.2	-5.2	-1.17	-1.02	0.18	-0.15	347	505	158
	(-36%)	(-27%)	(5%)	(-2%)								
II.(1995-1997)	-2.1	-1.9	0.0	0.1	-3.8	-0.65	-2.14	0.06	0.12	365	413	48
	(-36%)	(-35%)	(1%)	(3%)								
III.(1989-1990)	-2.3	-0.1	0.2	-0.1	-2.4	-0.79	-0.16	0.32	-0.17	453	450	-3
	(-55%)	(-4%)	(13%)	(-5%)								
IV.(1998-2000)	-0.8	-2.1	-0.4	0.9	-2.4	-0.22	-2.34	-0.56	0.91	389	334	-55
	(-13%)	(-31%)	(-13%)	(22%)								
V.(2002-2003)	0.0	-2.3	0.4	0.4	-1.6	-0.01	-1.05	0.47	0.37	299	294	-5
	(0%)	(-39%)	(13%)	(8%)								
TOT	-8.1	-8.7	0.3	1.0	-15.5	-2.85	-6.71	0.48	1.08			
	(-28%)	(-27%)	(4%)	(5%)								

Table 6: Cross Income Area comparison for the top 5 worst global trade shocks of soya in the period 1986-2011. $\Delta F_k(\tau)$ and ΔE^w are expressed in million of tonnes, while $\frac{\Delta F_k(\tau)}{POP}$ in kg per capita. Price are deflated and computed following equation (4). The average percentage $\phi_k = \frac{\Delta F_k(\tau)}{F_k(t_0)}$ for each income group are in brackets.

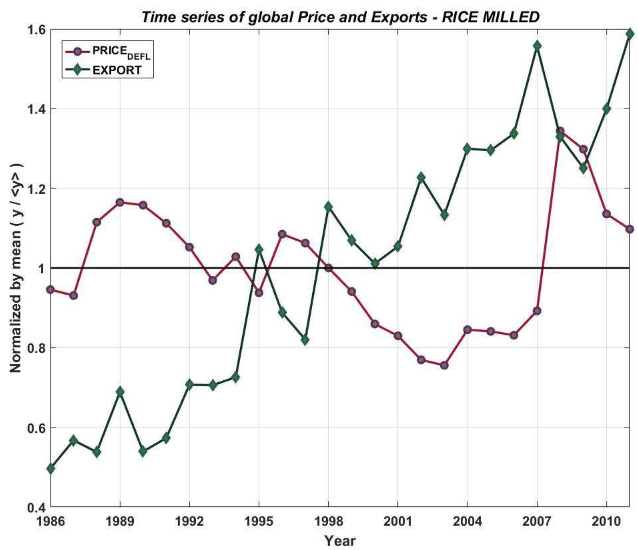
Global	$\Delta F_k(\phi_k)$				ΔE^w	$\frac{\Delta F_k(\tau)}{POP}$				**Price** (ρ_t)		
Crisis - soya	*Low*	*ML*	*UM*	*High*		*Low*	*ML*	*UM*	*High*	ρ_{t_0}	ρ_{t_1}	$\Delta\rho(\tau)$
I.(1987-1989)	-0.4	-1.4	-0.7	-3.0	-5.5	-0.17	-1.39	-1.24	-3.60	315	379	64
	(-95%)	(-43%)	(-18%)	(-13%)								
II.(2003-2004)	0.1	-1.2	-0.8	-3.6	-5.4	0.05	-0.52	-1.00	-3.63	289	307	18
	(35%)	(-4%)	(-9%)	(-12%)								
III.(1997-1998)	0.9	0.1	-1.2	-3.4	-3.6	0.27	0.06	-2.15	-3.52	311	251	-60
	(44%)	(3%()	(-17%)	(-11%)								
IV.(2001-2002)	0.0	-1.9	0.3	-1.2	-2.8	0.02	-0.80	0.45	-1.26	207	253	45
	(12%)	(-10%)	(4%)	(-4%)								
V.(1994-1995)	0.5	-0.5	-0.4	-0.6	-1.0	0.15	-0.62	-0.59	-0.66	278	261	-16
	(-28%)	(-8%)	(-2%)									
TOT	1.1	-4.8	-2.8	-11.9	-18.4	0.32	-3.27	-4.54	-12.66			
	(90%)	(-16%)	(-10%)	(-9%)								

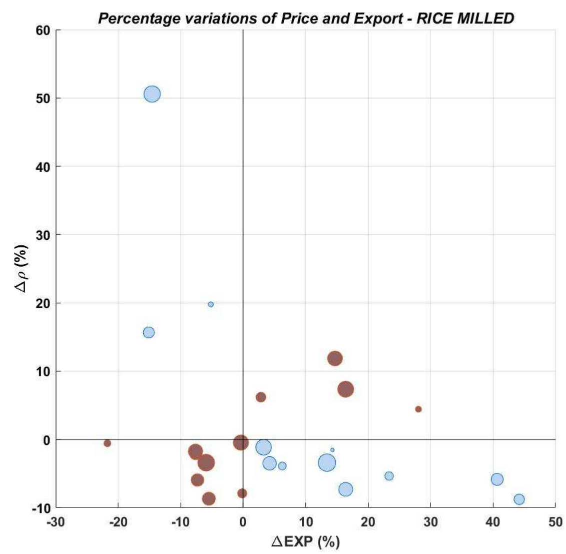
Table 7: Cross Income Area comparison for the top 5 worst global trade shocks of maize in the period 1986-2011. $\Delta F_k(\tau)$ and ΔE^w are expressed in million of tonnes, while $\frac{\Delta F_k(\tau)}{POP}$ in kg per capita. Price are deflated and computed following equation (4). The average percentage $\phi_k = \frac{\Delta F_k(\tau)}{F_k(t_0)}$ for each income group are in brackets. *The values corresponds to what we would obtain with the modified WB thresholds.

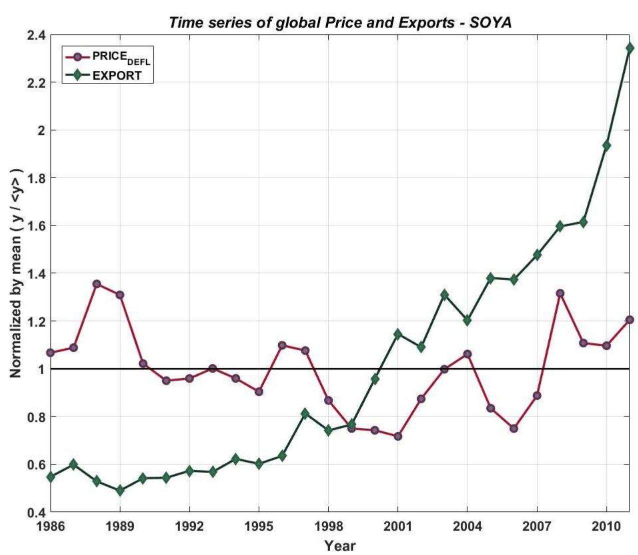
Global	$\Delta F_k(\phi_k)$				ΔE^w	$\frac{\Delta F_k(\tau)}{POP}$				**Price** (ρ_t)		
Crisis - soya	*Low*	ML	UM	$High$		*Low*	ML	UM	$High$	ρ_{t_0}	ρ_{t_1}	$\Delta\rho(\tau)$
I.(1989-1991)	0.3 (33%)	-5.2 (-19%)	-4.0 (-31%)	-0.6 (-2%)	-9.5	0.10	-5.90	-8.57	-0.65	192	167	-25
II.(1992-1994)	3.0 (126%)	0.0 (0%)	-2.3 (-8%)	-9.5 (-16%)	-8.8	1.22	0.01	-2.62	-9.01	166	166	0
III.(1995-1996)	-0.8 (-18%)	1.3 (12%)	-7.9 (-48%)	-0.4 (-1%)	-7.7	-0.23	2.30	-11.92	-0.45	164	157	-7
IV.(2002-2004)	-0.7 (-27%)	-1.2 (-6%)	-1.3 (-8%)	-3.6 (-7%)	-6.7	-0.28	-0.54	-1.65	-3.59	137	150	13
V.(2007-2009)	-5.7 (-84%)	-0.9 (-7%)	2.6 (22%)	-2.6 (-6%)	-6.6	-1.77	-1.02	3.77	-2.76	161	202	41
TOT	-3.8 (6.2%)	-6.0 (-4%)	-12.9 (-15%)	-16.6 (-6.1%)	-39.4	-0.97	-5.14	-21.00	-16.45			
TOT*	-3.8 (6.2%)	-19.0 (-15.2%)	+0.1 (+23%)	-16.6 (-6.1%)	-39.4	-0.97	-18.70	+11.26	-16.45			

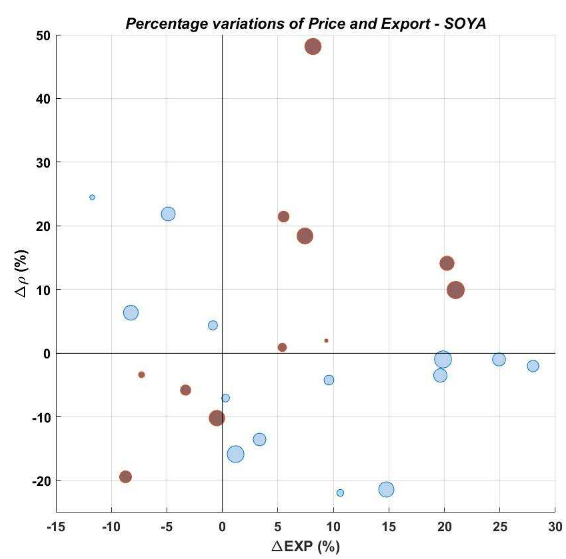
C.1 Figures

Finally, we show the time series of price level and export normalised by mean (left) and scatter plot of their yearly percentage variations (right), where the bubble size is porportional to the time, that is the most recent data have a bigger diameter. Similarly to the case of wheat, the other staple foods show a weak tie between the dynamic of tonnes and price as well.









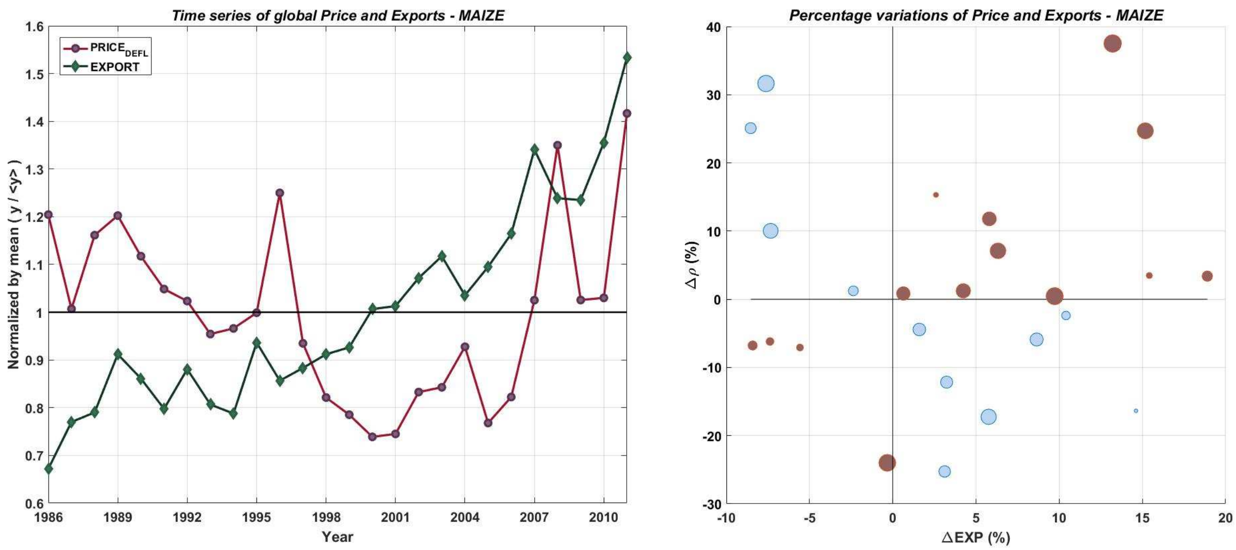


Figure 3: *Left panel: Time series of average global price and global export, normalised by mean, for rice (top), soya (center) and maize (bottom). Right panel: scatter plot of yearly percentage variations of global price and export, where the bubble size is proportional to the time, that is the most recent data have a bigger diameter. Red dots stand for negative correlations and blue dots for positive ones.*